Contents

Surgical cases

Non-surgical cases

Case number 1

Retreatment of maxillary left first molar in conjunction with apical surgery

Patient

A 41-year-old white Iranian male was referred to the Department of Endodontics, University of Oslo, by an undergraduate student April 27, 2004 for treatment of maxillary left first molar (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patient had been examined by an undergraduate dental student in December 2003. The radiographic examination revealed an apical radiolucency on maxillary left first molar. No clinical findings. The endodontic treatment was considered too difficult to be performed by an undergraduate student. The patient was referred to the postgraduate program.
The patient had no recollection of pain or prior endodontic treatment.

Clinical Examination

No pathology was found extra-orally.

A normal oral mucosa was observed.

Maxillary left second molar: An O amalgam restorationon was seen and the tooth responded positively to the electric pulp test and the Endo Ice test.
Maxillary left first molar: A MO amalgam restoration was seen and the tooth was blue-grayish discoloured. The tooth responded negatively to the electric pulp test and the Endo Ice test.
Maxillary left second premolar: A MODP amalgam restoration was seen and the tooth responded positively to the electric pulp test and the Endo Ice test.
Maxillary left first premolar: An OD amalgam restoration was seen and the tooth responded positively to the electric pulp test and the Endo Ice test.

Two preoperative photographs showed the region from maxillary left canine to maxillary second molar (Fig.2, 3).

Fig.2 Buccal view

Fig.3 Occlusal view

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative periapical radiograph showed the region from maxillary left first premolar to second molar (Fig.4).
Maxillary left second molar: An O radiopaque restoration was seen and lamina dura could be followed around the entire roots without disruption. A large pulp chamber was seen.
Maxillary left first molar: A MO radiopaque restoration was seen and lamina dura could be followed on the mesial side of the MB root to the apex were it widened into a radiolucent area apical of all the roots, and all the way to the mesial root of maxillary left

second molar. The radiolucent area was approximately 13 mm in diameter. Lamina dura could be followed on the distal side of the DB root almost to the apex. A radiopaque root filling material approximately 3 mm short of radiographic apex could be observed in the MB root. In the DB root it could be observed protruding gutta-percha approximately 1.5 mm. On the palatal root it can be observed a protruding of gutta-percha approximately 3 mm. It was also observed that the tooth had a taurodont look with large pulp chamber and small roots.
Maxillary left second premolar: A MOD radiopaque restoration was seen and lamina dura could be followed around the entire root without disruption.

Fig.4 Note the periapical radiolucency of maxillary left first molar.

The marginal bone level was within normal limits.

Diagnosis

Chronic apical periodontitis maxillary left first molar.

Tentative treatment plan

Retreatment of an endodontically treated maxillary left first molar

According to the outcome of the retreatment, the need of a surgical intervention would be evaluated at a later stage.

Treatment

May 25, 2004

The access cavity was prepared and a huge pulp chamber was located filled with dark cement like material. The rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. Three root canal orifices were localized with gutta-percha root filling material. The working length was reached by using K-flex nr 20 without the help of chloroform. A working length radiograph was taken with a K-Flex nr 20 in the distal canal and a NiTi nr 25 in the mesial canal (Fig.5). The working lengths were controlled with apex locator (Root ZX, J. Morita, Japan).

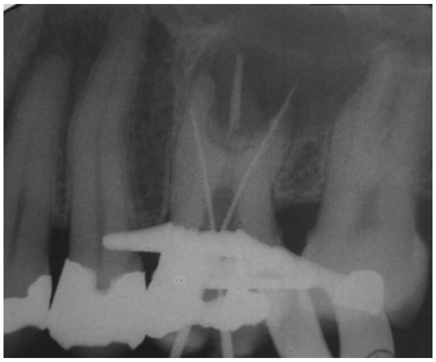


Fig. 5 Working length **Fig. 6** Cleaned canals

The root canal was instrumented up to NiTi nr 45 in the MB canal, and a length of 20 mm with the DP cusp as a reference point. The DB canal was instrumented up to NiTi nr 50, and a length of 20 mm with the O amalgam filling as a reference point. P canal was instrumented up to NiTi nr 60, and a length of 21 mm with the B cusp as a reference point. Irrigation was done with 1% sodium hypochlorite and 17% EDTA. Both the distal and palatinal canal had bleeding within the radiographic limits of the root indicating root resorptions or perforations (Fig.6). An MB 2 canal was not localized.
The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

June 16, 2004

The patient returned to the clinic 3 weeks later. The tooth was asymptomatic. The canals were decided to fill with MTA because of the resorptions/perforations, and a very little chance to healing because of protrusion of gutta-percha in D and P canals, and too short working length in the M canal due to a step formation, and to prevent surplus of sealer and gutta-percha.
Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. IRM and Cavit G were removed, and calcium hydroxide was removed with irrigation with 1% sodium hypochlorite and 17% EDTA. The root canals were dried with sterile paper points. Grey MTA was filled in all 3 root canals with the help of an LM endo-plugger and sterile paper points (Fig.7)

The pulp chamber was partly filled with a wet cotton pellet, and sealed off with IRM

Fig.7 Root canals filled with MTA

October 26, 2004

The patient returned to the clinic 4 months later. The tooth was asymptomatic. Rubber dam was applied, and the area disinfected with chlorhexidine-ethanol solution. IRM, amalgam restoration, and the wet cotton pellet were removed. It was placed a composite restoration all the way down to the MTA to try to reinforce both the root and the crown (Fig.8, 9).

Fig.8 Buccal view

Fig.9 Occlusal view

The radiographic examination did not reveal any healing. The tooth was asymptomatic. The patient was referred to Capio Røntgen Oslo for examination of the tooth with Computed Tomography Scanning (CT) to give preoperative information about size and relation to sinus (Fig.10, 11, 12, 13, 14, 15).

The CT was described from Capio røntgen Oslo:
An odontogenic cyst from tooth 26 was seen. The cyst was approximately 15 mm in diameter. It had made a small perforation to the sinus and the cortical bone buccaly.

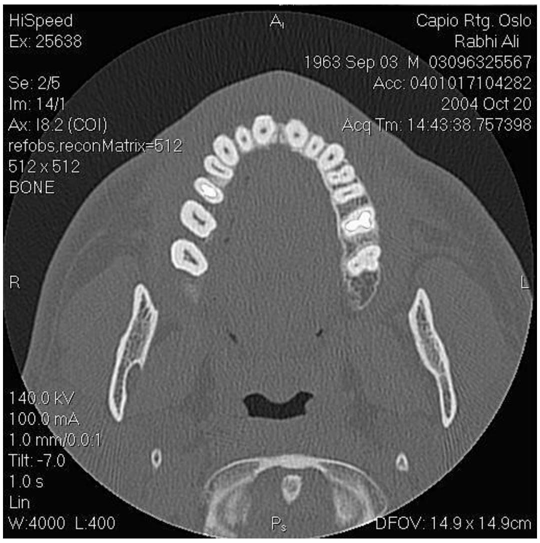

Fig. 10 Axial image of the pulp chamber of left first maxillary molar

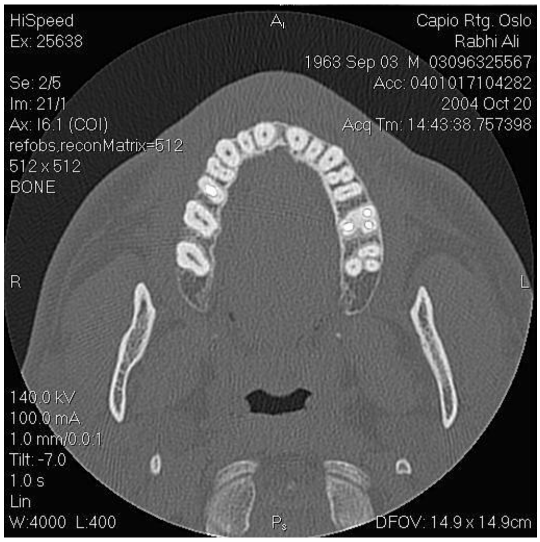

Fig. 11 Axial image more apical

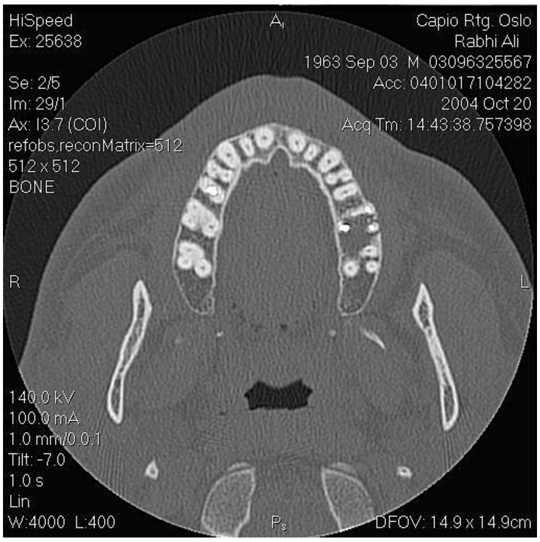

Fig. 12 Axial image showing the apices placed close to the cortical bone both buccal and palatinal, and a broad MB root.

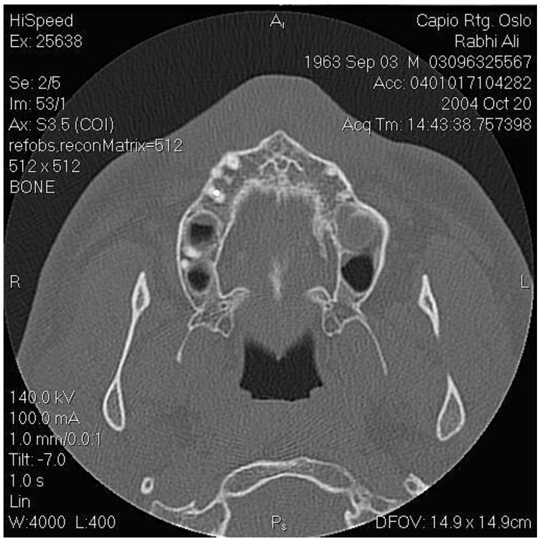

Fig. 13 Axial image showing the outline of the cystic process.

Fig. 14 Saggital image true the left first maxillary molar.

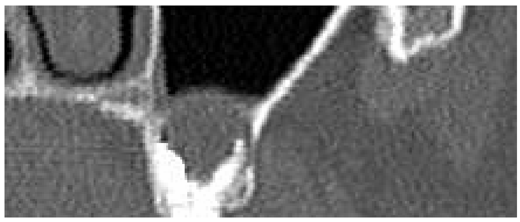

Fig. 15 Saggital image more mesial than the previous.

New treatment plan

Apicoectomy of the maxillary left first molar.

November 17, 2004

The patient returned to the clinic 4 weeks later for performing apicoectomy on maxillary left first molar. Four carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision starting from the mesiobuccal gingival line angle of the canine approximately 1 cm in a superior aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of the maxillary left second molar. Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap. A pathological bone fenestration was detected outside the mesiobuccal and distobuccal root (Fig.16). The lesion was removed with periodontal curettes. It was found a paper point in the lesion (Fig.17).
Osteotomy of the outer cortical plate was accomplished with an nr 6 round bur on a 45° angled high speed hand piece under irrigation with sterile saline to adequately expose the root ends. Two-three mm of the roots apexes were resected with a long fissure bur.

Fig.16 Fenestration of the buccal bone plate.

Fig.17 Paper point found in the cavity

A small area with peroration to the sinus was localaized. It was difficult to get access to the palatal root from the buccal aspect. It was necessary to elevate a palatal flap. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision starting from the mesiopalatal gingival line angle of the canine approximately 1 cm in a superior aspect of the palatal. An intrasulcular incision extending from the releasing incision to the distal aspect of the left second maxillary molar was performed. Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. Osteotomy of the outer cortical plate was accomplished with an nr 6 round bur on a 45° angled high speed hand piece under irrigation with sterile saline to adequately expose the root end. Two mm of the palatal root apex was resected (Fig.18). A microscope was being used most of the time in order to achieve maximal visibility.

Fig.18 Resection of the palatal root

The surgical field was irrigated with sterile saline. The flaps were repositioned, and were hold tight in place with finger pressure for five minute in order to reduce the post operative haematoma and pain. The two vertical realising flaps were sutured in place with four 4-0 silk suture. The four other interrupted sutures was placed inter-approximally in the papilla (Fig.19, 20). A final radiograph was taken, and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

Fig.19 Buccal view

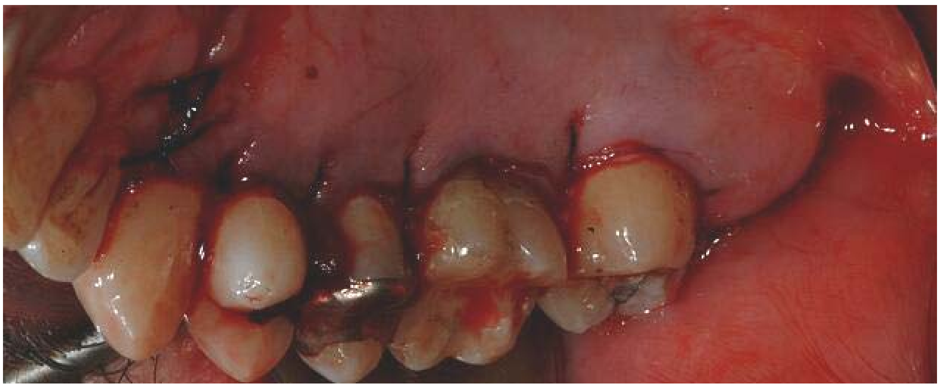

Fig.20 Palatal view

November 24, 2004

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed and a control radiograph was taken (Fig.21, 22. 23).

Fig.21 Buccal view one week postoperative

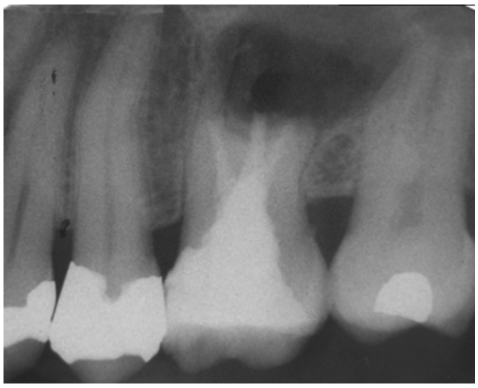

Fig.23 Radiograph one week postoperative. Note the MB2 root

Fig.22 Palatal view one week postoperative

Evaluation

MTA was chosen as a root filling material.
To prevent extrusion of sealer and gutta-percha in the canals with resorptions or perforations.
To eventually make the surgical procedure easier.
A MB2 root was not found treating the tooth orthograd, and was also missed in surgery.
The small perforation to sinus was not considered as a complication.

Prognosis

Endodontic prognosis was considered uncertain

6 months follow-up

May 03, 2005

The patient returned to the clinic six months later. The tooth was asymptomatic. The gingival healing was satisfactory. The follow-up radiograph revealed signs of healing (Fig. 24)

Fig.24 Periapical radiograph six months post-operative.

One year follow-up

January 31, 2006

The patient returned to the clinic one year after surgery. The tooth had remained asymptomatic. The control radiograph showed favourable outcome (Fig.25, 26).

Fig.25 Start of treatment

Fig.26 One year follow-up

Discussion

On the buccal aspect of the maxillary posterior arch, the major anatomical considerations include the malar (zygomatic) process, exostoses, muscle attachments and the maxillary antrum (Gutmann & Harrison 1985).
Often, the malar process is directly above or overlies the apex of the mesiobuccal root of the maxillary first molar. Ironically, this root is the frequent subject of surgical endodontics due to its anatomical canal variations (Bjorndal & Skidmore 1983). The process consists of thick dense bone, and flap retraction and access to the root may be impeded. Also, there may be difficulty in discerning the proper outline of the root within its dense bony housing.
Exostoses or buttressing of bone along the gingival crest may affect flap design, flap reflection and flap replacement. Possible considerations include osseous recontouring subsequent to root-end surgical procedures. In these cases, care must be exercised in making the intrasulcular incision and in soft tissue reflection. Failure to do so may result in a lacerated or torn flap of soft tissue.
High muscle attachments pose same problems in the maxilla as in the mandible.
While much has been written about the potential problems of entering the maxillary antrum during surgical procedures, very little documentation exists to support its effect on the prognosis of apical procedures (Ericson et al. 1974, Ioannides & Borstlap 1983). Care must always be exercised when violation of the Schneiderian membrane has occurred, especially in preventing the entry of foreign objects and bacteria (Skoglund et al. 1983), but apical procedures can usually be carried out safely.
On the palatal aspect, the main considerations are the vessels and nerves which emerge from the greater palatine foramen, the height of the palatal vault and the thickness of the palatal soft tissue. A shallow vault is accompanied by thicker bone, limited access, and impaired approach to the root end. High vaults generally present a more favorable approach to palatal surgery, especially access to the palatal root apices.

In addition to being close to the maxillary antrum, roots may be severely dilacerated or widely divergent, which may necessitate a palatal surgical approach in specific situations. Pulpal anastomoses in roots with broad buccopalatal dimensions are common and are often exposed in apical root resection procedures.

Maxillary molars present more varied problems, especially the mesiobuccal root. Anatomical variations of this root can range from a single oval root with one canal, to a large broad root which is attached to the palatal root by a web of cementum and contains extensions of the pulp across the entire width of the root. Even if this root does not connect with the palatal, a common occurrence is a figure-of-eight or dumb-bell shaped root with the palatal aspect of the root being very thin and susceptible to perforation when trying to prepare it for a reverse filling.

The distobuccal root of the maxillary molar is generally round or oval, but can also exhibit variations such as severe distal curvatures. Generally, the distobuccal root is located deeper within the alveolar bone than the mesiobuccal. Both roots are usually in close proximity to the maxillary antrum and care must be taken to prevent debris being pushed from the surgical site into the antrum (Ericson et al. 1974).

Penetration of the maxillary antrum may occur when the root apices are in close approximation. However, management of this occurrence is straightforward (Killy & Kay 1975, Skoglund et al. 1983) and consists of:

Proper surgical closure, which is accomplished with good flap positioning, pressure to ensure a good clot formation and sufficient suture placement.

Administration of an appropriate antibiotic to prevent secondary infection

Administration of local decongestants to encourage drainage.

Administration of analgesics as necessary for discomfort.

Full explanation to the patient of the occurrence and how to manage the situation postoperatively.

The close anatomical relationship of the maxillary sinus and the roots of maxillary molars, premolars and in some instances canines, can lead to several endodontic complications. Periapical periodontitis may result in maxillary sinusitis of dental origin with resultant inflammation and thickening of the mucosal linig of the sinus in areas adjacent to the involved teeth. In cases of sinusitis of dental origin conventional endodontic treatment or retreatment is the treatment of choice, with surgical intervention only indicated in refractory cases. Conventional root canal treatment may result in the perforation of the sinus floor in one or more of the stages of treatment with resultant irritation and inflammation of the maxillary sinus mucosa. This inflammation may be owing to overinstrumentation and/or inadvertent injection or extrusion of irrigants, intracanal medicaments, sealers or solid obturation materials. Furthermore, endodontic surgery performed on maxillary teeth may result in sinus perforation. Perforation caused during endodontic surgery constitutes a low risk to the maxillary sinus in the presence of a good knowledge of the specific anatomic conditions, an adequate diagnosis and an appropriate surgical procedure. Root ends and/or materials may enter the sinus during conventional or surgical endodontic therapy with the need for a subsequent Caldwell-Luc approach. Antibiotics, decongestants and analgesics are indicated for the treatment of sinusitis or when the sinus is penetrated during surgical endodontic procedures (Hauman et al. 2002).

Although (Ericson et al. 1974) found no difference in prognosis in cases with and without oroantral communicationin periapical surgery of maxillary teeth, this does not mean that care should not be taken to prevent sinus exposure. It is well documented that inflammatory periapical pathosis can cause sinusitis; however, the reverse is not true. If sinusitis persists as a sequela of maxillary periapical surgery, the patient should be referred to an atolaryngologist for evaluation and treatment (Lin et al. 1985).

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Case number 2

Apicoectomi of maxillary left first premolar

Patient

A 50-year-old white Norwegian female was referred to the Department of Endodontics, University of Oslo, by her GP September 21, 2005 for treatment of maxillary left first premolar (Fig.1)

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patients GP treated her maxillary left first premolar endodontically one year ago. The one year follow-up revealed no healing. The patient was referred to the Department of Endodontics.
The patient had no symptoms from the area.

Clinical Examination

No pathology was found extra-orally

A normal oral mucosa was observed.

Maxillary left first molar: A MOD amalgam restorationon was seen and the tooth responded positively to the Endo Ice test.
Maxillary left second premolar: A PFM crown was seen and the tooth responded negatively to the Endo Ice test.

Maxillary left first premolar: The crown of the tooth was lost, and an IRM temporary restoration sealed the root canal. The tooth responded negatively to the Endo Ice test.
Maxillary left canine: An OD composite restoration was seen and the tooth responded positively to the Endo Ice test.

Two preoperative photographs showed the region from maxillary left central incisor to maxillary left first molar (Fig.2, 3).

Fig.2 Buccal view

Fig.3 Occlusal view

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.
The patient was a heavy smoker

Radiographic Examination

The preoperative periapical radiograph showed the region from maxillary left canine to first molar (Fig.4).

Fig.4 Note the periapical radiolucency maxillary left first premolar, and excess gutta-percha on second premolar.

Maxillary left first molar: A MOD radiopaque restoration was seen and lamina dura could be followed around the entire roots.
Maxillary left second premolar: A radiopaque restoration in the crown and in the root canal were seen. Lamina dura could be followed around the entire root. A radiopaque material was seen peri-apical approximately 2 mm long.
Maxillary left first premolar: A radiopaque material in the root canal was seen and lamina dura could be followed down the root apical where it widened to a circumscribed radiolucency of approximately 4 mm.
Maxillary left canine: A DP radiopaque restoration was seen and lamina dura could be followed around the entire root.

Mild to medium bone loss was seen.

Diagnosis

Chronic apical periodontitis maxillary left first premolar

Treatment plan

Apicoectomy of maxillary left first premolar

Treatment

September 21, 2005

The first consultation was examination and treatment planning.

October 05, 2005

The patient returned to the clinic two weeks later for performing apicoectomi. Three carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision, starting from the mesiobuccal gingival line angle of the maxillary left canine approximately 1 cm in a superior aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of maxillary left first molar.
Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap. No bone fenestration was detected outside the root.
Osteotomy of the outer cortical plate was accomplished with an nr 6 round bur on a 45° angled high speed hand piece under irrigation with sterile saline to adequately expose the root end (Fig.5). The lesion was removed with periodontal curettes (Fig.6). Three mm of the root apex was resected with a long fissure bur. A retrograde preparation was carried out with the piezoelectric Satelec ultrasound device using ultrasonic tip CT under constant cooling with rinsing sterile saline. The cavity was extended up to 3 mm in the root canal and followed gutta-percha at all times. A microscope was being used most of the time in order to achieve maximal visibility.

Fig.5 Exposing the apex

Fig.6 The lesion removed

Stryphnon gauze was placed in the bone cavity in order to achieve haemostasis. The cavity was then irrigated with sterile saline and dried with sterile paper points. A retrograde MTA filling was placed into the cavity using plastic instrument as a carrier, and condensed with micro condensing pluggers. A burnisher was used at the end. The retro-filling was examined under high magnification with an explorer to check marginal adaptation and integrity.
The Stryphnon gauze was removed. The surgical field was irrigated with sterile saline. The flap was repositioned and was hold tight in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical realising flap was sutured in place with three 4-0 silk suture. The four other interrupted sutures were placed inter-approximaly in the papilla (Fig.7). A final radiograph was taken (Fig.8) and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

Fig.7 Sutures in place

Fig.8 Final radiograph

October 28, 2005

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed (Fig.9, 10).
The patient was referred back to her GP to make a crown on the tooth.

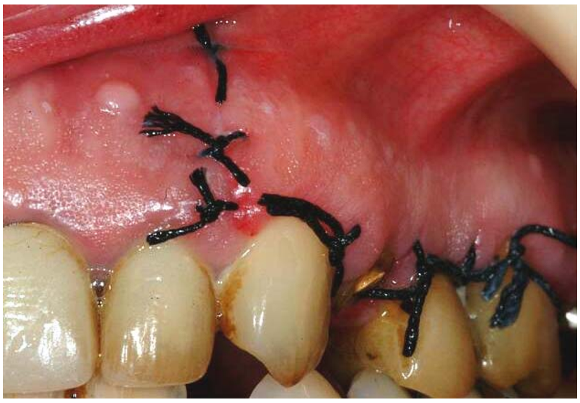

Fig.9 One week post operative

Fig.10 Sutures were removed

Evaluation

Everything went as planned.
Her GP had placed IRM two weeks earlier because of fracture of the tooth crown. The patient was toled to get in contact with her GP for further treatment.

Prognosis

Endodontic prognosis was considered favourable.

5 months follow-up

21.03.06

The patient returned to the clinic 5 months later for a follow-up. Healing of the oral mucosa without any scare formation was seen and healing in progress in the apical area (Fig.11, 12). The patient was asked to consult her GP for further treatment of the tooth as soon as possible.

Fig.11 Five months follow-up

Fig.12 Five months follow-up

Discussion

Management of the resected root end during periradicular surgery is critical to a successful outcome (Gutmann 1993). The portion of root apex that is inaccessible to instrumentation and, as a consequence, cannot be cleaned, shaped or filled, or is associated with extraradicular infection that is unresponsive to non-surgical treatment, is removed. A filling material is then placed into a prepared root-end cavity as a 'physical seal' to prevent the passage of microorganisms or their products from the root canal system into the adjacent periradicular tissues. The placement of a root-end filling is one of the key steps in managing the root end.

The ideal healing response after periradicular surgery is the re-establishment of an apical attachment apparatus and osseous repair (Andreasen 1973, Craig 1993). However, histological examination of biopsy specimens reveals three types of tissue response (Andreasen 1972): healing with reformation of the periodontal ligament; healing with fibrous tissue (scar); and moderate-to-severe inflammation without scar tissue. The deposition of cementum on the cut root face is considered a desired healing response and a pre-requisite for the reformation of a functional periodontal attachment (Andreasen 1973). Resection of the root end results in an exposed dentinal root face surrounded peripherally by cementum with a root canal in the middle. Cementum deposition occurs from the circumference of the root end and proceeds centrally toward the resected root canal. The cementum provides a 'biological seal,' in addition to the 'physical seal' of the root-end filling, thereby creating a 'double seal' (Regan 2002).

Mineral Trioxide Aggregate (MTA)

MTA was developed as a new root-end filling material at Loma Linda University, California, USA. A study on the physical and chemical properties of MTA investigated the composition, pH, radiopacity, setting time, compressive strength and solubility of the material compared with amalgam and reinforced ZOE cements (Torabinejad 1995). Unlike a number of dental materials that are not moisture-tolerant, MTA actually requires moisture to set. The MTA powder consists of fine hydrophilic particles. When mixed with sterile water, hydration of the MTA powder results in a colloidal gel that solidifies into a hard structure. It has a long setting time (2 h 45 min) so the material must be protected before it is fully set. The pH of MTA rises from 10.2 after mixing to 12.5 after 3 h, remaining unchanged afterwards. Likewise, the compressive strength of MTA increases with time, from 40.0 MPa after 24 h to 67.3 MPa after 21 days.

The sealing ability of MTA was investigated using fluorescent dye and confocal microscopy (Torabinejad 1993), methylene blue dye (Torabinejad 1994), and bacterial marker (Torabinejad 1995); its marginal adaptation was assessed using scanning electron microscopy (Torabinejad 1995); the long-term seal was measured over a 12-week (Bates 1996) and 12-month period (Wu 1998) using different fluid transport methods. They all reported good results with MTA when ranked with other materials. This may be because of its moisture tolerance and long setting time.

The antibacterial activity of MTA was investigated using the agar diffusion inhibitory test (Torabinejad 1995) and the mutagenicity by the Ames test (Kettering 1995). The antifungal (Al-Nazhan 2003), and both antibacterial and antifungal effects (Estrela 2000) of MTA were also evaluated.

The biocompatibility assessment of MTA encompassed *in vitro* cell culture techniques using established cell lines, primary cell cultures or a combination (Huang 2005, Koh 1998). Apart from variations in sensitivity because of the cell type used, the results showed MTA to be biocompatible. Tissue response evaluated *in vivo* by intraosseous and subcutaneous implantation experiments (Torabinejad 1998, Yaltirik 2004) found MTA to be well tolerated. MTA was also shown not to have an adverse affect on connective tissue microcirculation when assessed using an improved rabbit ear chamber (Torabinejad 1995). *In vivo* usage testing (Torabinejad 1995, 97) revealed less inflammation with MTA root-end fillings compared with amalgam, in addition to the presence of new cementum formed adjacent to the MTA.

MTA has the ability to encourage hard-tissue deposition and the mechanism of action may have some similarity to that of calcium hydroxide (Holland 1999). Although hard-tissue formation occurs early with MTA (Economides 2003), there was no significant difference in the quantity of cementum or osseous healing associated with freshly placed or set MTA (Apaydin 2003). The patterns of osteogenesis for intraosseous implants of MTA and EBA were similar at 15 and 30 days but interestingly, at 60 days, EBA exhibited greater osteogenesis than MTA (Moretton 2000). If the assessment period were longer, the difference may not have been significant.

Investigations of why MTA appears to induce cementogenesis found that the material seemed to offer a biologically active substrate for osteoblasts, allowing good adherence of the bone cells to the material, while also stimulating the production of cytokines (Koh 1997, 98). Cytokine release was not detected in another study on MTA (Haglund 2003) and the difference may be due to a number of factors.

The effects of MTA on cementoblast growth and osteocalcin production were investigated in a tissue culture experiment (Thomson 2003). Results suggested that MTA permitted cementoblast attachment and growth, whilst the production of mineralized matrix gene and protein expression indicated that MTA could be considered cementoconductive. MTA was found to stimulate extracellular regulated kinases, members of the mitogen-activated protein kinase pathway, which are involved with bone cell proliferation, differentiation and apoptosis (Huang 2003). Subsequently, the effects of a calcium hydroxide liner, EBA, and MTA were evaluated on U2OS human osteosarcoma cells and the expression of inflammatory cytokines. The best cell attachment and the higher cytokine levels were found with MTA (Huang 2005). MTA also induced fibroblasts to express genes associated with cementum formation of an osteogenic phenotype (Bonson 2004). When the *in vitro* behavior of bone marrow cells to MTA and IRM was investigated, MTA had low toxicity compared with IRM. However, it did not inhibit cell growth, but rather seemed to suppress their function as osteoblasts and promoted their function as fibroblasts (Nakayama 2005).

A study to elucidate the physicochemical basis of the biological properties of MTA concluded that calcium, the dominant ion released from MTA, reacts with tissue phosphates yielding hydroxyapatite, the matrix at the dentine-MTA interface (Sarkar 2005). The sealing ability, biocompatibility, and dentinogenic activity of MTA may be attributed to these physicochemical reactions.

ProRoot MTA (Dentsply/Maillefer, Ballaigues, Switzerland) is the first commercially available version of MTA. Initially, ProRoot MTA was grey in color but because of aesthetic concerns (Mitchel 1999), a white version is now available. Both products have similar composition but tetracalcium aluminoferrite is absent in white MTA (Al-Hezaimi 2005). Principle differences in the constitution of the two versions of MTA were confirmed by X-ray energy dispersive analysis and X-ray diffraction analysis (Camilleri 2005).

The use of electron probe microanalysis of the elemental constituents indicated that the most significant differences between grey and white MTA were the measured concentrations of Al_2O_3, MgO and especially FeO (Asgary 2005). However, when two different osteoblast cell lines were evaluated morphologically to characterize their behavior when in contact with grey and white MTA (Peréz 2003), the MG-63 osteosarcoma cells adhered to white MTA for periods twice as long as primary osteoblasts. While there was no difference between cell lines in their adherence to grey MTA, primary cell cultures were considered more appropriate for *in vitro* testing of endodontic materials.

The first randomized prospective clinical study on the use of MTA as a root-end filling material was published by Chong et al. (Chong 2003). After 24 months, of the 108 patients reviewed (47 in IRM group, 61 in MTA group), the highest number of teeth with complete healing was observed with MTA. When the numbers of teeth with complete and incomplete (scar) healing were combined, the results for MTA were higher (92%) compared with IRM (87%). However, statistical analysis showed no significant difference in outcome between materials. The good results with both materials may be due to the strict entry requirements and stringent, established criteria for assessing treatment outcome. Similar results were reported by Lindeboom et al. (Lindeboom 2005) in a clinical study consisting of 100 single-rooted teeth; there were no statistically significant differences between MTA (92%) and IRM (86%) after 1 year.

A Brazilian version of MTA was developed to improve it handling and setting properties (Duarte 2003). The product is MTA-Angelus (Angelus Dental Solutions, Londrina, Paraná, Brazil) and is claimed by the manufacturer to have an initial setting time of 10 min. While the sealing ability and marginal adaptation of MTA-Angelus were shown to be good (Xavier 2005), the pH and calcium released from MTA-Angelus were slightly higher than those from ProRoot MTA (Duarte 2003). The cytotoxicity of MTA-Angelus on ECV 304 human endothelial cells was found to be similar to ProRoot MTA and a Portland cement (De-Deus 2005). In another study, using different cells, no cytotoxic effect was found with MTA-Angelus, a grey and a white Portland cement (Ribeiro 2005).

Further attempts to improve the handling properties of MTA include the formulation of an experimental endodontic cement which handles like a gel (Santos 2005). Viscosity Enhanced Root Repair Material (VERRM) is another recently formulated material based on Portland cement (Chng 2005).

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Case number 3

Retreatment of mandibular left first molar in conjunction with hemisection

Patient

A 52-year-old white Norwegian female (Fig.1) was referred to the Department of Endodontics, University of Oslo, by me December 10, 2004 for treatment of mandibular left first molar.

Fig. 1 Frontal view

Medical history

Non-contributory.

Dental History & Chief Complaint

Patient consulted me in my private practice March 22, 2004 because of pain and swelling in left lower jaw. Seven years earlier I had made an Empress crown on mandibular left first molar. The root canal treatment was done another 10 years earlier by another GP. Patient had felt sore on biting on the tooth for 2 weeks, and the last couple of days a swelling in the gum outside the tooth had evoked.

Clinical Examination

Preoperative photo showed the region from mandibular left canine to mandibular left second molar (Fig.2).

No pathology was found extra-orally.

A normal oral mucosa was observed.

Mandibular left second molar: A MOB composite restoration and L a small amalgam restoration were seen. The tooth responded positively to the sensibility test with Endo Ice.
Mandibular left first molar: An Empress crown was seen and the tooth responded negatively to the sensibility test with Endo Ice. It was tender to palpation and percussion, and a hard swelling was seen and palpable buccally.

Fig. 2 Region from mandibular left canine to left second molar.

Mandibular left second premolar: An OD composite restorationon was seen and responded positively to the sensibility test with Endo Ice.
Mandibular left first premolar: The tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower left and right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from mandibular left second premolar to left second molar (Fig. 3).

Mandibular left second molar: A MO and B radiopaque restoration were seen and lamina dura could be followed around the entire root.
Mandibular left first molar: A radiopaque restoration was seen in the crown. A radiopaque material could be seen in the root canal approximately 3 mm short of apex in the mesial root, and a radiolucent area in the coronal part of the distal root. The mid and apical part of the distal root was under instrumented. Lamina dura could be followed around the distal root. Radiolucency was seen in the furcation area. On the mesial root lamina dura could be followed apical where it widened to a radiolucent area of approximately 6 mm in diameter.

Mandibular left second premolar: Lamina dura could be followed around the entire root. A OD radiopaque restoration was seen.

Fig.3 Radiolucent area mesial root 36

The height of the marginal bone was within normal limits except in the furcating area of mandibular left first molar.

Diagnosis

Acute apical periodontitis with abscess mandibular left first molar

Treatment Plan

Retreatment of an endodontic treated mandibular left first molar

Treatment

March 22, 2004

Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution. The gutta-percha in the 2 mesial canals were localized, and were removed with the help of Protaper F3 and F2.
Irrigation was done with 5% sodium hypochlorite and 15% EDTA. An nr 15 K-flex was taken to working length using a balanced force technique. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig. 4)
Working length was 20 mm with B cusp as a reference point in both MB and ML canal. The last instrument was NiTi nr 45. Finally canals were dressed with Consepsis (2% chlorhexidine digluconate - Ultradent) for 5 minutes. The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.
The distal canal was not treated because no pathology was seen, and a ”post” of composite reinforced with Ribbond could possibly make the retreatment difficult.

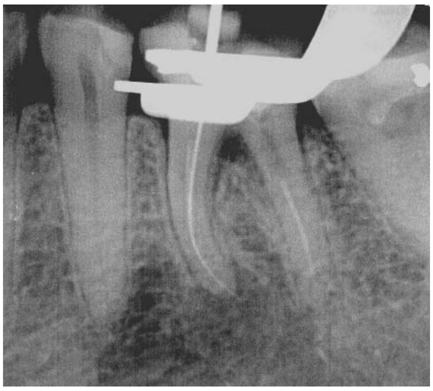

Fig.4 Working length mesial canals

Fig.5 Retreated mesial canals

June 16, 2004

The patient returned two months later with no symptoms from the tooth. Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi nr 45, and irrigation with 5% sodium hypochlorite, 15% EDTA and the canals were dressed for 5 minutes with Consepsis. The root canals were dried with sterile paper points, and filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. The access cavity was filled with composite after etching, silane treatment and bonding (Fig.5).

June 22, 2004

The patient returned one week later with the same symptoms as first time.

Differential diagnosis was root fracture.

I wanted to retreat also the distal canal to be sure I had done the best possibly non-surgical retreatment, and in case of need of further treatment.
Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution.
The distal canal was filled with composite reinforced with Ribbond in the coronal part of the canal acting as a post. This was removed with a round burr 010.
Irrigation was done with 5% sodium hypochlorite and 15% EDTA. An nr 15 K-flex was taken to working length using a balanced force technique. There was no need of chloroform.
Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig. 6)
Working length was 21mm with B cusp as a reference point (Fig.6).The last instrument was NiTi nr 60. The canal was finally dressed for 5 minutes with Consepsis. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

August 04, 2004

The patient returned six weeks later and the tooth was still symptomatic.
It was decided to do an explorative surgery to see if it was a vertical root fracture. If not, there would be done an apicoectomi.

The rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi nr 60, and irrigation with 5% sodium hypochlorite, 15% EDTA and the canal was dressed for 5 minutes with Consepsis. The root canal was dried with sterile paper points, and filled with AH Plus and gutta-percha with cold lateral condensation technique. The root-filling was removed 2 mm apical to the orifice and sealed with IRM plug. The access cavity was filled with composite after etching, silane treatment and bonding (Fig.7).

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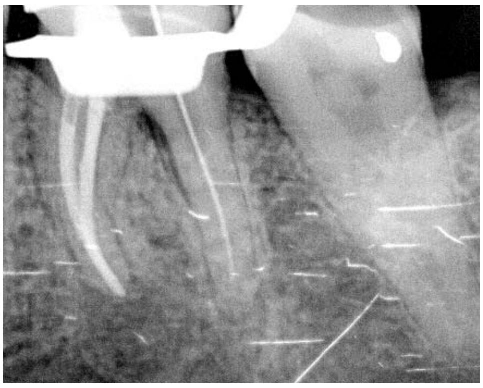

Fig.6 Working length distal canal.

Fig.7 Retreated distal canal.

The patient was referred to the Endodontic Department, University of Oslo, for explorative surgery.

September 08, 2004

Clinical and radiographic examination was done before surgery.
The clinical examination revealed two sinus tracts buccal of mandibular left first molar (Fig.8, 9, 10). The sinus tracts were traced with two #40 gutta-percha points. The tracing radiograph showed that the origin was the mesial canals (Fig.11).

Fig.8 Frontal view

Fig.9 Two sinus tracts were seen **Fig.10** Gutta-percha in the sinus tracts

Fig.11 Sinus tracts tracing

Three carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision starting from the mesiobuccal gingival line angle of the canine approximately 1 cm in an inferior aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of mandibular left second molar. Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap.
A root fracture was detected on the MB root as soon as the flap was raised (Fig.12).

Fig.12 Detection of a vertical root fracture on the mesial root

It was done a hemisection of the mesial part of the tooth (Fig.13).
The distal root and the distal part of the crown were shaped in a fashion to facilitate cleaning.
The mesial root was fractured in a mesial and distal part. The fracture went almost all the way down to apex (Fig.14, 15).

Fig.13 Hemisection of mesial root

Fig.14 The fractured mesial root

Fig.15 The fractured mesial root, note the black colour of gutta-percha

The surgical field was irrigated with sterile saline. The flap was repositioned, and was hold tight in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical realising flap were sutured in place with two 4-0 silk suture. The four other interrupted sutures were placed inter-approximately in the papilla (Fig.16). A final radiograph was taken, and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

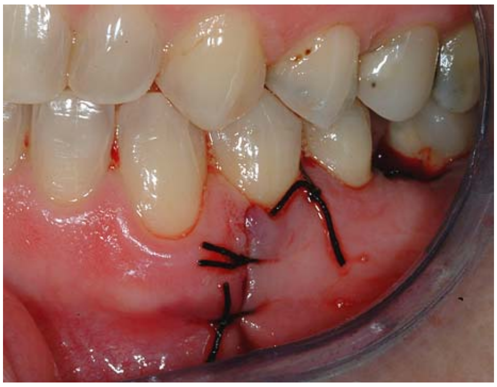

Fig.16 Sutures in place

September 15, 2004

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed (Fig.17, 18).

Fig.17 One week post operative

Fig.18 Removed sutures

Evaluation

Differential diagnosis was vertical rootfracture from the beginning. Due to incomplete root-filling and no clinical findings of VR retreatment was started.
The distal root was retreated foremost because of eventually the need of a hemisection.
Treatment options were discussed with the patient and she preferred hemisection if that was possible. The distal root had a curvature in the furcation area that made it suitable for hemisection

Prognosis

Endodontic prognosis was considered favorable

One year follow-up

February 10, 2006

The patient returned to the clinic one year after surgery. The tooth had remained asymptomatic (Fig.22, 23).The patient was satisfied with the function of the tooth.
The healing of the gingival and periodontal aspects was satisfying.
The control radiographs showed favorable outcome (Fig.24, 25).

Fig.22 Buccal view one-year follow-up

Fig.23 Occlusal view one year follow-up

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Fig.24 BW one year follow-up

Fig.25 One year follow-up

Discussion

As early as 1931, it was suggested that root canal treatment was a factor influencing the incidence of vertical root fractures (Arnold 1931). Although case reports have demonstrated that vertical root fractures can occur in nonroot-filled teeth (Yang *et al.* 1995), the principal feature associated with vertically fractured roots is prior root canal treatment (Gher *et al.* 1987). Further studies have shown that vertical root fracture occurs most commonly in the buccolingual plane (Pitts & Natkin 1983, Saw & Messer 1995), may be initiated anywhere at or between the apex and the crown (Pitts & Natkin 1983), and is responsible for 4.3% of endodontic failures (Vire 1991). Attempts have been made to treat these fractures (Friedman *et al.* 1993, Selden 1996, Dederich 1999, Schwartz *et al.* 1999, Hayashi *et al.* 2002, Kawai & Masaka 2002), but a favourable long-term prognosis has yet to be achieved because of complexities associated with material biocompatibility and poor capacity of the restorative materials to achieve radicular resistance to refracture. Since vertical root fractures extend from the root canal to the periodontium, profound and rapid destruction of the bone and periodontium occur in a linear fashion adjacent to the fracture (Harrington 1979). The destruction is a manifestation of debris, necrotic tissue and bacteria harboured in the fracture which prevent repair, thus requiring extraction of the fractured root or entire tooth (Walton *et al.* 1984).

The influence of prior root canal treatment on propensity for vertical root fracture has been examined in several studies. It has been reported that excessive force during lateral compaction caused 84% of vertical root fractures with documentation of many patients experiencing a sound at the time of filling indicative of the root being fractured (Meister *et al.* 1980). Additionally, vertical root fractures have been shown to occur with spreader loads as small as 1.5 kgf (14.7 N) (Holcomb *et al.* 1987). In contrast, another investigation showed the mean load required to cause vertical root fracture was five to six times higher than the load used to fill a canal, casting doubt on the likelihood of fracture occurring at the time of filling (Saw & Messer 1995). It has been postulated that dentine may have sufficient elasticity to permit some separation of root segments without creating a complete fracture, manifesting in small, incomplete fractures created at the time of filling which may eventually become complete vertical root fractures upon extending completely to the periodontium (Walton *et al.* 1984). It is also possible that distortions are stored in dentine and remain quiescent over time. With additional stress applied through mastication or restoration, the latent fractures could occur as complete fractures at a later time (Dang & Walton 1989). Harvey et al.(1981) demonstrated that strain increased in the canal wall during compaction, but the photoelastic models used in their study returned to their original unstressed states after filling was completed, casting doubt on the likelihood that stresses were stored.Dang & Walton (1989) noted that it has not been established whether fractures occur at the time of filling or manifest themselves at a later time. At present, this fundamental question remains a point of contention because vertical root fracture is a complex issue that is difficult to study comprehensively.

One of the potential factors which may influence propensity for vertical root fractures is the prepared canal diameter. Generally, taper should be sufficient to permit deep penetration of spreaders or pluggers during filling but should not be excessive to the point where procedural errors occur, and the root is unnecessarily weakened (Walton & Torabinehad 1996). Holcomb *et al.* (1987) remarked that there must be a point at which increased canal width and taper begin to weaken the root. Intuitively, it is reasonable to speculate that increasing the taper of the canal preparation by removing more dentine from the canal wall would diminish the structural integrity of the root. Using finite-element analysis, Ricks-Williams et al (1995) found the magnitude of generated radicular stresses to be directly correlated with the simulated canal diameters. Wilcox *et al.* (1997) found that root surface craze lines formed on roots where greater percentages of the canal wall were removed. Conversely, it has been reported that no significant correlation exists between fracture load and size of the root, size of the prepared canal, width of the canal walls after instrumentation, and taper of the root or of the canal (Pitts *et al.* 1983). Additionally, greater flaring allows compaction forces to be delivered more effectively to the apical third of the canal and imparts better stress distribution (Harvey *et al.* 1981).

Localized stresses in inner dentin are most closely associated with VRF. These stresses may occur during or after endodontic treatment, when the tooth is subjected to occlusal force or further clinical procedures such as post placement. Thus, decreasing the applied force during endodontic or restorative procedures (obturation, post placement) is significant in reducing the risk of fracture, especially in teeth such as mandibular incisors and lower molars, which are susceptible to VRF.

Mechanical instrumentation of root canals can produce craze lines on the root canal wall (16), which may serve as localized sites of increased stress (in accordance with stress-concentration theory). Instrumentation procedures should be undertaken with gentle force and using copious irrigation to minimize crazing. The dentist's goal should be to create a root canal shape that maximizes radius of curvature of the root canal wall. A circular shape minimizes stress concentration areas and will distribute stress more uniformly. Furthermore, procedural errors that create stress concentration areas on the root canal wall, such as ledging, gouging, crazing, etc., should be avoided. Although canal cross-sectional shape seems more important than dentin thickness in stress distribution, removal of root dentin should be minimized. By maintaining dentin thickness as much as possible, especially in the proximal areas or in the thin part of root dentin, additional stress from bending mechanisms will be minimized. Caution has to be exercised in any procedure involving a tooth that is susceptible to VRF.

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Case number 4

Retreatment of maxillary left lateral incisor in conjunction with apical surgery

Patient

A 41-year-old white Norwegian male was referred to the Endodontic Department, University of Oslo, by me April 22, 2004 for treatment of maxillary left lateral incisor (Fig. 1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

Patient consulted me in my private practice August 13, 2003 because of pain and swelling from a tooth in the front upper jaw.
The lateral left incisor was endodontically treated approximately 15 years ago.
There had always been a feeling of numbness in the region after the endodontic treatment, but it had never been pain and swelling.
The patient was very concerned about the swelling.

Clinical Examination

Preoperative photo showed the region from maxillary right central incisor to maxillary left first premolar (Fig.2).

Fig.2 Abscess regio 22

No pathology was found extra-orally

A normal oral mucosa was observed.

Maxillary right central incisor: The tooth responded positively to the sensibility test with Endo Ice.
Maxillary left central incisor: A D composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Maxillary left lateral incisor: The entire crown was almost a composite build-up. It was tender to palpation and percussion and an abscess was seen buccaly. The tooth responded negative to the sensibility test with Endo Ice.
Maxillary left canine: The tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from maxillary left central incisor to maxillary left first premolar (Fig.3)

Maxillary left central incisor: A radiopaque restoration was seen distally and lamina dura could be followed around the entire root.
Maxillary left lateral incisor: A radiopaque restoration was seen in the crown. A radiopaque material was seen in the canal. A radiolucent area was seen in the approximately 3 mm of the apical part of the root. The root filling was under-instrumented. Lamina dura could be followed apical where it widened to a radiolucent area of approximately 10 mm in diameter.
Maxillary left canine: Lamina dura could be followed around the entire root.

Fig.3 An apical radiolucency was seen apical of 22

The height of the marginal bone was within normal limits.

Diagnosis

Apical periodontitis with abscess maxillary left lateral incisor.

Treatment Plan

Retreatment of an endodontically treated maxillary left lateral incisor.

Treatment

August 13, 2003

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The access cavity was irrigated with 5% sodium hypochlorite. The gutta-percha in the canal was localized, and was removed with the help of Protaper F3.
Irrigation was done with 5% sodium hypochlorite and 15% EDTA. A nr 45 NiTi was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig. 4)
Working length was 19.5 mm with the incisal edge as a reference point.
The last instrument was NiTi nr 60.
The root canal was dried with sterile paper points, and filled with UltraCal XS (calcium-hydroxide paste - Ultradent) intracanal dressing. The access cavity was sealed with IRM.

November 13, 2003

The patient returned three months later. The tooth was asymptomatic.
The radiograph revealed that the intracanal dressing was washed out in the apical part (Fig.5).
Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. UltraCal XS was removed with NiTi nr 60 and irrigation with 5% sodium hypochlorite and 15% EDTA. The root canal was dried with sterile paper points, and filled with UltraCal XS intracanal dressing. The access cavity was sealed with IRM.

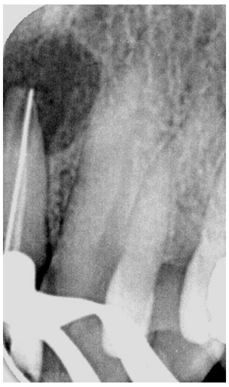

Fig.4 Working length **Fig.5** UltraCal XS washed out in the apical part. .

January 22, 2004

The patient returned 2 months later, and the tooth was asymptomatic. The radiograph revealed that the intracanal dressing was in place (Fig.6). The healing seemed to be in progress. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. UltraCal was removed with NiTi nr 60 and irrigation with 5% sodium hypochlorite and 15% EDTA. The root canal was dried with sterile paper points, and filled with AH Plus and master gutta-percha cone nr 60 with a cold lateral condensation technique (Fig.7, 8). The root-filling was removed 2 mm apical to the orifice and sealed with an IRM plug. Access cavity was sealed with IRM (Fig.9, 10).

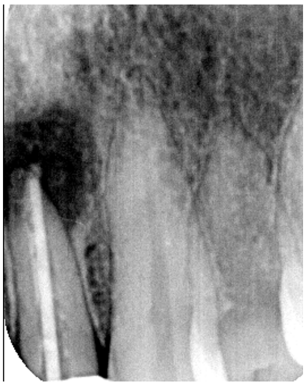

Fig.6 UltraCal XS in place after 2 months

Fig.7 Master cone

Fig.8 Root-filling with surplus of sealer

Fig.9 Buccal view **Fig.10** Palatal view

March 15, 2004

The patient returned two months later with a swelling and sinus tract from maxillary left lateral incisor (Fig. 11, 12, 13).

Fig.11 Sinus tract

Fig.12 Gutta-percha tracing

Fig.13 Drainage of puss

Diagnosis

Apical periodontitis with sinus tract maxillary left lateral incisor

Treatment plan

Apicoectomy of maxillary left lateral incisor

The patient was referred to the Department of Endodontics, University of Oslo, for apicoectomy of maxillary left lateral incisor.

April 28, 2004

The patient came to the Department of Endodontics six weeks later for performing apicoectomy on maxillary left lateral incisor. Four carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision, starting from the distobuccal gingival line angle of the right central incisor approximately 1 cm in a superior aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of left second maxillary premolar (Fig.14)

Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap. A pathological bone fenestration was detected outside the root (Fig.15).

Fig.14 The incision

Fig.15 A pathological bone fenestration was seen

The lesion was removed with periodontal curettes. Osteotomy of the outer cortical plate was accomplished with an nr. 6 round bur on a 45° angled high speed hand piece under irrigation with sterile saline to adequately expose the root end. Three mm of the root apex was resected with a long fissure bur (Fig.16). A retrograde preparation was carried out with the piezoelectric Satelec ultrasound device using ultrasonic tip CT under constant cooling with rinsing sterile saline. The cavity was extended up to 3 mm in the root canal and followed gutta-percha at all times. A microscope was being used most of the time in order to achieve maximal visibility.

Stryphnon gauze was placed in the bone cavity in order to achieve haemostasis. The cavity was irrigated with sterile saline and dried with sterile paper points. A retrograde MTA filling was placed into the cavity using plastic instrument as a carrier and condensed with micro condensing pluggers. A burnisher was used at the end. The retro-filling was examined under high magnification with an explorer to check marginal adaptation and integrity (Fig.17).

Fig.16 Resection of the root **Fig.17** Inspection of the MTA retrofill

The Stryphnon gauze was removed. The surgical field was irrigated with sterile saline.The flap was repositioned and was hold tight in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical realising flap was sutured in place with two 4-0 silk suture. The five other interrupted sutures wereplaced inter-approximaly in the papilla (Fig.18). A final radiograph was taken (Fig.19) and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

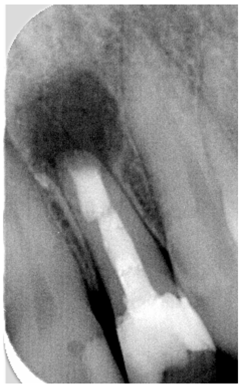

Fig.18 Sutures in place Fig.19 Final radiograph

May 06, 2004

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed (Fig.20)

Evaluation

The retrograd filling was extending the shape of the filled root canal. This will further weaken an already weak/thin root. No post placement recommended.

Prognosis

Endodontic prognosis was considered favourable

Fig.20 The sutures were removed one week post operative.

Two year follow-up

March 30, 2005

The 2 year follow-up examination revealed healing with scar tissue and the tooth had recived a PFM crown (Fig.21, 22, 23, 24, 25).

Fig.21 Two year follow-up

Fig.22 Two year follow-up

Fig.23 Start of treatment

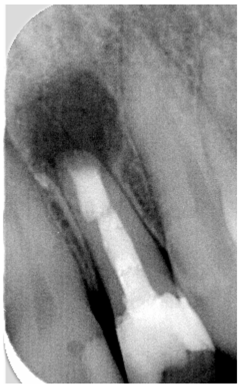

Fig.24 After surgery

Fig.25 Two year follow-up

Discussion

Within infected root canals, the inner layer of dentine next to the pulp space contains a large number of microorganisms (Valderhaug 1974, Peters *et al.* 2001). One aim of root canal instrumentation is to remove the inner layer of dentine together with the bacteria (Walton & Torabinejad 1996). However, in many cases bacteria have penetrated deeply into the dentinal tubules to such an extent that they cannot be removed mechanically (Armitage *et al.* 1983, Ando & Hoshino 1990, Peters *et al.* 2001).

Many rotary hand and rotary instrumentation techniques tend to produce round preparations (Vessey 1969, Hülsmann *et al.* 2001), leaving areas of the canal wall uninstrumented, especially in oval canals (Walton 1976, Gambill *et al.* 1996, Evans *et al.* 2001, Wu & Wesselink 2001, Ardila *et al.* 2003, Bergmans *et al.* 2003). Inevitably, as the canal is not instrumented in these regions the infected inner layer of dentine will remain. Recently it has been reported that in oval canals, even circumferential hand filing could only remove the inner layer of dentine from 58% of the circumference of the canal wall, leaving 42% unprepared (Wu *et al.* 2003). Thus, although pressure was applied to the shank of the file towards canal walls in all directions during outward stroking of the instruments, the cutting of the file in the apical root canal was not predictable. Rotary instruments without radial lands can be used in a circumferential motion, but even so, it has been shown that much of the canal wall remains unprepared following their use (Bergmans *et al.* 2003, Peters *et al.* 2003).

Clearly, no technique presently available is able to remove the entire inner layer of infected dentine from a root canal. Consequently, bacteria are likely to remain in dentinal tubules after instrumentation (Leonardo *et al.* 1994, Ricucci & Langeland 1998). It has been reported that the surface tension of sodium hypochlorite limits its ability to spread within the canal (Cunningham & Balekjian 1982). This irrigant solution is thus unable to penetrate and cleanse narrow, confined portions of root canal systems, particularly dentinal tubules (Senia *et al.* 1971, Salzgeber & Brilliant 1977).

The antimicrobial effect of calcium hydroxide, the most popular intra-canal medicament, is related to the release of hydroxyl ions in an aqueous environment; however, the free radical rarely diffuses away from the bulk of the material (Siqueira & Lopes 1999). In addition, dentine has an inherent buffering capacity to reduce the pH of calcium hydroxide pastes (Wang & Hume 1988). Thus, calcium hydroxide will have a limited lethal effect on bacteria within dentinal tubules and other inaccessible areas such as apical canal ramifications and isthmuses and it remains to be seen if other medicaments, for example, calcium hydroxide combined with chlorhexidine, are more potent (Shuping *et al.* 2000, Sirén *et al.* 2004).

It has been shown that microorganisms from the root canal of the tooth can invade periapical endodontic lesions of asymptomatic teeth and establish an infectious disease process extraradiculary (Tronstad et al.1987, Happonen et al. 1985, Sunde et al. 2000a & b, Gatti et al. 2000). The infection is usually polymicrobial**,** comprising anaerobic and facultative bacteria known from studies on the microflora of the root canal (Sundqvist 1976) and the periodontal pocket (Ximenez et al. 2000). In most instances, endodontic infections respond well to conventional root canal therapy.When the root canal is properly instrumented, disinfected, and obturated, follow-up studies show a success rate of teeth with apical periodontitis of 80% to 90% (Kerekes & Tronstad 1979, Bystrom et al. 1987). Still, this means that 10% to 20% of periapical lesions do not respond to local treatment of the tooth. It is not known wether the lack of response of refractory periapical lesions is due to the inaccessibility of the extraradicular microorganisms or to the presence of a microbiota, which is different from that normally found in endodontic infections. It has been shown that extraradicular bacteria may form colonies or aggregates where they are surrounded by extracellular material (Tronstad et al. 1990). Sometimes the bacterial aggregates have the form of granules with diameters up to 3 to 4 mm. These granules often have a bright, yellow color, and because of this, in older literature are referred to as sulfur granules (Kapsimalis et al. 1968). There are also indications that the flora of refractory lesions may be atypical. Thus, the root canal flora of root-filled teeth, where the treatment has failed, has been shown to differ markedly from the flora of infected root canals of untreated teeth (Moller 1966, Molander et al. 1998, Sundqvist et al. 1998).

It appears to be important to prevent pulpal infection because it is difficult to eliminate bacteria and biofilms from the root canal system, especially from the most apical portion of the root canal and apical ramifications (Nair *et al.* 1990a, 2005, Nair 2004). Furthermore, when the apical portion of the root has been infected, bacterial biofilms may occasionally be present on the external surface of the root tip (Siqueira & Lopes 2001, Leonardo *et al.* 2002, Tronstad & Sunde 2003). It is therefore preferable to perform root canal treatment in cases where the apical portion of the root has not been infected using a technique that prevents apical spread of microorganisms. .

When non-surgical root canal treatment is unsuccessful, surgical root canal treatment is often performed. Following root-end resection and ultrasonic root-end preparation, a root-end filling material is usually used to seal the root.

Mineral Trioxide Aggregate (MTA) has good physical, chemical and biological properties (Torabinejad *et al.* 1995), and has proven to be an excellent root-end filling material. IRM was for many years the golden standard of root-end filling material, and *in vivo* studies have shown no statistically significant difference in the healing capacity compared with the newer product, MTA (Chong *et al.* 2003; Lindeboom *et al.* 2005).

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Case number 5

Apicoectomi of maxillary right second premolar

Patient

A 37-year-old white Iranian male was referred to the Department of Endodontics, University of Oslo, March 24, 2004 for treatment of maxillary right second premolar after a two year follow-up revealed no signs of healing (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patient was treated at the Department of Endodontics 2 years ago by a postgraduate student. The endodontic retreatment of maxillary right second premolar showed no sign of healing after 2 year (Fig.2, 3, 4).
The patient had no symptoms from the area.

Fig.2 Start of retreatment

Fig.3 Final radiograph

Fig.3 Two year follow-up

Clinical Examination

No pathology was found extra-orally

A normal oral mucosa was observed.

Maxillary right first molar: A MODP amalgam restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Maxillary right second premolar: A composite build-up was seen and the tooth responded negatively to the sensibility test with Endo Ice. A sinus tract was seen in the buccal fold.
Maxillary right first premolar: Missing.
Maxillary left canine: The tooth responded positively to the sensibility test with Endo Ice.

Two preoperative photographs showed the region maxillary right second molar to canine (Fig.5, 6).

Fig.5 Buccal view

Fig.6 Occlusal view

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from maxillary right second molar to second premolar (Fig.7).

Maxillary right second molar: A MOD radiopaque restoration was seen and lamina dura could be followed around the entire roots.
Maxillary right first molar: A MOD radiopaque restoration was seen and lamina dura could be followed around the entire root.
Maxillary right second premolar: A radiopaque material in the root canal and crown was seen. Lamina dura could be followed down the root apical where it widened to a circumscribed radiolucency of 11 mm in diameter.

Fig.7 Periapical radiolucency of maxillary right second premolar,

The marginal bone level was within normal limits.

Diagnosis

Apical periodontitis with sinus tract maxillary right second premolar

Treatment plan

Apicoectomy of maxillary right second premolar

Treatment

March 24, 2004

The first consultation was examination and treatment planning.

May 19, 2004

The patient returned to the clinic two months later for performing apicoectomi. Three carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision, starting from the mesiobuccal gingival line angle of the maxillary right lateral incisor approximately 1 cm in a superior aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of maxillary right second molar was performed. Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap. No bone fenestration was detected outside the root.
Osteotomy of the outer cortical plate was accomplished with an nr 6 round bur on a 45° angled high speed hand piece under irrigation with sterile saline to adequately expose the root end. The lesion was removed with periodontal curettes. Three mm of the root apex was resected with a long fissure bur. A retrograde preparation was carried out with the piezoelectric Satelec ultrasound device using ultrasonic tip CT under constant cooling with rinsing sterile saline. The cavity was extended up to 3 mm in the root canal and followed gutta-percha at all times. A microscope was being used most of the time in order to achieve maximum visibility.

Stryphnon gauze was placed in the bone cavity in order to achieve haemostasis. The cavity was irrigated with sterile saline and dried with sterile paper points. A retrograde MTA filling was placed into the cavity using plastic instrument as a carrier and condensed with micro condensing pluggers. A burnisher was used at the end. The retro-filling was examined under high magnification with an explorer to check marginal adaptation and integrity.
The Stryphnon gauze was removed. The surgical field was irrigated with sterile saline. The flap was repositioned and was hold tight in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical realising flap was sutured in place with two 4-0 silk suture. The five other interrupted sutures were placed inter-approximaly in the papilla. A final radiograph was taken (Fig.8) and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

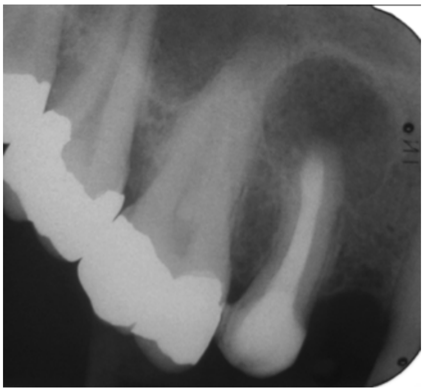

Fig.8 Final radiograph

May 26, 2004

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed (Fig9).

Fig.9 One week post operative

The microbiological and pathological results returned two weeks postoperatively.

Microbiological results

DNA probing:	Treponema socranskii ssp. socrans	(G- anaerobe spiral)
	Treponema denticola	(G- anaerobe spiral)
	Prevotella nigrescens	(G- anaerobe blackpigmented rod)
	Peptostreptococcus micros	(G+ anaerobe cocc)
	Eubacterium saburreum	(G+ anaerobe rod)
	Actinomyces israelii	(G+ anaerobe rod)
	Actinomyces gerecseriae	(G+ anaerobe rod)

Histological examination

Diagnosis: Part of a cystic wall which was sorrounded by squamous epithelial lining with moderate to intense chronic inflammation.

Evaluation

The lesion looked cystic and was almost nucleated in one piece. The histological result showed a cystic wall and that was probably the reason why it not healed in the first place. Also the microbiological results found bacteries that are afflicted with extraradicular infection, such as periapical actinomycosis.

Prognosis

Endodontic prognosis was considered favourable

Two year follow-up

April 18, 2006

The patient returned to the clinic two years later for a follow-up. Healing of the oral mucosa without any scare formation, and succesfull healing in the apical area was observed (Fig.7, 8). The patient was asked to consult his GP for further treatment of the tooth.

Fig.7 Two year follow-up

Fig.8 Two year follow-up

Discussion

When designing a tissue flap, various modes of incision can be selected, including horizontal, sulcular, submarginal, and vertical releasing incisions. The tissue flap in its entirety can be a full-thickness or a combination of a full- and a split-thickness flap. Consequently, a number of flap designs exist and are discussed in the literature, including specific rules and recommendations (1, 2, 3, 4, 5). The variety of flap designs reflects a number of variables to be considered. While many designs have been suggested over the years, some have become obsolete and new techniques have emerged (6).

It is critical that tissue incisions, elevations, and reflections are performed in a way that facilitates healing by primary intention. This goal can be obtained, firstly, by using a complete and sharp incision of the tissues, secondly, by avoiding severing and trauma of the tissue during elevation, and, finally, by preventing drying of tissue remnants on the root surface and drying of the reflected tissues during the procedure (1).

Triangular flap

The triangular flap design comprises a horizontal incision extending to several teeth mesial and distal of the involved tooth and one vertical-releasing incision, usually placed at the mesial end of the prospective flap (Fig. 1). A triangular flap exposes marginal and midsections of the root. Apical areas are generally difficult to reach without pulling extensively on the flap. If the access is too limited, the triangular flap can easily be converted into a rectangular flap by placing an additional releasing incision at the distal end of the horizontal incision. The triangular flap is mainly indicated for treatment of cervical resorptions, perforations, and resections of short roots. The main advantages for this flap design are the minimal disruption of the vascular blood supply to the reflected tissues and easy repositioning at wound closure. The drawback is a risk of recession due to the marginal line of incision.

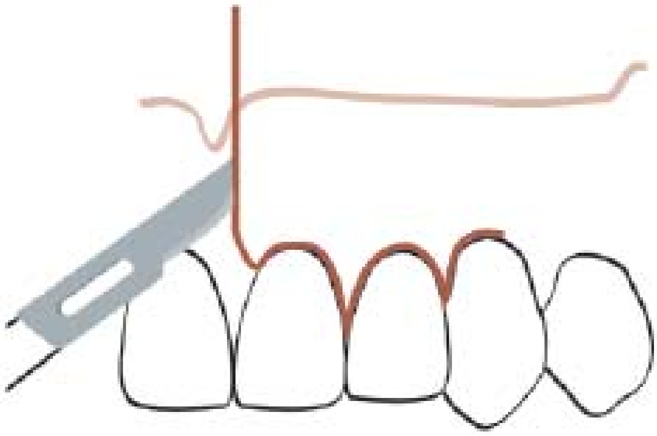

Fig.1 A triangular flap

Rectangular and trapezoidal flap

Rectangular and trapezoidal flaps are a continuation of a triangular design by adding a second vertical incision on the distal end of the flap (Fig. 2). The difference between the rectangular and trapezoidal version is the degree of divergence of the vertical incisions. Blood vessels run roughly parallel to the long axis of the teeth. In order to disrupt the vascular supply least, the vertical incision should be placed parallel to the root. This favors the rectangular flap (7, 8). On the other hand, the blood supply and survival of the mobilized tissue appeared to be the best when the basis was broader than the proximal end of the flap (9).

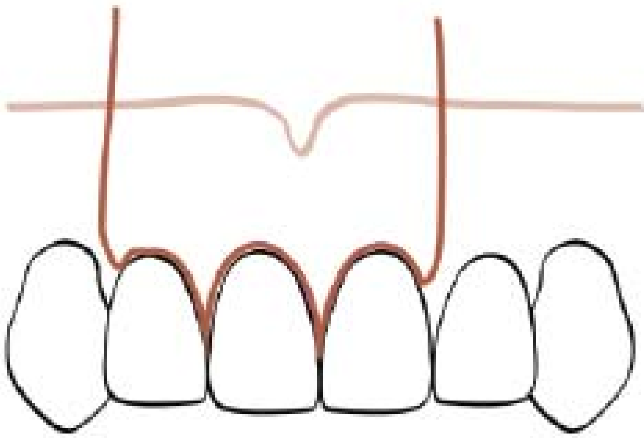

Fig.2 A rectungular flap

However, the unreflected tissue loses the greater part of its blood supply in broad-based flaps. For this reason, the vertical incisions should never be placed converging; rather, the flap width should be extended one or two teeth mesially or distally to the tooth involved. Mörmann & Ciancio (9) studied the effect of various types of surgical procedures on the gingival capillary blood circulation. The circulation changes observed suggested that flaps receive their major blood supply from their apical aspect, but not exclusively. However, the horizontal marginal incision severed the anastomoses between the gingival and periodontal vasculature. Flap blood perfusion was maintained up to the point where the ratio of length to width of the parallel pedicle flap equaled 2 : 1. The length/width ratio requirement usually favors a slight trapezoidal shape of the flap, with strong a preference of extending the horizontal dimension of the flap over several teeth.

Repositioning the tissue and wound closure in the rectangular and trapezoidal flaps is easy because of the definite position of the papillae during re-approximation of the tissue. In esthetically critical areas with prosthetic restorations involving subgingivally placed crown margins, a postoperative sequel can result in recession, leading to an esthetically compromising exposure of the crown margins.

Submarginal flap

The submarginal flap design also referred to as an Ochsenbein–Luebke flap (10) is similar to the rectangular flap, with the difference that the horizontal incision is placed within the attached gingiva. The two vertical incisions are connected by a scalloped horizontal incision, performed roughly parallel to the marginal contour of the gingiva (Fig.3).

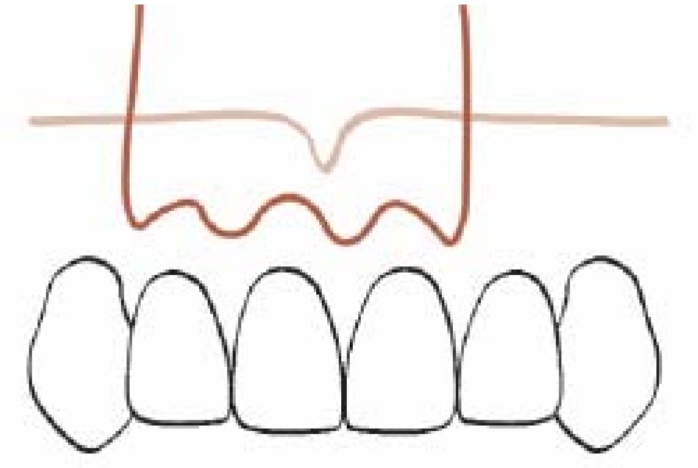

Fig.3 A submarginal flap

The submarginal incision should only be used when there is a broad zone of attached gingiva with a minimum of 2 mm (11). Leaving a sufficient amount of marginal attached gingiva in place is important to avoid deprivation of blood supply to this unreflected tissue and risk its necrosis. Such a tissue breakdown will lead to a major recession with devastating esthetic result. Nevertheless, the fear of even small recessions is the driving force for considering the submarginal flap. When properly planned and performed, the submarginal flap will leave the marginal gingiva untouched and does not expose restoration margins.

The crestal bone is not denuded, preventing potential attachment loss observed with marginal flaps. Pihlstrom et al. (60) studied healing results when a sulcular full-thickness flap was elevated in an area with shallow pockets (1–3 mm). They observed loss of attachment, which was still present 6.5 years postoperatively.

Incised tissue margins should not be placed over the underlying apical lesion or surgical bony access, as this scenario carries a higher risk of postoperative infection. Possible scar tissue formation is another disadvantage.

Papilla-base flap

The papilla-base flap was suggested to prevent recession of the papilla. This flap consists of two releasing vertical incisions, connected by the papilla-base incision and intrasulcular incision in the cervical area of the tooth. The name is derived from the preparation of the papilla base using a microsurgical blade. The size of the blade should not exceed 2.5 mm in width. Controlled and minute movement of the surgical blade within the small dimensions of the interproximal space is crucial.

The papilla-base incision requires two different incisions at the base of the papilla. A first shallow incision severs the epithelium and connective tissue to the depth of 1.5 mm from the surface of the gingiva (Fig. 4, blue line). The path is a curved line, connecting one side of the papilla to the other. The incision begins and ends perpendicular to the gingival margin (Fig. 5). In the second step, the scalpel retraces the base of the previously created incision while inclined vertically, toward the crestal bone margin. The second incision results in a split-thickness flap in the apical third of the base of the papilla (Figs 4, green line). From this point

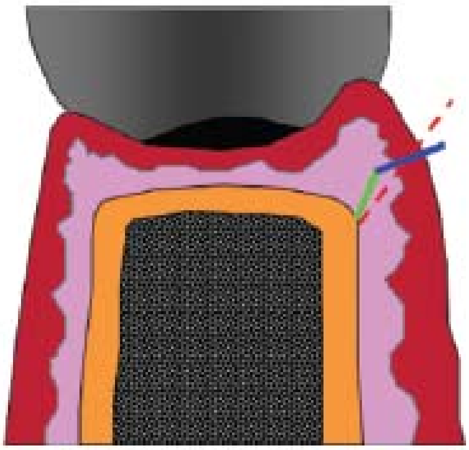

Fig.4 Schematic drawing of papilla base flap incision types.

Fig.5 Curved incision line placed perpendicular to the gingival margin.

on apically, a full-thickness mucoperiosteal flap is elevated. Although the papilla-base flap achieved very predictable healing results, this technique is challenging to perform. Atraumatic handling of the soft tissues is of utmost importance in order to obtain rapid healing through primary intention. The epithelium of the partial-thickness flap has to be supported by underlying connective tissue; otherwise, it will necrose and lead to scar formation. On the other hand, excessive thickness of the connective tissue layer of the split flap portion could compromise the survival of the buccal papilla left in place.

The ideal thickness of the partial-thickness flap has not been studied. Epithelium thickness varies between 111 and 619 µm with a mean of 364 µm. The recommended thickness of free gingival grafts was reported to be 1–2 mm (12). Based on the gingival graft studies, a thickness of 1.5 mm was chosen for the split-thickness flap in the papilla-base incision. The selected thickness resulted in excellent healing results (13).

The choice of flap designs should allow the maintenance of optimal and sufficient blood supply to all parts of the mobilized and nonmobilized portions of the soft tissues (14, 7, 8, 9). This implies specifically that vertical releasing incisions should run vertical, parallel to the long axis of the teeth and supraperiosteal blood vessels in the gingiva and mucosa. Paramedian releasing incisions are recommended to minimize the risk of recession (7). The initial portion of the vertical incision should be placed perpendicular to the marginal course of the gingiva toward the mid section of the papilla and gradually turning the incision parallel to the tooth axis (Fig. 6). Adequate micro-configuration of the gingival margins will minimize any potential recession of the tissues.

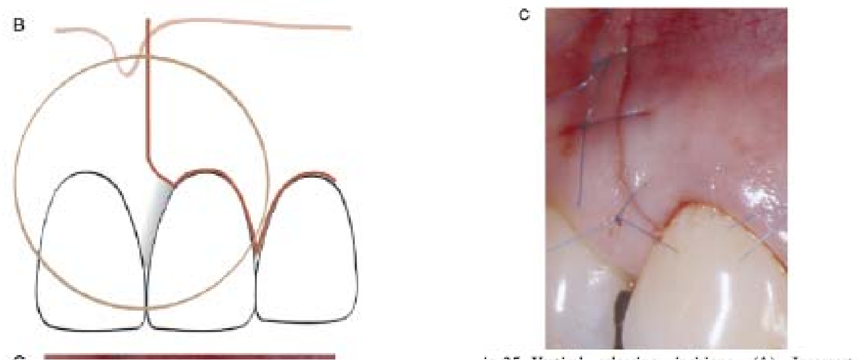

Fig.6 Correct placement of realesing incision

Postoperative results are also influenced by the amount of tissue shrinkage. With prolonged duration of the surgical procedure, there is a risk of drying out of the tissues, especially when a high degree of hemostasis has been achieved. The tissues must be kept moist at all time to help avoid shrinkage and dehydration. This can be particularly problematic in submarginal flap design, resulting in difficult flap re-approximation, with more tension on the tissues. Minimal tension during re-approximation and after suturing is important to avoid impairment of the circulation in the wound margins (9). Shrinkage of the reflected tissue with wound dehiscence will ultimately lead to increased scar formation.

Tissue trauma such as stretching, tearing, or distortion should be avoided through appropriate magnification and careful manipulation with microsurgical instruments. The elevation process following the incision is aimed at undermined elevation of the periosteum. In order to enhance regeneration of the bone and periodontal ligament over the resected root surface, certain cells have to be prevented from repopulating the bony defect. When the integrity of the periosteum has been maintained, it will serve as a barrier against the connective tissue cells, so that these cells cannot invade the bone cavity during the healing process and prevent a complete bone fill. Scaling of root attached tissue and tissue tags on the cortical bone should be avoided to allow rapid reattachment and protection against bone resorption (14, 8). After reflecting the mucogingival tissues, a retractor must be placed securely on sound bone to prevent compression or crushing of the soft tissue. Excessive trauma from retraction may cause increased swelling and delayed healing. As a practical measure to avoid tissue slipping under the retractor, a fine groove is made with a small round bur in which the retractor can be positioned (1).

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Case number 6

Endodontic treatment of maxillary left lateral incisor in conjunction with apical surgery

Patient

A 69-year-old white Norwegian male was referred to the Department of Endodontics, by me September 18, 2004 for treatment of maxillary left lateral incisor (Fig. 1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patient consulted me in my private practice August 25, 2003 because of pain and swelling from a tooth in the front upper jaw.
The patient told that he had been sore in the same area periodically for many years, but had never experienced much pain earlier.

Clinical Examination

Preoperative photo showed the region from maxillary right lateral incisor to maxillary left second premolar (Fig.2).

No pathology was found extra-orally.

A normal oral mucosa was seen.

Fig.2 Sinus tract was seen regio 22

Maxillary right central incisor: MDP composite restorations were seen and the tooth responded positively to the sensibility test with Endo Ice.
Maxillary left central incisor: MDBP composite restorations were seen and the tooth responded positively to the sensibility test with Endo Ice.
Maxillary left lateral incisor: MD composite restorations were seen. The tooth was tender to palpation and percussion, and a sinus tract was seen buccally. The tooth responded negatively to the sensibility test with Endo Ice, and was discoloured yellow-brown especially in the incisal part of the crown
Maxillary left canine: A M composite restoration and a DP amalgam restoration were seen. The tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from maxillary left central incisor to maxillary left first premolar (Fig.3)

Maxillary left central incisor: A radiopaque restoration was seen distally and lamina dura could be followed around the part of the root that was visible.
Maxillary left lateral incisor: A radiopaque restoration mesially and a radiolucent restoration distally with a radiopaque lining was seen. Lamina dura could be followed apically 3-4 mm where it widened to a radiolucent area of approximately 10 mm in diameter. Unfortunately the entire lesion was not present in the radiograph.
Maxillary left canine: Lamina dura could be followed in the visible part.

Fig.3 Radiolucent area apical 12

The height of the marginal bone was within normal limits

Diagnosis

Apical periodontitis with sinus tract maxillary left lateral incisor

Treatment Plan

Necrotic treatment of maxillary left lateral incisor
Root canal disinfection and filling

Treatment

August 27, 2003

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution.
The access cavity was irrigated with 5% sodium hypochlorite.
Irrigation was done with 5% sodium hypochlorite and 15% EDTA. An nr 15 K-Flex was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph
Working length was 24.5 mm with the incisal edge as a reference point.
The last instrument was NiTi nr 55.
The root canal was dried with sterile paper points, and filled with UltraCal XS intracanal dressing. The access cavity was sealed with IRM.

September 27, 2003

The patient did not return four weeks later to his appointment.

November 20, 2003

The patient returned three months later because of pain.
The radiograph revealed that the intracanal dressing was washed out in some part of the canal (Fig.4). Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. UltraCal XS was removed with NiTi nr 55, and irrigation with 5% sodium hypochlorite and 15% EDTA. A master cone radiograph was taken with a master gutta-percha

cone nr 55 to verify working length (Fig.5). The root canal was dried with sterile paper points and filled with UltraCal XS intracanal dressing. The access cavity was sealed with IRM. A control radiograph was taken (Fig.6).

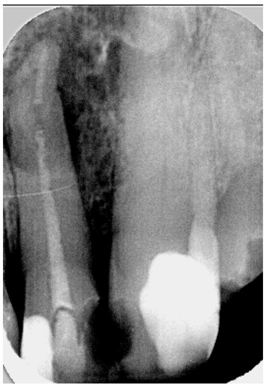

Fig.4 Intracanal dressing partly washed out.

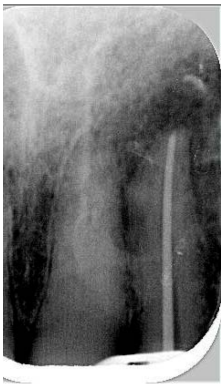

Fig.5 Master cone

Fig.6 Control of the fill of UltraCal XS.

December 15, 2003

Again the patient did not return four weeks later for his appointment.

August 09, 2004

The patient returned 9 months later with pain. A radiograph was taken to get information of the whole lesion. The intracanal dressing was washed out in the apical part (Fig.7).
One year after the treatment had started the sinus tract was still present, and the patient had periodically pain from the tooth.

New treatment plan

Necrotic treatment maxillary left lateral incisor in conjunction with apicoectomi

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. UltraCal was removed with NiTi nr 60, and irrigation with 5% sodium hypochlorite and 15% EDTA. The root canal was dried with sterile paper points, and filled with AH Plus and master gutta-percha cone nr 60 with a cold lateral condensation technique (Fig.8). The root-filling was removed 2 mm apical to the orifices and sealed with IRM plug. The access cavity was sealed with IRM.

The patient was given an appointment for surgery at the Department of Endodontics, UIO.

Fig.7 Intracanal dressing washed out in apical part

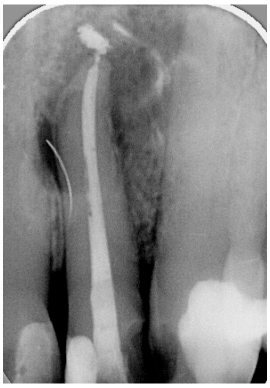

Fig.8 Root-filling with surplus sealer

18.09.04

The patient came to the Department of Endodontics 6 weeks later for performing apicoectomi on maxillary left lateral incisor. Four carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision, starting from the distobuccal gingival line angle of the right central incisor approximately 1cm in a superior aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of the left second maxillary premolar was performed.
Elevation of the full mucoperiostal flap was initiated with an nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap. A pathological bone fenestration was detected outside the root and the cortical bone was destructed in the entire length of the root (Fig.9).

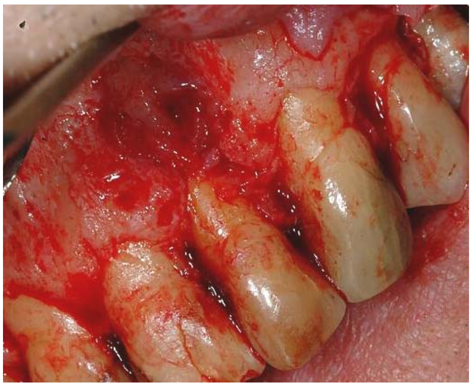

Fig.9 Bone fenestration in the entire length of the root

The lesion was removed with periodontal curettes. Three mm of the root apex was resected with a long fissure bur (Fig.10). A retrograde preparation was carried out with the piezoelectric Satelec ultrasound device using ultrasonic tip CT under constant cooling with rinsing sterile saline. The cavity was extended up to 3 mm in the root canal and followed gutta-percha at all times. A microscope was being used most of the time in order to achieve maximal visibility.
Stryphnon gauze was placed in the bone cavity in order to achieve haemostasis. The cavity was irrigated with sterile saline and dried with sterile paper points. A retrograde MTA filling was placed into the cavity using plastic instrument as a carrier, and condensed with micro

condensing pluggers. A burnisher was used at the end. The retro-filling was examined under high magnification with an explorer to check marginal adaptation and integrity (Fig.11).

Fig.10 Resection of the root **Fig.11** Retro-fill with MTA

The Stryphnon gauze was removed. The surgical field was irrigated with sterile saline. The flap was repositioned and was hold tight in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical realising flap was sutured in place with two 4-0 silk suture. The five other interrupted sutures were placed inter-approximaly in the papilla (Fig.12). A final radiograph was taken (Fig.13) and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

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25.09.04

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed (Fig.14)

Fig.12 Sutures in place **Fig.13** Post operative

Fig.14 One week post operative

Evaluation

To give a correct diagnosis it is important to have all the information needed. In this case a periapical radiograph showing the whole lesion was not available at the start of treatment.
The patient was not interessted in any kind of dental treatment, and it was difficult to get hold of him under the treatment and after the treatment to do a follow-up.
Breakdown of both the buccal and palatinal cortical plate often leads to healing with scar tissue. The lesion had probably been long-standing.
The retrograde filling was overextended removing more than necessary of the root, and thereby weakened the tooth.

Prognosis

Endodontic prognosis was considered favorable

18 months follow-up
13.03.06

The patient was gone again, but showed up to a control after 18 months. The tooth was asymptomatic. The clinical exam revealed no pathology (Fig.15).
The radiographic exam showed questionable healing after 18 months or healing with scar tissue (Fig.16).

Fig.15 18 months follow-up

Fig.16 18 months follow-up

Discussion

Bacteria play a definitive role in the development of periapical inflammatory disease (Kakehashi et al. 1965, Sundqvist et al. 1998). Successful root canal treatment aims to eliminate bacteria from the infected root canal and prevent reinfection. Cleaning, shaping, and irrigating the canal have been shown to greatly reduce the number of bacteria in infected canals; however, it has proved difficult to obtain complete disinfection in all cases (Bystrom & Sundqvist 1981, Orstavik et al. 1991, Peters et al. 1995). Bacteria remaining in obturated root canals may proliferate and invade ramifications, apical deltas, isthmuses and dentinal tubules (Orstavik & Haapasalo 1990, Safavi et al. 1990). In these locations, bacteria remain unaffected by chemomechanical preparation and may result in persistent endodontic infections (Akpata & Blechman 1982). Therefore, the use of intracanal medicaments is essential to eliminate bacteria that remain after mechanical debridement (Bystrom et al. 1985).
Whereas some studies have shown the efficacy of chlorhexidine (Almyroudi et al. 2002, Lin et al. 2003a & b), calcium hydroxide (CH) is currently the most widely used intracanal medicament. To effectively eliminate bacteria in the dentinal tubules, intracanal medication with CH should remain in the canal for at least 7 days (Sjogren et al. 1991). The antibacterial effect is due partly to its high pH (about 12), which prevents the growth and survival of many oral bacteria (Bystrom & Sundqvist 1981). CH alters the biologic properties of bacterial lipopolysaccharides in the cell walls of Gram-negative species (Safavi & Nicholls 1994) and inactivates membrane transportation mechanisms, resulting in cell toxicity (Estrela et al. 1998). The primary advantage of CH is its ability to kill microorganisms in the absence of direct contact by absorbing the CO_2 required for bacterial growth (Kontakiotis et al. 1997) and by the release of hydroxyl ions, which diffuse into dentinal tubules (Wakabayashi et al. 1995).

Earlier studies indicated that bacteria remaining after instrumentation can be eliminated or new bacteria can be prevented from reinfecting the root canal system by an interappointment dressing such as calcium hydroxide (Byström et al. 1985; Chong & Pitt Ford 1992). However, several studies have since demonstrated that calcium hydroxide does not consistently produce bacteria-free canals, and even may allow regrowth (Reit & Dahlen 1988; Ørstavik & Haapasalo 1990; Ørstavik et al. 1991; Peters & Wesselink 2002; Kvist et al. 2004). Calcium hydroxide is not effective against all bacterial species found in root canal infections (Siqueira Junior & Lopes 1999).
Apical periodontitis is caused by root canal infection usually dominated by obligate anaerobes, and the number of cultivable species varies from two to eight (Dahlén 1998). Recent molecular analyses of the microflora suggest a much higher number of microbial species (Munson 2002). Control and elimination of the root canal infection is achieved by the combined action of several treatment procedures. During treatment, ecological conditions change remarkably in the root canal system contributing to the elimination of the microflora. Chemomechanical preparation aims at removing necrotic pulp tissue and infected dentine, and mechanical instrumentation augmented with antimicrobial irrigation kills the majority of the microorganims from the root canal. However, some microorganims may survive and therefore, an interappointment dressing, commonly calcium hydroxide is often used to complete the disinfection of the root canal system before obturation.
Sodium hypochlorite is an effective disinfectant used for irrigation during mechanical preparation of the root canals. It has a wide antimicrobial spectrum and is potent also in low concentrations (Waltimo 1993, Zehnder 2003). Calcium hydroxide is a commonly used root

canal dressing. It has been found useful in treatment of immature roots for completion of root end formation, of root open teeth for the formation of an apical barrier, in traumatized teeth for the prevention or arrest of inflammatory root resorption, and of infected pulps with apical periodontitis (Fava 1999). The antibacterial properties of calcium hydroxide are of primary importance, and several laboratory and clinical studies have testified to the efficacy of calcium hydroxide in the treatment of infected root canals (Fava 1985, Kerekes 1979, Byström 1986, Sjögren 1991). Its antimicrobial activity in the root canal is supposedly based on its high alkalinity and mechanical blocking of nutrients from the periapical area. Calcium hydroxide is effective on the majority of bacteria isolated from infected root canals (Fava 1985, Haapasalo 1987). However, the microflora of infected root canal is, occasionally, resistant against routine treatment procedures and medicaments. Microbiological investigations have shown that *Enterococcus faecalis* and *Candida albicans* can often be isolated from such persistent infections (Fava 1985, Waltimo 1997, Molander 1998, Peciuliene 2001). Several factors may contribute to the survival of these microorganisms during the treatment. They may for example tolerate high alkalinity caused by calcium hydroxide or they may be capable to penetrate into dentinal tubules and thus avoid effective concentrations of therapeutic agents (Haapasalo 1987, Waltimo 1999). It may be seen as a problem that a medicament, in this case calcium hydroxide, indirectly may favour the growth of relatively resistant organisms, which may maintain the infection and be ever more resistant to therapeutic efforts. The tooth may also be susceptible to reinfection through the temporary filling and dressing during the interim period.

The present results (Waltimo 2005) question the efficacy of calcium hydroxide as an interappointment dressing. However, calcium hydroxide is an efficient antimicrobial agent and tissue solvent and remains a recommended interappointment dressing, not least in cases with complicated root canal anatomy that confounds efficient chemomechanical preparation (Zehnder 2003, Law 2004). Because of the various good properties of calcium hydroxide, a combination with, e.g., chlorhexidine, to improve the antimicrobial activity, should be investigated clinically (Waltimo 1999).

It must be emphasized that an absence of bacteria before obturation resulted in the best treatment results (Waltimo 2005). Therefore, rather than to conclude on the relevance of single vs. multiple visit protocols, one should continue to search for better antibacterial protocols to ensure that canals are predictably rendered bacteria-free before root filling.

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Case number 7
Apicoectomy of mandibular right central incisor

Patient

A 50-year-old white Iranian male was September 21, 2005 referred to the Department of Endodontics, University of Oslo, by her GP for treatment of mandibular right central incisor (Fig.1)

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patient was 2 years ago treated at the Department of Endodontics by a postgraduate student. The endodontic treatment of mandibular right central incisor showed no signs of healing after 2 years (Fig.2, 3, 4).
The patient had no symptoms from the tooth.

Fig. 2 Start of treatment

Fig.3 Final radiograph

Fig.4 Two year follow-up

Clinical Examination

No pathology was found extra-orally.

A normal oral mucosa was observed.

Mandibular right canine: The tooth responded positively to the sensibility test with Endo Ice.
Mandibular right lateral incisor: The tooth responded positively to the sensibility test with Endo Ice.
Mandibular right central incisor: A L composite restoration was seen and the tooth responded negatively to the sensibility test with Endo Ice.
Mandibular left central incisor: The tooth responded positively to the sensibility test with Endo Ice.

Preoperative photograph showed the region from mandibular right canine to mandibular left canine (Fig.5).

Fig.5 Buccal view

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from mandibular right lateral incisor to mandibular left lateral incisor (Fig.6).

Mandibular left lateral incisor: Lamina dura could be followed around the entire root.
Mandibular left central incisor: A radiopaque restoration in the root canal was seen and lamina dura could be followed towards the apex where it widened to a circumscribed radiolucency of 3 mm in diameter.
Mandibular right central incisor: Lamina dura could be followed around the entire root.
Mandibular right lateral incisor: Lamina dura could be followed around the entire root.

Mild bone loss was seen.

Fig.6 Apical radiolucency tooth 41 .

Diagnosis

Chronic apical periodontitis mandibular right central incisor

Treatment plan

Apicoectomy of mandibular right central incisor

Treatment

September 21, 2005

The first consultation was examination and treatment planning.

November 02, 2005

The patient returned to the clinic 6 weeks later for performing apicoectomi. 3 carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision, starting from the distobuccal gingival line angle of the mandibular riht canine approximately 1 cm in a inferiorr aspect of the oral buccal mucosa. An intrasulcular incision extending from the releasing incision to the distal aspect of mandibular left canine was performed (Fig.7). Elevation of the full mucoperiostal flap was initiated with a nr 149 periostal elevator. The flap was carefully elevated at the junction between the vertical releasing incision and horizontal incision extending apical and lateral. A retractor was used facilitating the reflection of the flap. A small bone fenestration was detected outside the root (Fig.8).
Osteotomy of the outer cortical plate was accomplished with an nr 6 round bur on a 45° angled high speed hand piece under irrigation with sterile saline to adequately expose the root end. The lesion was removed with periodontal curettes. 3mm of the root apex was resected with a long fissure bur. A retrograde preparation was carried out with the piezoelectric Satelec ultrasound device using ultrasonic tip CT under constant cooling with rinsing sterile saline.

The cavity was extended up to 2 mm in the root canal and followed gutta-percha at all times. A microscope was being used most of the time in order to achieve maximal visibility.

Fig.7 The flap was raised

Fig.8 Small bone fenstartion was detected

Stryphnon gauze was placed in the bone cavity in order to achieve haemostasis. The cavity was then irrigated with sterile saline and dried with sterile paper points. A retrograde MTA filling was placed into the cavity using plastic instrument as a carrier, and condensed with micro condensing pluggers. A burnisher was used at the end. The retro-filling was examined under high magnification with an explorer to check marginal adaptation and integrity.
The Stryphnon gauze was removed. The surgical field was irrigated with sterile saline. The flap was repositioned and was hold tight in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical realising flap was sutured in place with three 4-0 silk suture. The four other interrupted sutures were placed inter-approximaly in the papilla (Fig.9). A final radiograph was taken (Fig.10) and the patient received an ice pack to reduce post operative haematoma and pain. The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

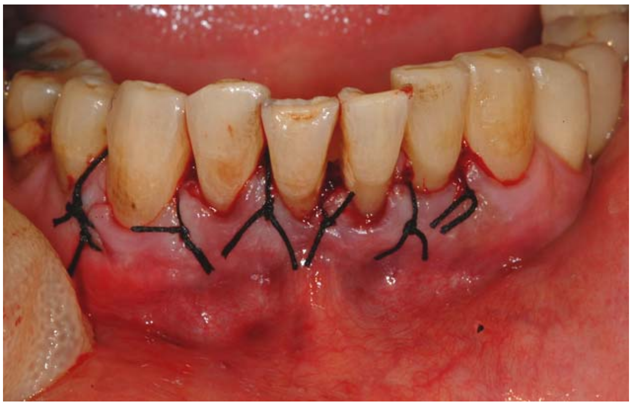

Fig.9 Sutures in place

Fig.10 Final radiograph

November 09, 2005

The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed (Fig.11, 12).

Fig.11 One week post operative

Fig.12 The sutures were removed

Evaluation

I tried to achieve a depth of the retrograde filling of 3 mm, but the retrograde MTA-filling was 2mm or less.

Prognosis

Endodontic prognosis was considered favourable

5 months follow-up

March 21, 2006

The patient returned to the clinic 5 months later for a follow-up. Healing of the oral mucosa without any scare formation was seen, and the radiograph revealed healing in progress (Fig.13, 14, 15).

Fig.13 Five months follow-up

Fig.14 Five months follow-up

Fig.15 Five months follow-up

Discussion

In a comprehensive review of the studies on apical surgery, Friedman (8) has listed several factors that appear to influence the outcome of treatment to some extent.

Pre-operative factors

The pre-operative prognostic factors form the basis for estimating the outcome after apical surgery, and thus the expected benefit that the patient can weigh against those of alternative treatments. Therefore, it is important to recognize the pre-operative factors and to take them into account at the stage when treatment decisions are formulated.

Patient's age, gender, and systemic health

In the studies that examined the patients' age (2, 3, 6) and gender (2, 3, 6), these factors have not significantly influenced the outcome of treatment. Systemic health has not been assessed as a prognostic factor in any of the studies. Thus, none of these factors should be considered to influence the outcome of apical surgery.

Tooth location

In several studies (2, 3, 6, 7), comparable outcomes have been reported for different tooth types, in both the maxilla and mandible. The only outcome feature related to tooth location is the frequent healing by scar tissue observed in maxillary lateral incisors (9, 10). Apparently, when apical surgery is performed on any tooth, anterior or posterior, the specific convenience of access and root anatomy influences the outcome to a greater extent than the location of the tooth *per se* (8).

Clinical signs and symptoms

A comparable treatment outcome has been reported for asymptomatic teeth and for teeth presenting with pre-operative symptoms (3, 6). Therefore, the presence or absence of symptoms should not be considered to influence the outcome of apical surgery, even though in one study a poorer outcome was reported in teeth with a sinus tract present.

Lesion size

One study (3) suggests that the lesion size has no significant influence on the outcome of treatment. However, in another study (6) a better outcome is reported in teeth with small lesions, up to 5 mm in diameter, than in teeth with larger lesions. The authors hypothesize that when the lesion is small, surgical enlargement of the crypt is required to gain adequate access, resulting in eradication of the pathological lesion and creation of an excisional wound in the surrounding bone (13). When the lesion is large, the access is adequate and the crypt is not enlarged to avoid injury to adjacent anatomic structures; therefore, curettage of the pathological lesion may be incomplete and an excisional wound is not created. Thus, a better outcome may be expected when the lesion diameter does not exceed 5 mm. When the lesion is very large, exceeding 10 mm in diameter, more healing by scar tissue occurs (9, 10).

Supporting bone loss

The treatment of teeth where the entire buccal bone plate is missing has not been assessed in any of the selected studies. However, several other studies (19, 20) have suggested a poor prognosis for teeth with considerable bone loss, either vertical or marginal. Such bone loss can compromise periodontal reattachment by apical migration of gingival epithelium. Consequently, bacteria present in the periodontal sulcus may invade the periapical site and prevent healing (8).

Restoration of the tooth

Apical surgery is frequently performed on teeth that are already restored; in these teeth, the restorative status is a pre-operative consideration. In one study (3), a poorer treatment outcome is reported in teeth with a faulty coronal seal or with a post; however, this finding is not corroborated by another study (6). Although there is insufficient data to assess the prognostic significance of the restoration, it is clear that a defective restoration can impair the survival of endodontically treated teeth (14). Indeed, Wang et al. (6) report that of 10 teeth lost after apical surgery, seven teeth (70%) were extracted because of restorative considerations, while two teeth were extracted because of fracture and one tooth because of persistent apical periodontitis.

The existing root filling

The root filling with which the tooth presents for surgery can be characterized by its material, density, and length. The type of filling material does not influence the outcome of apical surgery (3, 6). The filling density – absence or presence of voids – also does not appear to influence the outcome (3, 6). With regard to the filling length, a significantly better outcome is reported when the filling is too short (≥2 mm from the root end) or too long (extruded beyond the root end) than when its length is adequate (6); however, this finding is not supported by another study (3).

Repeat (second-time) surgery

Two studies focusing on repeat surgery (7, 11), and a systematic review of several non-selected studies (15) have concluded that the prognosis after repeat surgery is poorer than after first-time surgery. This finding is contradicted by two other studies (3, 6). Wang et al. (6) report a non-significant difference in outcome between first-time (79% healed) and second-time (62% healed) surgery. As only eight teeth received repeat surgery, this analysis may be underpowered. Nevertheless, the authors speculate that in the other studies, surgery was frequently repeated using the same case selection criteria and techniques as in the first surgery, whereas in their study orthograde retreatment was preferred over repeat surgery. In the few cases of second-time surgery, the technique differed from that of the first-time surgery. The authors suggest that the modified case selection and techniques may have resulted in a higher healing rate after repeat surgery in their study than in previous studies (6). Thus, the outcome of repeat surgery may be poorer than that of first-time surgery, unless the repeat procedure is performed with an improved approach.

Intra-operative factors

The intra-operative prognostic factors can be instrumental in maximizing the patient's benefit by improving the outcome of the apical surgery procedure. Therefore, it is important to recognize the intra-operative factors and to take them into account at the stage when treatment strategies and techniques are selected.

Level of apical resection and degree of bevelling

In one study (17), a better outcome is reported after resection at the mid-root level, than at a more apical level. Resection close to the apex may expose many ramifications of the canal system that, if not sealed by the root-end filling, can comprise pathways for intra-canal bacteria to sustain disease after surgery (18). Therefore, the resection should be performed approximately 3 mm from the apex, where ramifications are fewer (16). Furthermore, resection at a more coronal level facilitates preparation of the root-end cavity and filling. Thus, a better outcome may be expected after a more radical resection of the root than after a very conservative resection. The degree of bevelling has not been assessed in relation to treatment outcome. Nevertheless, the bevel should be minimal to avoid the risk of missing canals emerging at the lingual aspect of the root (18), and to reduce the number of exposed dentinal tubules on the cut root surface, that comprise a bacterial pathway for persistence of disease (12).

Presence/absence of a root-end filling

Placement of a root-end filling is consistent with the rationale of apical surgery – to establish an effective barrier that will prevent interaction of intra-canal bacteria with the periapical tissues (21). This rationale applies in all teeth where it is assumed that apical periodontitis is sustained by persistent *intra-canal bacteria* (21). However, a root-end filling may be superfluous when the disease is assumed to be sustained by *extra-radicular bacteria* (6, 21). Indeed, in one study (6) seven out of eight teeth (88%) suspected for extra-radicular infection healed without receiving a root-end filling.

From a historic perspective, many studies indicate that the presence of a root-end filling impairs the prognosis (9, 10, 17, 20, 23). For example, Grung et al. (39) conclude that 'retrofills have a strong negative effect on the end results,' In these studies, root-end fillings were placed in the teeth *treated exclusively by apical surgery*, but not in the teeth *treated concurrently by surgery and orthograde treatment*; therefore, comparison of teeth without and with root-end fillings was confounded by orthograde treatment, performed in the former but not in the latter (8, 21). However, limiting the analysis in the same studies and others to teeth treated only surgically reveals better outcomes with than without root-end fillings (17, 24).

Root-end management

In the past two decades, the classical root-end cavity drilled with a small round bur gave way to two main modifications. Rud and co-workers (25, 27), developed the method of bonding a 'cap' of Retroplast (a composite resin) over the cut root surface, to seal all of the main canal, accessory canals, isthmuses, and exposed dentinal tubules. Retroplast is not placed into a root-end cavity to avoid adverse effects of shrinkage. Instead, it is placed as a thin layer into a concavity created in the resected surface with a large round bur. One of the selected studies (4) reports a 'healed' rate of 73% and a 'healing' rate of 17% 1 year after treatment with Retroplast. The outcomes in this study and several others where Retroplast was used (25, 26, 28) appear to surpass the outcomes reported in studies where root-end cavities have been prepared and filled with a variety of materials. Conceivably, Geristore (29, 30) and OptiBond can be used as alternatives to Retroplast for establishing the apical 'cap' (18); however, their clinical effectiveness in this capacity has not been reported.

To modify the form of the root-end cavity, Carr (18, 31) developed special angled tips for ultrasonic cavity preparation. The use of these tips requires less bevelling of the cut root surface and a smaller bony crypt preparation than the use of burs (18,33,35). More importantly, the resulting cavities are deeper, allowing the root-end filling to seal exposed dentinal tubules from within the canal (32, 35). The cavities are also cleaner and aligned better with the long axis of the canal, so that the risk of perforation of the lingual wall of the root is reduced (35). Two studies (36, 37) have reported a better outcome in teeth where root-end cavities were prepared with ultrasonic tips than when cavities were prepared with burs; however, the analyses in both studies were confounded by extraneous factors, undermining their conclusions. Importantly, the 'healed' rates (37–91%) reported in the selected studies in which root-end cavities were prepared with ultrasonic tips (2, 3, 5, 6, 7) are not different from those in other studies where root-end cavities were drilled with burs.

Although there is no strong evidence to suggest that the apical 'cap' and the ultrasonic root-end cavity preparation offer a better prognosis, there is a sound clinical rationale for using both approaches. Both also offer greater ease and consistency of application than drilling the root-end cavity with small round burs, as in the past.

Root-end filling material

Many restorative and endodontic materials used in dentistry over the years have also been considered as root-end filling materials, including amalgam with or without varnish, plain or reinforced zinc-oxide eugenol cement, EBA and Super-EBA cement, polycarboxylate cement, glass-ionomer cement, burnished or injectable gutta-percha, composite resin, cyanoacrylate glue, Teflon, gold foil, titanium screws, and Cavit. These materials have been comprehensively reviewed by Friedman (21). In the past decade, MTA, a material developed specifically for root-end filling, has also been used (38, 40). This plethora of materials has primarily been assessed by *in vitro* methods and characterized by inconsistency of the results (21, 39). To overcome the limitations of *in vitro* studies, an *in vivo* simulation model was developed by Friedman et al. (50). Variations of this model have been used in several studies (40, 41) with better consistency of the results than in the *in vitro* studies. In these animal studies, IRM (41), Super-EBA, MTA (40), and Diaket (42) have performed better than other materials. Nevertheless, these *in vivo* studies do not provide the evidence base required for supporting the clinical effectiveness of these root-end filling materials.

Several non-randomized clinical trials have assessed different root-end filling materials, including Biobond, Cavit, glass-ionomer cement, Retroplast (26), IRM (24, 52), EBA (24, 52, 53), gold leaf, and titanium inlay. Amalgam has been frequently used as the control with which other materials are compared. The methodology in all these studies does not comply with an adequate level of evidence, negating their conclusions. For example, EBA cement is significantly superior to amalgam in one study (95% vs. 51% success, respectively) (52), marginally superior in another study (57% vs. 52%, respectively) (53), and marginally inferior in a third study (65% vs. 71%, respectively) (24). Better evidence can be derived from recent RCTs (4, 5). For use as an apical 'cap,' Retroplast is significantly better than glass-ionomer cement, which was observed to detach in several of the teeth (4). For filling a root-end cavity, IRM and MTA are reported to be equally effective (5); however, the validity of this finding can be disputed because the root canals sealed by these materials may not have been infected after a previous retreatment. A comparable outcome is also reported for root-end fillings with Super-EBA and 'other materials' (IRM, MTA, composite resin, amalgam) in a recent cohort study (6). Thus, the outcome of apical surgery relying on a bonded 'cap' critically depends on the bonding properties of the material used. When an intra-canal root-end cavity is filled, a similar outcome may be expected if IRM, EBA cements, or MTA is used.

Method of hemostasis

Different hemostatic agents, including epinephrine (adrenalin)-saturated (1 : 1000) pellets, ferric sulfate, bone wax, thrombin, calcium sulfate, Gelfoam, Surgicel, and collagen wound dressing, have been routinely used for crypt control by many clinicians (18). Good hemostasis is critically important for the quality of the root-end filling (18) and bonding of an apical 'cap' (4). However, in a recent study (6) a comparable outcome has been reported with and without the use of hemostatic agents, suggesting that these agents do not influence the prognosis of apical surgery.

Combination with orthograde treatment

Apical surgery performed concurrently with orthograde root canal treatment or retreatment addresses all possible sites where bacteria colonize – the root canal system including apical ramifications, the apical root surface, and the periapical tissue. Furthermore, according to Molven et al. (10), 'infection is eliminated and reinfection is prevented'. Consequently, studies in which both procedures were combined in the majority of the sample usually showed a better outcome than those in which only apical surgery was performed (8). The difference between the two approaches has also been demonstrated in specific studies (19, 17, 19, 21). Currently, however, apical surgery is not considered imminent when the root canal is accessible from the coronal pathway; rather, it is performed alone as an alternative to orthograde treatment. Therefore, the better prognosis offered by combining apical surgery with orthograde treatment is merely of academic interest. It confirms that root canal bacteria are the predominant cause of post-treatment apical periodontitis (51), and that they may still sustain the disease process in spite of the root-end filling.

Retrograde root canal retreatment

A modified approach to apical surgery, focusing on instrumentation, irrigation, and filling of the root canal as far coronally as can be reached from the apical end, can be used as an alternative to the standard root-end filling. According to several clinical studies (6), the 'healed' rate after such retrograde retreatment ranges from 71% to 100%, and the rate of persistent disease does not exceed 16%. Clearly, this procedure offers a better outcome than the standard root-end filling, as it places a deeper barrier between intra-canal bacteria and the periapical tissue. However, if bacterial ingress continues coronally under the restoration and along the post into the canal, with time, bacteria may overcome this barrier, resulting in recurrence of disease.

Quality and depth of root-end filling

Only one study (3) highlights the significance of the quality of the root-end filling, particularly its correct placement. In another study (6), comparable outcomes are reported for root-end fillings extending up to 2 mm or deeper into the canal space. However, the depth of the root-end filling cannot be reliably assessed in radiographs because its apical surface is frequently bevelled (3). Thus, the accurate placement of the root-end filling influences the prognosis of apical surgery, while the effect of the filling depth, ranging from 1 to 4 mm, can only be speculated.

Magnification and illumination

In the past decade, the use of aids to enhance visualization during apical surgery has become increasingly popular among clinicians. Magnification aids include loops, operating microscopes and endoscopes. The latter two also greatly enhance illumination. Apart from considerations of convenience, use of these aids facilitates identification of intricate anatomic features and improves control of all aspects of the surgical procedure, from incision placement to suturing (18). Reporting 97%'success,' one study (59) implies that the outcome of apical surgery can be improved by using the operating microscope and Super-EBA cement as the root-end filling. Among the selected studies, loops were used to enhance visualization (6, 7), or the operating microscope was used to inspect the adaptation of the root-end filling

(5). However, the true influence of magnification and illumination aids on the outcome of apical surgery has not been assessed at an adequate level of evidence.

Laser irradiation

Laser irradiation of the resected root surface and crypt has been suggested as a means of sterilization and hemostasis (48), but also to render the dentin on the cut root surface impermeable to bacteria (49). Despite these theoretical benefits of laser irradiation, it has not been shown to influence the outcome of apical surgery when applied *in vivo*, in animal studies (50) and in a clinical trial (36). Thus, use of laser irradiation in different steps of the apical surgery procedure does not influence the outcome of treatment.

Barriers and bone grafting substances

The use of guided regeneration barriers in apical surgery has been advocated in case reports (45). Similarly, the use of various bone-grafting substances in the crypt has been described (46). The handful of clinical studies and case reports published (45, 47) do not provide evidence to support the routine use of these procedures in apical surgery. Thus, use of barriers and bone grafting substances does not enhance the prognosis, while care must be taken to avoid infection of the foreign materials placed.

Operator skill

Resident students were the treatment providers in only a few of the studies (3, 4, 6), while in the majority of studies treatment was performed by specialists, either oral and maxillofacial surgeons or endodontists. Therefore, reference to operator skill is scarce. Nevertheless, studies have suggested that the outcome of apical surgery may depend on the individual operator's skill (17).

Complications

Occasionally during apical surgery, a perforation can occur in the opposing (lingual or palatal) aspect of the root or cortical bone plate, or the maxillary sinus may be exposed. Perforation of the opposing bone plate does not appear to influence the outcome beyond an increased rate of healing by scar tissue (6). Similarly, perforation into the sinus does not appear to influence the prognosis (43, 44).

Antibiotics

Antibiotics may be prescribed to prevent infection of a post-operative hematoma. However, a course of systemic antibiotics starting before and continuing after treatment does not influence the outcome of apical surgery (3, 6).

Post-operative factor

The only post-operative prognostic factor highlighted below may modify the prognosis estimated after completion of the apical surgery procedure. It may be considered when the follow-up schedule is devised.

Results of biopsy

Periapical biopsies are frequently obtained during apical surgery. Theoretically, the biopsy results defining the pathological lesion – granuloma or cyst – might be used as indicators of the prognosis. Jensen et al. (4) report a significant association between the biopsy results and the outcome of apical surgery; however, no such association has been reported in 2 other studies (2, 6). These conflicting reports may be a result of the differences in the processing of the biopsy specimens. Routine biopsies are seldom subjected to serial sections, and therefore may not accurately reflect the nature of the pathological lesion. Thus, a biopsy report on the nature of the lesion removed during apical surgery does not contribute to the estimation of the prognosis.

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Case number 8

Endodontic retreatment of endodontically treated maxillary right first molar in conjunction with apical surgery

Patient

A 63-year-old white Norwegian female was referred to the Department of Endodontics, University of Oslo, by her GP March 16, 2004 for treatment of maxillary right first molar (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The maxillary right first molar was endodontically treated April 2001 by her GP. The sinus tract did not disappear after treatment and she has had several flare-ups. Her GP started retreatment in January 2004, but the sinus tract was still present, and three weeks earlier she had another flare-up. The patient was worried about the infection, and was tired of all the antibiotic treatment she received when the flare-ups occurred.

Clinical Examination

No pathology was found extra-orally.

A normal oral mucosa was observed.

Maxillary right second molar: A MO composite restoration and an O amalgam restoration were seen and the tooth responded positively to the sensibility test with a electric pulp test and Endo Ice test.
Maxillary right first molar: A MODP composite restoration was seen and IRM was placed as a temporary filling in the access preparation. The tooth was tender to percussion and palpation. The tooth responded negatively to the sensibility test with a electric pulp test and Endo Ice test. A sinus tract was seen palatally.
Maxillary left second premolar: A MOD composite restoration and a P amalgam restoration were seen and the tooth responded positively to the sensibility test with a electric pulp test and Endo Ice test.
Maxillary left first premolar: A PFM crown was seen and the tooth responded negatively to the sensibility test with a electric pulp test and Endo Ice.

The preoperative photograph showed the region from maxillary right second molar to lateral incisor (Fig.2).

Fig.2 Buccal view

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from maxillary right second molar to first premolar (Fig.3).

Maxillary right second molar: A MO radiopaque restoration was seen and lamina dura could be followed around the entire roots without disruption.
Maxillary right first molar: A MOD radiopaque restoration was seen and lamina dura could be followed to the apex where it widened into a radiolucent area 12 mm in diameter. A radiopaque root filling material could be seen in MB and DB roots.
Sinus tract tracing showed the source to be the palatal root (Fig.4)
Maxillary right second premolar: The entire crown had a radiopaque restoration. Lamina dura could be followed around the entire root without disruption.

The marginal bone level was within normal limits.

Fig.3 Note the periapical radiolucency right maxillary first molar.

Fig.4 Sinus tract tracing

Diagnosis

Apical periodontitis with sinus tract maxillary right first molar

Treatment plan

Retreatment of an endodontically treated maxillary right first molar

Treatment

March 16, 2004

The access cavity was prepared and three canals were localized. Rubber dam was applied, and the area disinfected with chlorhexidine-ethanol solution. The working length was reached by using K-flex nr 20. A working length radiograph was taken with a K-Flex nr 20 in the distal canal, NiTi nr 25 in the mesial canal, and NiTi nr 30 in the palatal canal (Fig.5). The lengths were controlled with an apex locator (Root ZX, J. Morita, Japan).

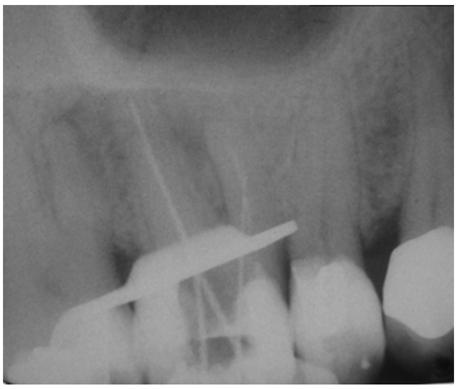

Fig. 5 Working length

The root canals were instrumented up to NiTi nr 45 in the MB canal, and a length of 15 mm with B cusp as a reference point. The DB canal was instrumented up to NiTi nr 50, and a length of 17 mm with the O filling as a reference point. P canal was instrumented up to NiTi nr 60, and a length of 17 mm with the O filling as a reference point. Irrigation was done with 1% sodium hypochlorite and 17% EDTA. A MB 2 canal was not localized.
The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

May 18, 2004

The patient returned to the clinic 8 weeks later. The tooth was asymptomatic and the sinus tract was closed
Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution. IRM and Cavit G were removed, and calcium hydroxide was removed with irrigation with 1% sodium hypochlorite and 17% EDTA. The root canals were dried with sterile paper points. Master gutta-percha cones were tried in and a master cone radiograph was taken (Fig.6). The root canals were dried with sterile paper points and filled with AH Plus and master gutta-percha cones with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. The access cavity was sealed with IRM. A final radiograph was taken after the removal of the rubber dam (Fig.7).

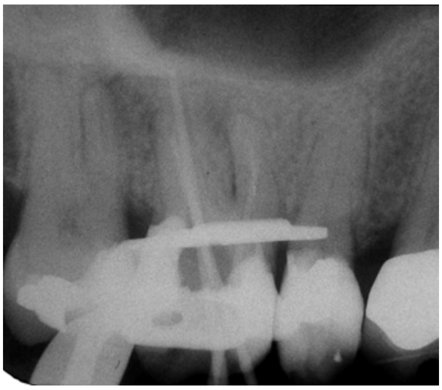

Fig.6 Master cone

Fig.7 Final radiograph, surplus sealer distal canal

Evaluation

It was caries in the pulp chamber, probably due to leakage. A MB2 canal was not found. The tooth was asymptomatic and the sinus tract was gone after the first treatment.
The apical periodontitis had been long standing, but the findings of caries in the pulp chamber gave hope that coronal leakage was the main reason for the infection.

Prognosis

Endodontic prognosis was considered favourable

10 months follow-up

March 03, 2005

The patient returned to the clinic 10 months later. The tooth was symptomatic and a sinus tract was found palatally. Four carpules with Xylocain with Adrenalin (20 mg/ml + 12.5 µg/ml) were used to establish anesthesia. It was decided to just elevate a palatal flap. An incision was made with a scalpel blade nr 15C starting with a vertical releasing incision, starting from the mesiopalatal gingival line angle of the maxillary right canine, approximately 1 cm in a superior aspect of the palate. An intrasulcular incision was done extending from the releasing incision to the distal aspect of the right second maxillary molar. Elevation of the full mucoperiostal flap was initiated with a nr 149 periostal elevator (Fig.8). A retractor was used facilitating the reflection of the flap, and a suture was made between the flap and tooth 24 to hold the flap out of the way (Fig. 9, 10). The entire palatal bone plate was missing (Fig.11). Three mm of the palatal root apex was resected (Fig.12, 13). A microscope was used most of the time in order to achieve maximal visibility. Stryphnon gauze was placed in the bone cavity in order to achieve haemostasis. The cavity was irrigated with sterile saline and dried with sterile paper points. A retrograde MTA filling was placed into the cavity using a plastic instrument as a carrier, and condensed with micro condensing pluggers. A burnisher was used at the end (Fig.14).

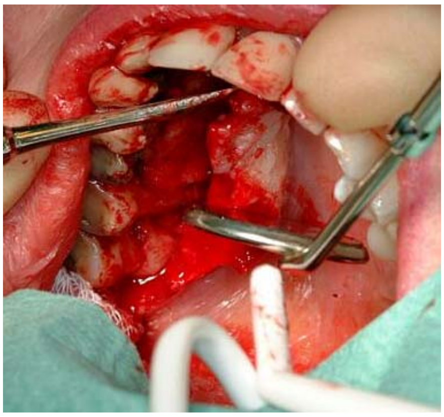

Fig.8 Elevation of palatal flap

Fig.9 Suture in the palatal flap

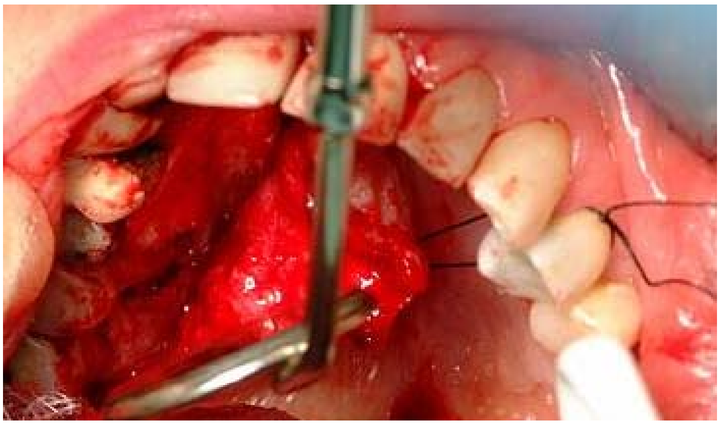

Fig.10 Flap attached to tooth 24

Fig.11 Fenestration of palatal bone

Fig.12 Resection of the palatal root

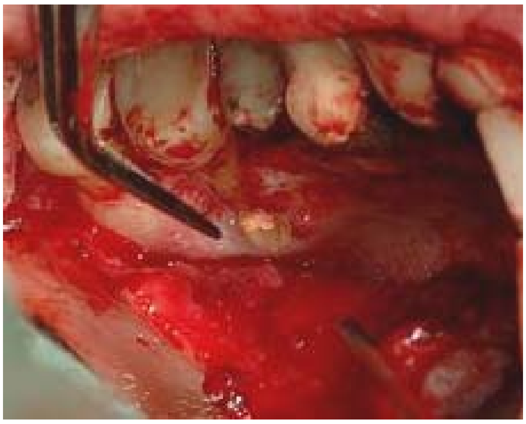

Fig.13 Removing the apical fragment

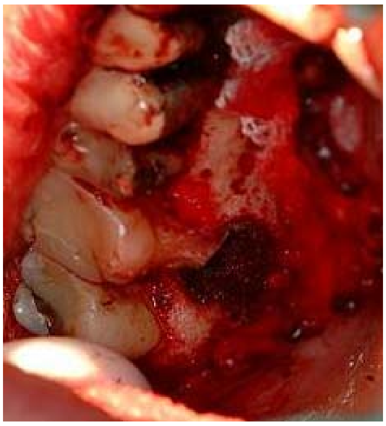

Fig.14 Extensive bone loss

The surgical field was irrigated with sterile saline. The flap was repositioned, and was held tightly in place with finger pressure for five minutes in order to reduce the post operative haematoma and pain. The vertical releasing flap was sutured in place with two 4-0 silk sutures. The four other interrupted sutures were placed inter-approximally in the papilla. A final radiograph was taken, and the patient received an ice pack to reduce post operative haematoma and pain. The final radiograph revealed a gap between the root-filling and the retrograde MTA filling (Fig.15). The pain killer Ibuprofen; Ibux 600 mg, was prescribed and the antiseptic mouthwash Corsodyl. Post operative instructions were given.

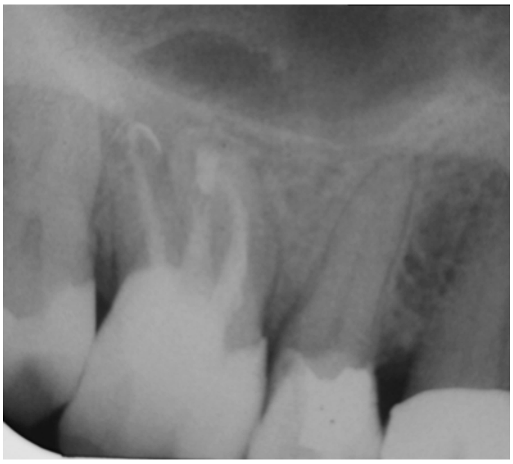

Fig.15 Final radiograph revealing a gap between root-filling and MTA retrograde-filling

March 09, 2005
The patient returned to the clinic one week later. The tooth was asymptomatic and the sutures were removed.

Two months follow-up

May 15, 2005
The patient returned to the clinic two months later because of a flare-up. The sinus tract was back and a periodontal pocket disto-palatinally all the way to the apex. A radiograph was taken tracing both the sinus tract and periodontal pocket (Fig.16).
It was decided to extract the tooth because of the clinical and radiological findings.
The patient was not interested in extracting the tooth.

May 25, 2005
The patient called and she wanted to try antibiotics. She got Apocillin 660 mg 1x1x2 tablets for 5 days.

6 months follow-up

September 7, 2005
The patient returned to the clinic 6 months after surgery. The tooth was asymptomatic. The gingival healing was satisfactory. The postoperative radiograph revealed signs of healing (Fig.17).

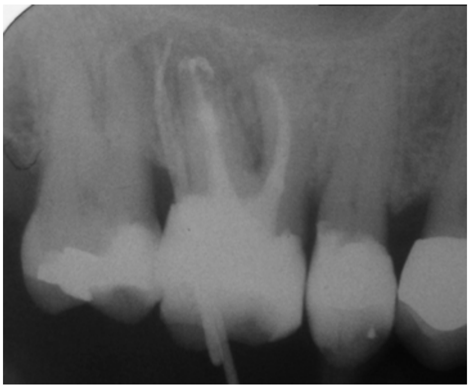

Fig.16 Periodontal pocket 2 months follow-up

Fig.17 Six months follow-up

One year follow-up

March 30, 2006

The patient returned to the clinic one year after surgery. The tooth was asymptomatic. No sign of a sinus tract or periodontal pocket were visible (Fig.18). A radiograph revealed signs of healing (Fig.19, 20).

Fig.18 One year follow-up

Fig.19 Start of treatment

Fig.20 One year follow-up

Discussion

Apical curettage, apical root resection and reverse fillings

Once access to the surgical site has been established, any soft tissue located at or around the apex is curetted. This is usually accomplished with a large endodontic spoon or bone curette, with its concave surface facing the bone to peel away the soft tissue from the bony walls as opposed to a scooping, scraping and tearing action (Arens 1984). The latter technique severely shreds the tissue, induces excessive haemorrhage, and prolongs the removal of tissue. Soft tissue which is tenaciously attached to the palatal or lingual aspect of the roots may have to be removed with periodontal curettes, although access to this tissue is usually enhanced after apical root resection. Care must be exercised when removing the soft tissue along the sides of the root when it extends coronally or near adjacent root apices. Direct communication to the gingival sulcular area or devitalization of adjacent teeth may occur.

Apical root resection (apicectomy)

Apical root resection is performed to:
Remove resorptive processes;
Remove anatomical variations, e.g. accessory canals, apical deltas;
Remove iatrogenic conditions, e.g. ledges, perforations, blockages, separated instruments;
Evaluate the apical seal;
Create an apical seal;
Gain access to diseased soft tissue lingual or palatal to the root;
Gain access to major secondary canals inaccessible through non-surgical treatment;
Reduce fenestrated root tips within a sound, healthy bony housing;
Obtain an apical biopsy when indicated;

This procedure requires the use of surgical-length straight or tapered fissure burs (preferably with long cutting surfaces) on high-speed handpieces, and sterile saline or water for irrigation. The degree of root-end removal during resection is related to what is necessary to accomplish the purpose of treatment. There are no valid indications for routinely removing the apex to the coronal depth of the bony cavity. The practitioner must decide in each situation how much root structure should be eliminated to remove the cause of the problem and create an apical seal.
During the resection procedure, a clean, flat, bevelled root face must be established. This is best accomplished by moving the handpiece in a mesiodistal plane, avoiding a scooping or ditching effect. The entire root face must be exposed and any remaining root fragments or tips removed.

Suturing and care of the surgical site

After completing the periradicular surgery, the surgical site should be thoroughly lavaged with steraile water or saline from a hand operated syringe. A thorough examination of the osseous and soft tissues is made to ensure that no foreign debris remains, and the flap is repositioned.

It is essential that pressure is applied to the flap (Harty 1982). This pressure establishes close approximation and initial adhesion of the reflected tissue to bone, which causes the initial

fibrin clot to form and capillary leakage to decrease, and greatly reduces the potential for postsurgical haemorrhage or haemotoma.
A gauze pad is moistened with water or saline, placed over the flap, and firm finger pressure is applied for 3-4 minutes. This simple step is amazingly effective in reducing postoperative swelling and pain. The periphery of the flap is disturbed during suturing, and so this step is repeated after suturing.

Postoperative considerations

Bleeding, swelling, pain and infection are potential untoward postoperative sequelae which should be discussed with the patient prior to dismissal from the surgery appointment.

Bleeding and swelling

Oozing of blood from torn capillaries will occur for several hours after endodontic surgery. Slight swelling of oral and facial tissues is a common occurrence. It is caused by leakage of blood into surrounding tissues and the inflammatory response which follows surgical procedures. The finger pressure exerted against the surgical flap before and after suturing greatly diminishes postoperative bleeding and swelling. As additional supportive therapy, the patient is instructed to apply an ice pack to the facial area over the surgical site. This is done to reduce the flow of blood, promote coagulation and, thus, decrease bleeding and swelling. Application of cold also has the added advantage of reducing the sensitivity of peripheral nerve endings, providing an analgesic effect.
Discoloration (ecchymosis) of the mucosal and adjacent facial tissues may occur but is of no consequence other than aesthetics. It is caused by the breakdown of blood that has leaked from vessels into surrounding tissues. The application of moist heat to ecchymotic facial tissues the flow of blood within vascular channels. Promotes fluid exchange and speeds resorption of the discoloring agents from the tissues.
Applying moist heat to the face also enhances the inflammatory response which is essential for healing to occur. However, heat should not be applied until the day after surgery. Heat application during the first 24 hours will cause increased bleeding and swelling (Gutmann & Harrison 1985).

Supportive therapy

The patient is also instructed on the importance of proper diet, fluid intake and maintenance of oral hygiene. A soft diet with plenty of liquids is essential supportive therapy following surgery. Oral hygiene presents a problem during the postsurgical period and also requires specific instructions from the practitioner. The teeth should not be brushed for 24 hours following surgery. A cotton swab, moistened with mouth-rinse (Corsodyl or Listerine) can be used to remove food and debris and reduce foul taste. On the day following surgery, brushing is limited to the occlusal surfaces in the quadrant affected by surgery while all surfaces are brushed carefully in the other quadrants. After 48 hours, gentle horizontal brushing of the more occlusal parts of the buccal and lingual surfaces can be added.

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Case number 9

Retreatment of endodontically treated mandibular right second molar

Patient

A 37-year-old white Latin American female (Fig.1) was referred to the Department of Endodontics, University of Oslo by her dental undergraduate student October 26, 2004 for retreatment of mandibular right second molar.

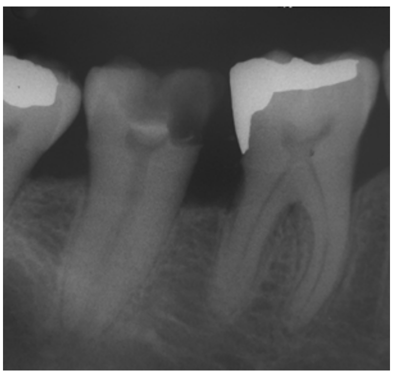
Fig.1 Frontal view

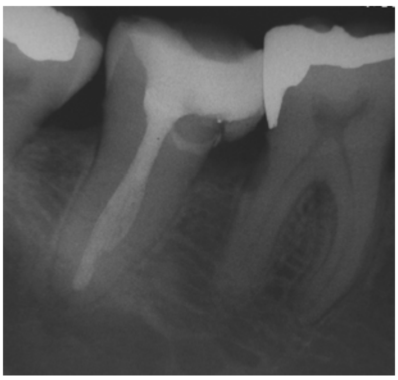
Medical history

Non-contributory.

Dental History & Chief Complaint

Endodontic treatment of the mandibular right second molar was performed in the student clinic in February 2001. Follow-up radiology exams of the tooth revealed an enlarging radiolucent area at the apex (Fig. 2, 3, 4).





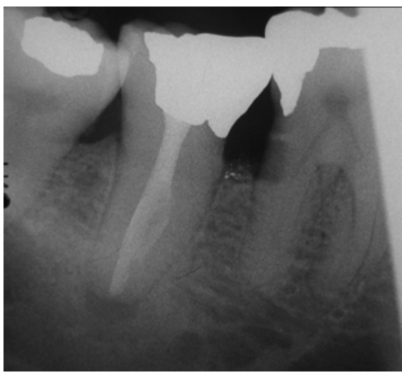


Fig.2 13.02.01 **Fig.3** 23.02.01 **Fig.4** 03.06.04

The patient had felt intermediate pain from the tooth after the endodontic treatment. She avoided eating on her right side.

Clinical Examination

Preoperative photos showed the region from mandibular right third molar to mandibular first premolar (Fig.5, 6).

Extra-orally no pathology was found.

A normal oral mucosa was observed.

Fig.5 Buccal/occlusal view

Fig.6 Occlusal view

Mandibular right third molar: Amalgam restoration on O surface and the tooth responded positively to sensibility test with Endo Ice.
Mandibular right second molar: Amalgam restoration on MOL surfaces, and the tooth responded negatively to sensibility test with Endo Ice. The tooth was tender to percussion.
Mandibular right first molar: Amalgam restoration on OD surfaces and the tooth responded positively to sensibility test with Endo Ice.

The other teeth in the upper and lower right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from mandibular right second molar to second premolar (Fig. 7).

Mandibular right second molar: A MO radiopaque restoration was seen and lamina dura could be followed around the root where it widened to a radiolucent area of approximately 3 mm. A radiopaque material was seen in the canal with an area in the apical part with incomplete obturation.

Mandibular right first molar: An OD radiopaque restoration was seen and lamina dura could be followed around the entire roots. In the cervical area of the distal root a radiolucent area was seen.
Mandibular right second premolar: An O radiopaque restoration was seen and lamina dura could be followed around the entire root.

The height of the marginal bone was within normal limits except distally on tooth 46.

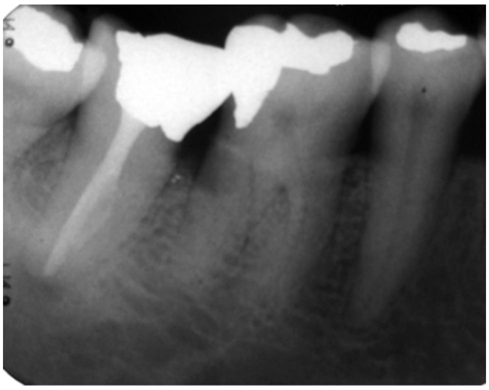


Fig.7 Apical radiolucency of tooth 47

Diagnosis

Chronic apical periodontitis mandibular right second molar

Treatment Plan

Retreatment of an endodontically treated mandibular right second molar
Root canal disinfection and filling

Treatment

September 29, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution.
Access cavity was prepared, and one canal was found filled with gutta-percha.
Gutta-percha was removed with the help of ProTaper F3.
Irrigation was done with 1% sodium hypochlorite and 17% EDTA. A nr 15 K-Flex was taken to working length. The working length was controlled with an apex locator (Root ZX), and verified by a working length radiograph (Fig.8).
Working length was 19.5 mm with the buccal cusp as reference point.
The last instrument was NiTi nr 60.
Ultrasound with a K-Flex reamer nr 25 was used to clean the irregular shaped canal. The canal was dressed for 5 minutes with 2% chlorhexidine digluconate. The root canal was dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canal with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

October 20, 2004

The patient returned to the clinic three weeks later with no symptoms from the tooth. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi nr 60. Irrigation was done with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. Master gutta-percha cone nr 60 was tried in, and a master cone radiograph was taken (Fig.9).

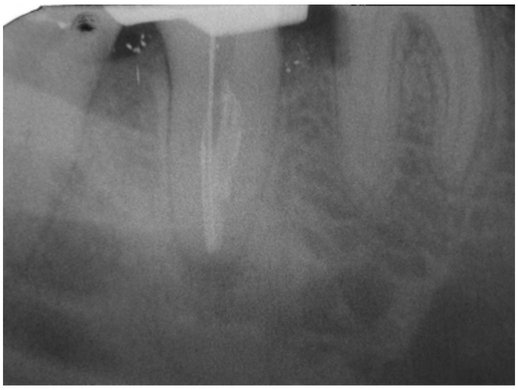


Fig.8 Working length

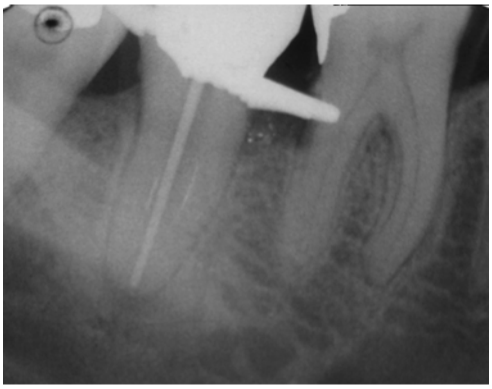


Fig.9 Master cone

There was still some sealer left and this was attempted removed with the help of ultrasound and irrigation. The root canal was dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a Thermafill hybrid technique using a Thermafill nr 35 as a lateral condenser.The root-filling was removed 2 mm apical to the orifice and sealed with an IRM plug. The access cavity was filled with IRM (Fig.10). The patient was referred back to her undergraduate student with the recommendation of a crown treatment due to a big amalgam filling, little remaining tooth substance and root canal treatment.

Fig.10 Final radiograph

Evaluation

The treatment goal was a better clean, shape and fill in the apical part of the root, thereby achieving an asymptomatic tooth and healing of the periapical bone.
To be able to do this it was necessary to use a microscope to identify the thin fins of the canal system. Ultrasound was necessary to clean these areas mechanically without removing too much tooth substance in the more coronal part of the canal system. To achieve a good obturation a hybrid technique with a master gutta-percha cone and lateral condensation with

Thermafill was used. This is a technique that gives you the benefit of good apical control with a master cone, and the benefit of the flow of warm gutta-percha in an irregular shaped canal. The treatment goal had been accomplished according to the final radiograph and the tooth had become asymptomatic.

Prognosis

The endodontic prognosis was considered favourable.

15 months follow-up

March 21, 2006

The patient returned to the clinic 15 months later. The tooth was asymptomatic, but the amalgam restoration was lost a couple of weeks after the endodontic treatment was completed (Fig.11). She had been in her home country for a longer period of time, and had not got

Fig 11 Almost 15 months without a restoration, note IRM

in touch with her undergraduate student or a GP for further treatment.
The root canal system was sealed with IRM despite the loss of the amalgam filling. A radiograph showed healing (Fig.12). The tooth was cleaned and the IRM removed, and there was no sign of bacterial leakage. A new IRM plug was done, and the tooth was restored temporarily with a composite build-up, and the patient was referred to the student clinic for further treatment (Fig.13, 14, 15).

Fig.12 15 months without restoration

Fig.13 Temporary composite build-up

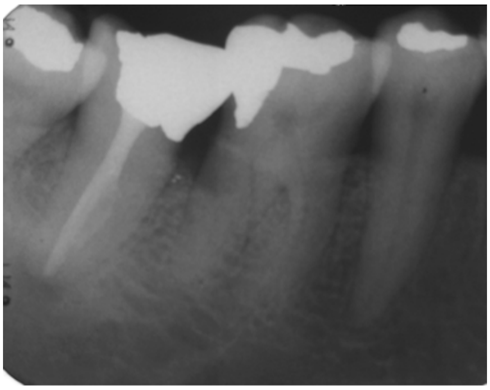
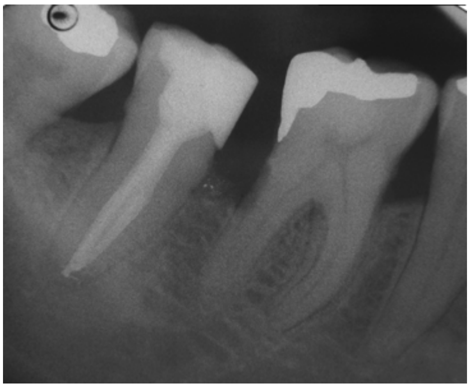
 

Fig.14 Start of treatment Fig.**15** Final radiograph with composite build-up

Discussion

Coronal leakage

One of the main principles for successful endodontic treatment is the prevention of microorganisms and toxins from the oral flora penetrating through the root canal system into the periapical tissues. A number of studies have indicated that leakage, whether from a coronal or apical direction, adversely affects the success of root canal treatment. The significance of the coronal seal has been increasingly recognized in dental literature.
After non-surgical endodontic therapy, the amount of time that passes before the tooth receives a coronal restoration can vary from a few days to years. Several things can happen before the tooth is permanently restored: (a) the temporary restoration may be lost; (b) the seal may be compromised; (c) recurrent decay may be introduced into the obturated canal; and (d) the tooth may fracture Begotka (1996). Any of these situations can lead to contamination of the canal. Coronal leakage warrants evaluation in cases of endodontic retreatment. Several studies demonstrate that coronal leakage is a factor in treatment failure. These studies have evaluated bacterial penetration through temporaries, effect of sealers, radiographic analysis, and obturation techniques (2–6). However, two clinical articles found, that the role of coronal leakage may not be of such great importance as implicated by numerous studies in vitro Riccucci (2000) and Sequeira (2004).

In Vitro Studies
Alves et al. (3) examined the possible penetration of post-prepared canals by endotoxin and bacterial cells derived from mixed bacterial communities. The results showed that both bacteria and endotoxin were able to penetrate the obturating materials in post-prepared canals; however, endotoxin penetration was faster. They summarized nine coronal leakage studies with respect to obturating material, methodology, mean leakage and time. Different methodologies and the time specimens were exposed account for the variation in contamination. Contamination throughout the canal space varied from 3 to 90 days. They concluded that their study supported several other in vitro bacterial leakage studies and reinforced the need for coronal restoration immediately after endodontic therapy. It was noted that the important consideration is not the differences in time of penetration but rather that the phenomenon does occur.

Magura et al. (2) evaluated histological linear measurements of bacterial penetration with teeth exposed to human saliva. These authors suggested that clinicians consider retreating obturated root canals that have been exposed to the oral environment for more than 3 months. Torabinejad et al. (4) found that over 50% of root canals were completely contaminated after a 19-day exposure to Staphylococcus epidermis and that 50% of canals were contaminated when the coronal surface of their fillings were exposed to Proteus vulgaris for 42 days.

In Vivo Studies/Radiographic Analysis

Through radiographic analysis, Ray and Trope (5) evaluated the periapical status of 1010 endodontically treated teeth with respect to the quality of the coronal restoration and obturation. They concluded that the quality of a coronal restoration is more important than the quality of the obturation.

In a seemingly contrasting retrospective analysis of the clinical significance of coronal leakage, Riccucci et al. (7) used radiographic and clinical determinants to evaluate cases obturated at least 3 yr earlier. Fifty-five teeth were evaluated radiographically and clinically. Teeth were classified as open group or intact group. Their results showed that 18% of the 55 teeth presented with osteolytic lesions. The remaining teeth showed no obvious periapical lesions. Among the teeth with lesions, three lesions were larger than at the time of treatment and seven were smaller. The authors noted that although their study lacked sufficient sample size, they found no statistical difference between the open and intact groups. This study suggested that coronal leakage might not be of great clinical importance if instrumentation and obturation are carefully performed.

Krakow et al. (6) evaluated the efficacy of temporary filling materials in vivo. Cavit, Caviton, gutta-percha, three types of zinc phosphate, and zinc oxide eugenol were tested. All materials were placed in the access cavity of an anterior tooth in 10 different patients for a minimum of 1 week. They determined the amount of leakage by culturing a cotton pellet that was sealed into the access cavity for bacteria. On the basis of quantity of microorganisms grown anaerobically, leakage was rated as no leakage, minor leakage, or gross leakage. They found that Cavit and Caviton showed no or minor leakage in the vast majority of tests and that gutta-percha showed gross leakage in six out of eight tests. Phosphate cements showed no leakage in more than 2/3 of the tests.

Siqueira JF Jr (8) found in their study that even though the coronal restoration had a significant impact on the periradicular health, the quality of the root canal fillings was found to be the most critical factor in this regard.

The most suitable material to stop coronal leakage is very difficult to say anything about because few studies compare different kind of materials, but all show that materials tested are leaking. A study by Galvan et al (9) shows more leakage with IRM than resin materials (Fig.15).

Tselnik et al (10) shows MTA and Fuji II LC work well as a coronal barrier for up to 3 months, but also in their study some of the samples showed leakage.

Jenkins et al (11) show Tetric demonstrates significantly better seal than Pro Root or Cavit.

Vol. 28, No. 2, February 2002 Coronal Microleakage 61

TABLE 1. Microleakage of resin seal on pulpal floor (10^{-4} μL min^{-1} cm H_2O^{-1})

	Immediately	1 day	7 days	1 month	3 months
Amalgabond	0.79 ± 0.78^{a}	0.60 ± 0.69^{a}	0.20 ± 0.26^{a}	0.70 ± 0.35^{a}	0.35 ± 0.41^{a}
C&B Metabond	0.99 ± 0.62^{a}	0.50 ± 0.60^{a}	$0.45 \pm 0.28^{a,b}$	0.70 ± 0.63^{a}	$0.45 \pm 0.44^{a,b}$
One-Step Æliteflo	1.24 ± 0.88^{a}	0.45 ± 0.50^{a}	$0.89 \pm 0.80^{b,c}$	0.89 ± 1.12^{a}	1.34 ± 1.35^{b}
One-Step Palfique	5.32 ± 6.36^{a}	3.53 ± 6.22^{a}	0.94 ± 0.76^{c}	0.75 ± 0.82^{a}	$0.65 \pm 0.67^{a,b}$
IRM	1.89 ± 2.32^{a}	2.58 ± 3.51^{a}	1.19 ± 0.58^{c}	43.6 ± 125^{b}	55.4 ± 144^{c}

Groups identified by the same superscript letters are not significantly different ($p > 0.05$). Groups identified by different superscript letters are significantly different ($p < 0.05$). Values are mean ± SD (N = 10).

Fig.15 Microleakage of resin seal on pulpal floor (Galvan et al. 2002)

According to the numerous in vitro studies on coronal leakage, tooth 47 should have been retreated because of the elapsed time. However, other factors were considered. The patient’s lack of symptoms, the positive radiographic appearance of the endodontic fill, the apparent apical healing, and negative clinical findings were all factors in the decision not to retreat tooth 47

Clinicians are often presented with endodontically treated teeth that have not been restored for a long period of time. The question of whether or not to retreat needs to be addressed. The studies on coronal leakage imply that time may not be a sole indicator to retreat as some in vitro studies indicate. Rather the clinician should evaluate the existing conditions radiographically and clinically to determine a course of treatment. When considering the need for retreatment due to leakage, the literature suggests that clinicians need to evaluate the quality of endodontic treatment along with clinical and radiographic conditions of each individual case.

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Case number 10

Endodontic treatment of mandibular left first molar with a sinus tract and obturated with a novel root-filling material

Patient

A 15-year-old white Norwegian female (Fig.1) was referred to the Department of Endodontics, University of Oslo, August 31, 2005 by her GP for treatment of mandibular left first molar.

Fig.1 Frontal view

Medical history

Non-contributory.

Dental History & Chief Complaint

Mandibular left first molar was treated with a stepwise excavation of caries in order to avoid endodontic treatment. Her last examination revealed that the tooth had a negative response to the sensibility test, and radiographic examination demonstrated apical radiolucency.
The patient had experienced pain in the area for some days a couple of months ago.

Clinical Examination

Clinical photos showed the region from mandibular left canine to mandibular left second molar (Fig.2, 3).

No pathology was found extra-orally

A normal oral mucosa was observed.

Fig.2 Buccal view

Fig.3 Occlusal view

Mandibular left second molar: An OB composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice. There was no tenderness on either percussion or palpation.
Mandibular left first molar: An O composite restoration and an IRM temporary filling on the distal part were seen. The tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion. A distal cavity was explored. Probing depths in the furcation area both buccally and lingually were 11 mm.
Mandibular left first premolar: The tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits except tooth 36.

Radiographic Examination

The preoperative radiograph showed the region from mandibular left second premolar to second molar (Fig. 4).

Mandibular left second molar: An O radiopaque restoration was seen and the radiograph demonstrated an incomplete root formation
Mandibular left first molar: An OD radiopaque restoration. A radiolucent area under the opaque restoration was seen distally. Lamina dura can be followed apical on the mesial side of the mesial root, and distal side of the distal root. A radiolucent area around both apices was seen, reaching the furcation area from both the mesial and the distal root
Mandibular left second premolar: Lamina dura can be followed along the root.The radiograph demonstrated an incomplete root formation.

The height of the marginal bone was within normal limits.

Fig.4 Apical radiolucency of tooth 36

Diagnosis

Apical periodontitis with sinus tract mandibular left first molar

Treatment Plan

Necrotic treatment of mandibular left first molar
Root canal disinfection and filling

Treatment

August 31, 2005

Small amounts of Xylocain /adrenalin was infiltrated in the gingiva buccally and lingually. Some of the composite restoration was removed, and caries found distally was excavated. A matrice band was applied and the tooth was restored with a composite restoration.
Rubber dam was applied and the area disinfected with chlorhexidine-ethanol solution. The access cavity was irrigated with 1% sodium hypochlorite. Working length was established by the use of K-Flex nr 15 with the aid of an apex locator (Root ZX), and verified by a working length radiograph (Fig.5).

Fig.5 Working length

The working lengths were: MB canal 22 mm Last instrument size NiTi nr 40
ML canal 22 mm Last instrument size NiTi nr 40
DB canal 23.5 mm Last instrument size NiTi nr 55
DL canal 23.5 mm Last instrument size NiTi nr 45

The MB cusp was the reference point for all the canals.

Irrigation was performed with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the aid of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

October 05, 2005

The patient returned six weeks later. The tooth was asymptomatic and the sinus tract was closed. Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi instruments and irrigation with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. Master Resilon cones were tried in, and a master cone radiograph was taken (Fig.6).
The root canals were dried with sterile paper points. The canals were primed with Epiphany Primer and excess primer was dried with paper points. The Epiphany sealer was applied with a Lentulo spiral and Resilon points coated with sealer and filled by cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. The access cavity was filled with IRM. A final radiograph was taken after the removal of the rubber dam (Fig7).
The patient was referred back to her GP recommending a porcelain onlay or a crown.

Fig.6 Master cone

Fig.7 Final radiograph

Evaluation

Four canals were found and cleaned. After treatment with calcium hydroxide for six weeks, healing was already in progress. Epiphany/Resilon was chosen in the hope of getting some of the effect from the monobloc theory, considering the patient`s age and breakdown of the tooth.
Despite the monobloc theory, an IRM plug was placed 2 mm coronally in all the canals. This was a result of the deep composite restoration in the distal part of the tooth. Possible future leakage from this area is the reason why we traditionally use IRM as a sealing material.

Prognosis

Endodontic prognosis was considered favourable

Prognosis of the tooth was considered uncertain in the long run, and much depended on the quality and type of restoration.

5 months follow-up

March 22, 2006

The patient returned to the clinic 5 months later. The tooth was asymptomatic. The GP had placed an O composite restoration only removing a small amount of the IRM.
Clinical and radiographic examinations revealed favorable healing (Fig.8, 9).

Fig.8 Start of treatment

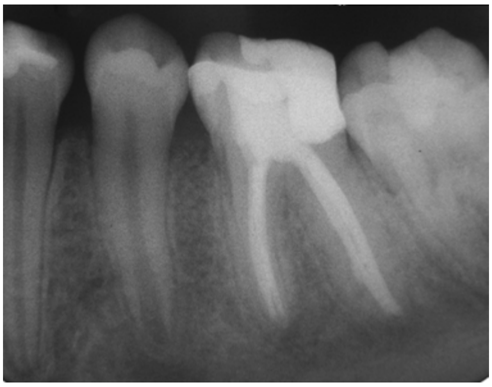

Fig.9 Five months follow-up

Discussion

This new material Epiphany/Resilon is promoted with:
It seals significantly better than conventional materials
It can help strengthen the root
It can easily be retrieved just like conventional materials
It is highly radiopaque
It can be used in any technique with virtually no learning curve

Several studies show less leakage with the use of Epiphany/Resilon compared to AH Plus and gutta-percha (Shipper et al.2004, Stratton et al. 2005).
The fact that it is highly radiopaque is obvious on radiographs.
It can easily be retrieved, according to the study by Schirrmeister et al. (2006) and by Oliveira et al. (2006).
Reinforcement of the root is highly questionable (Stuart et al 2006, Williams et al.2006).
The monobloc theory is also questionable because the amount of dimethacrylate incorporated in Resilon may not yet be optimized for effective chemical coupling to methacrylate resins (Hiraishi 2005).

Studies by Tay et al. (2005) also show susceptibility to degradation. It may be concluded that the quality of apical seal achieved with the new polycaprolactone-based root filling material and methacrylate-based sealer is not necessarily superior to gutta-percha and a conventional epoxy-resin sealer. Another area of concern is the biodegradability of Resilon, in the event that a hermetic seal is not established. Whereas gutta-percha is a relatively inert material, polycaprolactone is biodegradable under microbial attack. It is well known that lipases released by bacteria can cleave the ester bonds of polycaprolactone. Further studies should be performed to confirm the hydrolysis of Resilon by salivary/bacterial enzymes (Tay et al. 2005).

A study by Debelian showed 91.6% healing of apical periodontitis in a 2 year follow-up clinical study using Epiphany/Resilon (not published).

There are a lot of studies coming out on this material and some look promising especially regarding leakage. Other studies indicate caution.

Debelians study shows no better clinical performance than conventional methods.
His study is comparable with other studies using NaOCL and gutta-percha (Weigers 2000, Peters 2002).
Debelian's results do not show any evidence that the materials used in his study are in any respect superior to the traditional ones. If you go for sense and simplicity then why make it more expensive and complicated than is strictly necessary, and also the uncertainess on how well this material will perform in the long run

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Case number 11

Endodontic treatment of multiple teeth in conjunction with pain management

Patient

A 32-year-old white Norwegian male was referred to the Department of Endodontics, University of Oslo, by Professor Preus October 20, 2004 because of pain and numerous ongoing endodontic treatments (Fig.1).

Fig.1 Frontal view

Medical History

The patient was operated in the left sinus maxillaries three times over a period of five years. The pain had come and gone in periods since the last surgery two years ago. In the last year the patient had received treatment for his problems mainly by painkillers. He had also received several antibiotic treatments in conjunction with dental treatments. He had used Sobril 10 mg, Ibux 600 mg, Pinex Forte, Napren-e 500mg and Nobligan 50 mg. He tested positive for cannabinoids. That is normally a result of the use of hashish or marihuana.
He had also been to a consultation at Gjøvik hospital to control his sinuses, and they concluded that his pain did not have its origins in that area. He had also been examined at Rikshospitalet where no pathology was found. He had been tested for allergic reactions, and he tested positive for different pollen - diagnosis clinical allergies.
He used six Nobligan 50 mg tablets per day and two Sobril 10 mg tablets per day because of pain mainly on the left side of the head, going from the teeth and upwards.

Dental History & Chief Complaint

Several teeth on his left side both in the upper and lower jaw had been extracted because of pain. Five teeth had been left open after the endodontic treatment was started. After receiving endodontic treatment the pain and pressure had been so intense that the dentists had removed the temporary filling. The patient had more pain at that time than one year earlier in spite of all his dental treatment. He was however convinced that his problems were related to his teeth.

Clinical Examination

No pathology was found extra-orally.

A normal oral mucosa was observed.

The patient had received a lot of dental treatment, both conservative and prosthodontic. Teeth 24, 26, 27, 36, 37 and 48 had been extracted over the last two years.

Endodontic treatment on the following teeth had been started:
Maxillary right second premolar: A broken MOD composite restoration with no temporary filling in the access cavity. The tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion.
Maxillary left central incisor: A porcelain crown and no temporary filling in the access cavity were seen. The tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion.
Maxillary left second premolar: A MOD composite restoration and no temporary filling in the access cavity were seen. The tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion and palpation.
Mandibular left second premolar: A broken down tooth with some IRM and no temporary filling in the access cavity was seen. The tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion.
Mandibular left first premolar: A MOD composite restoration and no temporary filling in the access cavity were seen. The tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion.

Five preoperative photographs showed the teeth with started endodontic treatment (Fig.2, 3, 4, 5, 6).

Fig.2 Buccal view right side

Fig.3 Buccal view left side


Fig.4 Occlusal view upper right jaw **Fig.5** Occlusal view upper left jaw

Fig.6 Occlusal view lower left jaw

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The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiographs showed the teeth where the endodontic treatment had been started (Fig.7, 8, 9, 10).



Fig.7 Tooth 15 **Fig.8** Tooth 21 **Fig.9** Tooth 25

Fig.10 Teeth 34 and 35

In all the teeth the lamina dura can be followed around the entire root.

The marginal bone level was within normal limits.

Diagnosis

Necrotic tooth maxillary right second premolar
Necrotic tooth maxillary left central incisor
Necrotic tooth maxillary left second premolar
Necrotic tooth mandibular left first premolar
Necrotic tooth mandibular left second premolar

Non-odontogenic cause of pain
Neuropaty

Treatment plan

Necrotic treatment of maxillary right second premolar
Necrotic treatment of maxillary left central incisor
Necrotic treatment of maxillary left second premolar
Necrotic treatment of mandibular left first premolar
Nectotic treatment of mandibular left second premolar

Root canal disinfection and filling

Treatment of pain: Focus on all the dental treatment that had already been done without any release of pain. On the contrary, the pain had increased. The patient was told that he was not allowed to get dental treatment from others without my permission. I focused on convincing him to entrust his treatment to me in a way that would not give him additional pain teeth will not give him additional pain.
It was also agreed that pain killers would be prescribed by his doctor, and that he should follow the treatment plan and consultations his doctor ordered.

The patient was referred to Rikshospitalet pain clinic for neuropathy.

Overall goal of dental treatment: No extraction and convince the patient that the pain was not of dental origin.

Treatment

October 20, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The access cavity was irrigated with 1% sodium hypochlorite. Working length was established by the use of K Flex nr 15 with the aid of an apex locator (Root ZX), and verified by a working length radiograph (Fig.11).

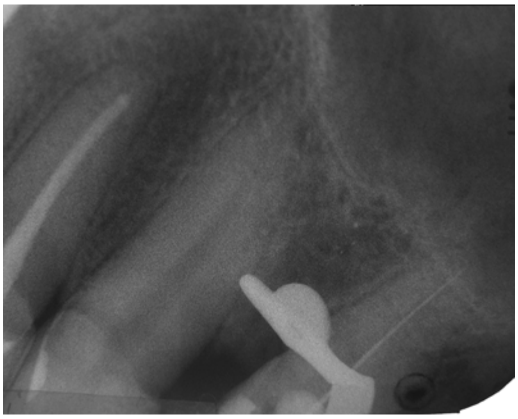


Fig.11 Working length

The working length was: B canal 22 mm. Last instrument size NiTi nr 45
P canal 22 mm. Last instrument size NiTi nr 45

The B cusp was the reference point for both canals.

Irrigation was done with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. Root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was applied in slurry into the canals with the help of a Lentulo spiral. The access cavity was sealed with Cavit G and IRM.

The treatment was ended with motivation and information.

All the other teeth were treated with the same procedures and a lot of motivation through conversation.

November 30, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi instruments nr 45, and irrigation with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. Two number 45 master gutta-percha cones were tried in, and a master cone radiograph was taken (Fig.12). The root canals were dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. The access cavity was filled with IRM. After the removal of rubber dam a final radiograph was taken (Fig.13).

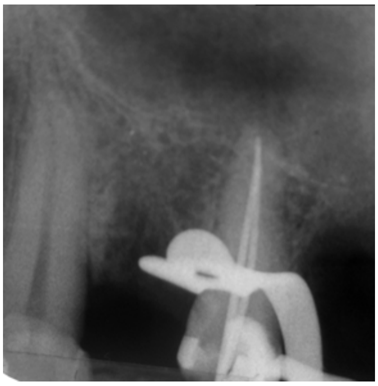


Fig.12 Master cone **Fig.13** Final radiograph

January 12, 2005

All treatment sessions were started with conversation. The patient was still not convinced that his teeth were not the origin of the pain. The other teeth were root-filled without any problems (Fig.14 – 28). They were all asymptomatic, but the patient`s pain problem was not solved.

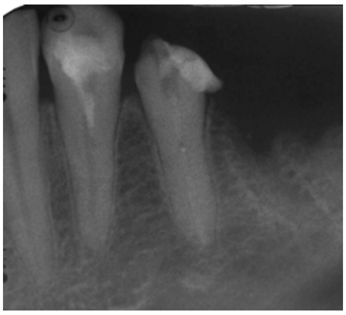
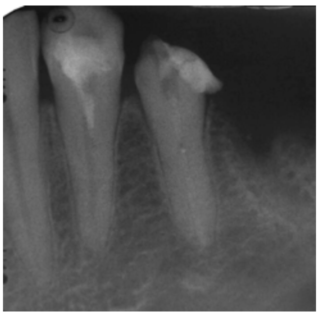
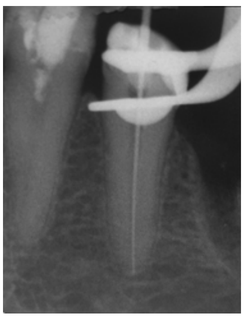


Fig.14 Start treatment 34 **Fig.15** Working L. **Fig.16** Master C. **Fig.17** Final





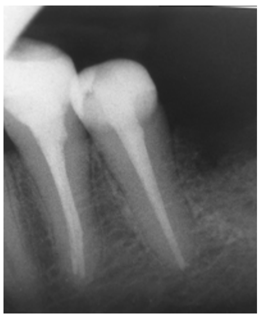


Fig.18 Start treatment 35 **Fig.19** Working L. **Fig.20** Master C. **Fig.21** Final

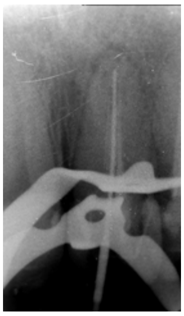


Fig.22 Start 21 **Fig.23** W.L. **Fig.24** M.C. **Fig.25** Final

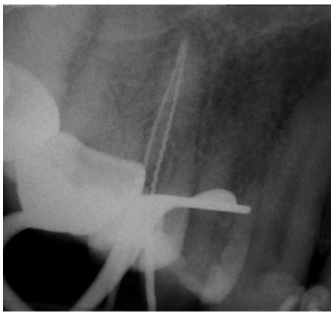


Fig.26 Start treatment 15 **Fig.27** Master cone **Fig.28** Final radiograph

The endodontic treatment was considered successful.
All the treated teeth were asymptomatic, and I hoped to have motivated the patient to keeping his teeth.

Evaluation

It was decided that my main concern was the treatment of the teeth. He was under medical treatment and the dental treatment was more to rule out that the teeth were the cause of the pain.
In a period of six months I was able to complete the endodontic treatment that had previously been started. I was not sure that the patient was convinced about the origins of his pain, but no exacerbation, antibiotic treatment or extraction had been done in these 6 months.
Compared to the previous year this was satisfying.
He still used the same amount of pain killers to be able to function and was still waiting for a consultation at the pain clinic.

Prognosis

Endodontic prognosis for all teeth treated was considered favoruable.
The patient mental condition felt unstable.

6 months follow-up

August 28, 2005

The patient returned to the clinic for a six-month follow-up. The patient still had the same pain. He said he had convinced a dentist to extract two teeth in July (Fig.29, 30).
I tried again to convince him that extraction was not helping him. He still believed that his problem was related to his teeth. The patient was asked to call if any further problems with his teeth arose.

Fig.29 Extraction of 15 was done

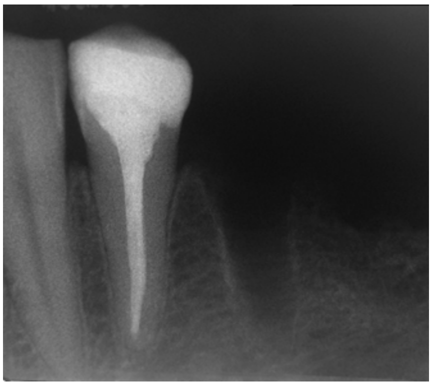


Fig.30 Extraction of 35 was done

One year follow-up

March 28, 2006

The patient returned to the clinic 7 months later. The patient was still in pain. He said he had convinced another dentist to extract two more teeth (Fig.31, 32, 33, 34, 35, 36, 37, 38, 39, 40). So four out of five teeth treated by me had been extracted.
He now started to realize that the pain possibly had some other origin. He was now using 8 Nobligan 50 mg tablets and two Sobril 10 mg tablets every day to be able to work 50%. He was scheduled for an examination at Rikshospitalet painclinic at the end of April.

Fig.31 Front view

Fig.32 Tooth 21

Fig.33 Buccal view right side

Fig.34 Buccal view left side

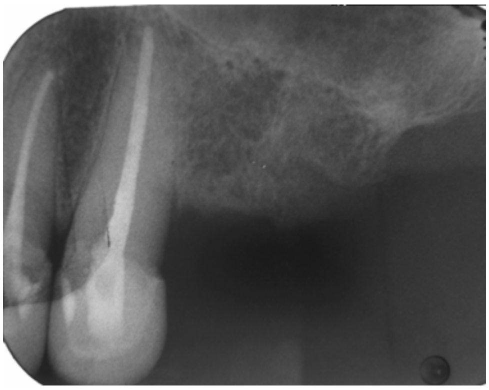


Fig.35 Occlusal view maxilla left side

Fig.36 Maxilla left side

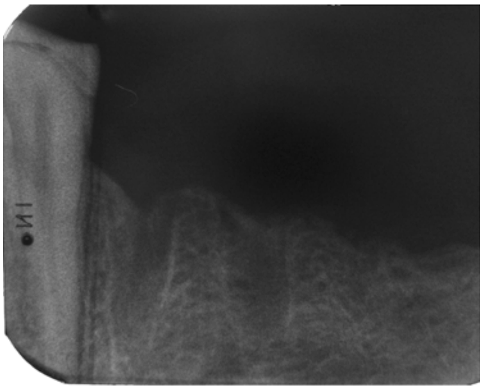


Fig.37 Occlusal view mandibular left side

Fig.38 Mandibular left side

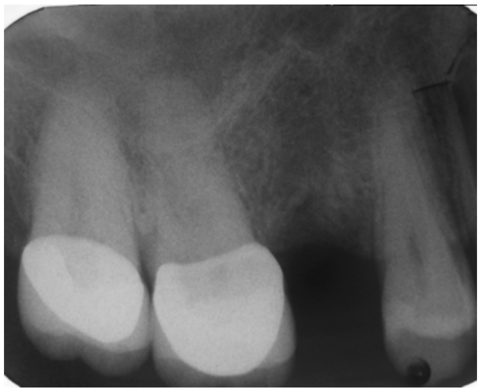


Fig.39 Occlusal view maxilla right side **Fig.40** Maxilla right side

Discussion

Damage to somatosensory peripheral nerves may produce a loss of sensation, with the amount of loss corresponding approximately to the severity of the nerve damage. This is what usually occurs, but in some cases nerve injury produces positive symptoms, and these almost always include dysesthetic sensations or 1 or more types of pain. Itch may also appear as a symptom, but this appears to be rare. The abnormal pain experienced after nerve injury is called neuropathic pain. Neuropathic pain is a chronic, difficult-to-treat condition that is assumed to be due to dysfunction of the pain-processing neurons in the peripheral nervous system and central nervous system (CNS). Neuropathic pain is seen with injury to all somatic nerves, including the trigeminal nerve and the nerves arising from the upper cervical spinal segments that inervate the rest of the face and head. Neuropathic pain is also sometimes seen after injury to the somatosensory processing regions of the spinal cord, brain, stem, and higher levels of the CNS. For example, such "central pain" can occur in the trigeminothalamic pathway.

Nerve damage leading to neuropathic pain has many causes, only some of which are prevalent in the orofacial region. For example, painful diabetic neuropathy is a common condition that produces pain felt in the feet, hand and midline thorax, but it rarely affects orofacial dermatomes. However, other causes of neuropathic pain commonly affect orofacial structures. The two most common are postherpetic neuralgia and posttraumatic painful peripheral neuropathy

Posttraumatic Painful Peripheral Neuropathy

Somatosensory nerves are damaged in all types of orofacial trauma, including dental procedures. Every pulpal extirpation and every third molar extraction is a blunt trauma to a dental nerve. These are certainly the most common nerve injuries of all; they must occur thousands of times a day, yet there is a question of how frequently they produce neuropathic pain, what symptoms they produce, and how they are to be diagnosed.

The orofacial pain literature contains many descriptions, under different labels, that might qualify as posttraumatic painful peripheral neuropathy: atypical facial pain, atypical facial neuralgia, atypical odontalgis, dental causalgia, neuropathic orofacial pain, phantom orofacial pain, and phantom tooth pain. Major questions for the field are to determine which, if any, of these are neuropathic pain, and to agree upon a nomenclature. This is not particularly difficult when there is clear evidence of nerve injury, ongoing pain is accompanied by hyperalgesia and allodynia, and the pain is resistant to nonsteroidal anti-inflammatory drugs and opioids. The difficult cases are those in whom there is no definitive evidence of nerve injury. Injury to small nerves and partial injury to even large nerves can be difficult to prove. Quantitative sensory testing may be of help here.

A second major challenge to the field is to determine the incidence of orofacial posttraumatic painful peripheral neuropathy. One gets the impression that these are very rare problems, especially when considered in the context of the large number of nerve injuries due to dental procedures. Only very limited epidemiological data are available. Retrospective studies of the incidence of painful phantom tooth suggest that at least 2 % to 3 % of endodontic surgery cases may be affected. This is a surprisingly large percentage; if true, then dentistry is facing a much greater problem than is generally acknowledged.

Despite this caveat, the possibility must be considered that posttraumatic painful peripheral neuropathy is indeed relatively rare and that the response to trigeminal nerve injury is some different than the response to injury of other nerves. There are 3 factors that might be relevant. First, it is often noted that the trigeminal nerve innervates highly specialized tissues that participate in highly specialized functions (implying unique neural circuitry) that somehow render it relatively immune to the development of neuropathic pain. For example, the innervation of the tooth pulp and the tongue are certainly highly specialized, and the neural circuitry of the innervation of orofacial structures is functionally specialized for mastication and speech. However, I do not think that this argument is very persuasive. Other somatosensory nerves also innervate highly specialized tissues with highly specialized functions. For example, consider the innervation of the finger tips, genitalia, anal mucosa, and the nipples. The second factor that might render the trigeminal nerve relatively resistant to the development of neuropathic pain concerns 2 unique developmental events in the oral cavity. Only the trigeminal system has a biologically programmed pain event and a biologically programmed denervation event-the eruption and loss of the primary teeth. Might these events in early life somehow offer protection against the consequences of later nerve injury? The third factor concerns dental surgery. Nearly all dental surgeries are performed under local anesthesia-no other type of surgery routinelyblocks the innervation of the injured tissues. Consequently, in dental surgery the barrage of nerve impulses generated by the trauma does not gain access to the CNS. The injury-evoked impulse barrage, especially that from C-fiber nociceptors, is known to engage a process of central sensitization that may have relevance for the initiation of neuropathic pain.

There are now several animal models of posttraumatic painful peripheral neuropathy, and the last 15 years have seen an explosion in our knowledge of potential pain-producing mechanisms. The majority of work has been done on the rat's sciatic nerve, but it is possible to use an experimental injury to a branch of the rat's trigeminal nerve. Analysis of the rat's behaviour after trigeminal injury confirms the presence of a neuropathic pain syndrome.

Nerve damage activates those processe of the innate immune system that are involved in inflammation and healing.It is important to note that this occurs even with a completely sterile injury. An experimental inflammation of the rat`s sciatic nerve (a neuritis) at mid thigh level produces neuropathic pain sensations in the animal`s hind paw. The inflammation does not produce axonal degeneration. A similar syndrome is produced by creating an experimental inflammation of the rats infraorbital nerve. The pain is believed to be due to the activation of noiciceptors coursing through the inflamed region by proinflammatort cytokines susch as tumor necrosis factor-alpha.

The clinical significance of this sort of neuritic pain is unclear. A persistent inflammatory process (due to occult infection, bone resorption, or mechanical irritation), even if it is a relatively low level, might produce neurophatic painlike symptoms, which would necessarily be accompanied by any of the traditional signs of nerve damage.

There are characterisitic features of trigeminus neuralgia that are clearly different from other neuropathic pains.
First, paroxysmal electric schock-like pains with intervening pain-free intervals are phathognomonic. The paroxysms may be followed by a lingering soreness, but abscense of pain in the abscense of paroxysms is usually a very clear feature of the disease.
Paroxysmal pain is sometimes seen in patient with PHN, but in this case the patients also have a more or less continous background pain that they describe as burning or aching.
Second, they have a refractory period, ie, an interval of seconds to minutes after a paroxysm during which triggering stimuli fail to launch another paroxysm.
Third, some have referred proxysmal pain, ie, triggering stimulation in 1 location evokes pain in a distant location with no pain felt in the intervening region.
Forth, sometimes remits for weeks, months or years. This never occurs with any other kind of neuropathic pain.
Fifth, many obtain excellent pain relief with carbamazepine (Tegretol). This is rarely effective in other kinds of neuropathic pain.

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Case number 12

Endodontic treatment of a severely broken down mandibular right first molar with separated instruments

Fig.1 Frontal view

Patient

A 35-year-old white Norwegian female (Fig.1) was referred to the Department of Endodontics, University of Oslo, by her general practioner September 7, 2005 for treatment of mandibular right first molar.

Medical history

Non-contributory.

Dental History & Chief Complaint

The patient consulted her general practitioner in November 2004 because of pain in her right lower jaw. The patient had several appointments with her GP. During the root canal therapy the GP failed to negotiate the mesial canals, and separated three instruments. The GP filled the pulp chamber with calcium hydroxide and IRM as a temporary filling. Some time later the lingual part of the tooth was broken. It was done a build-up with a glass ionomer filling material, and   the patient was referred to the Department of Endodontics.
The patient was not comfortable about chewing on her right side, and had difficulties keeping the interdental space clean with a toothpick or dental floss.

Clinical Examination

Preoperative photos showed the region from mandibular right second molar to mandibular right canine (Fig.2, 3).

No pathology was found extra-orally

A normal oral mucosa was observed.

Fig.2 Buccal view

Fig.3 Occlusal view

Mandibular right second molar: A MOD composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice. No tenderness on either percussion or palpation.
Mandibular right first molar: A MODL glass-ionomer build-up and B an amalgam restoration was seen. The build-up was ill fitting and was fractured. The tooth responded negatively to the sensibility test with Endo Ice and was tender to percussion. The fractured build-up was removed, and revealed very little tooth substance left especially distally and lingually.
Mandibular right second premolar: The tooth responded positively to the sensibility test with Endo Ice. The tooth was rotated 90 degrees.

The other teeth in the upper and lower right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from maxillary right second molar to second premolar (Fig. 3). Another radiograph was taken after the fractured build-up had been removed (Fig.4).

Mandibular right second molar: A MOD and B radiopaque restorations were seen, and lamina dura could be followed around the entire root.

Mandibular right first molar: A radiopaque restoration was seen in the crown, and lamina dura could be followed around the entire roots. It was observed 3 fragments of separeted files in the two mesial canals.
Mandibular right second premolar: Lamina dura could be followed around the entire root.

The height of the marginal bone was within normal limits

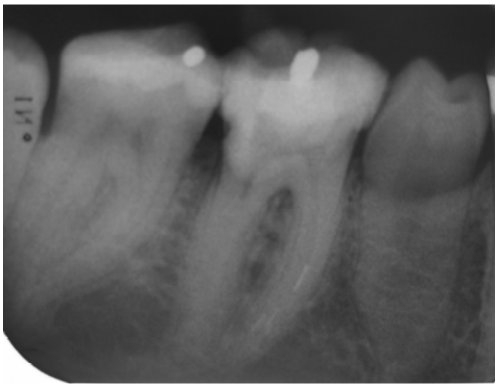

Fig.3 Huge build-up of crown tooth 46

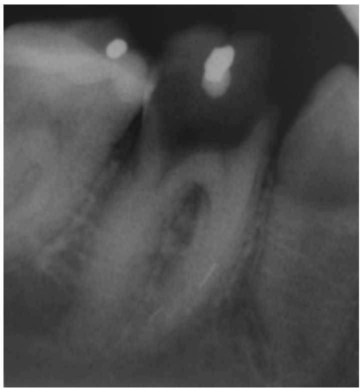

Fig.4 Fractured build-up removed

Diagnosis

Necrotic mandibular right first molar with separated instruments

Treatment Plan

Treatment of necrotic mandibular right first molar with separated instruments.
Root canal disinfection and filling

Treatment
September 07, 2005

Removal of the fractured build up revealed very little tooth substance (Fig.5).
The patient was given ½ a carpules of Xylocain/Adrenalin. A gingivectomy was done mesially, distally and lingually. The bleeding was stopped with ferric sulphate (Fig.6)

Fig.5 Lingual view showed growth of granulation tissue under the restoration..

Fig.6 The bleeding was controlled with the help of ferric sulphate

There was little tooth substance left, especially distally and lingually. A matrice was applied in a Nystrom matrice holder and a composite build-up was done. The composite build-up was polished and a cotton pellet with Eugenol was applied in the pulp chamber, and the access cavity sealed with IRM (Fig.7, 8, 9, 10).
The patient was now able to maintain good oral hygiene, and the placement of rubber dam would not pose any problem.

Fig.7 Buccal view of restoration

Fig.8 Occlusal view

Fig.9 Lingual view

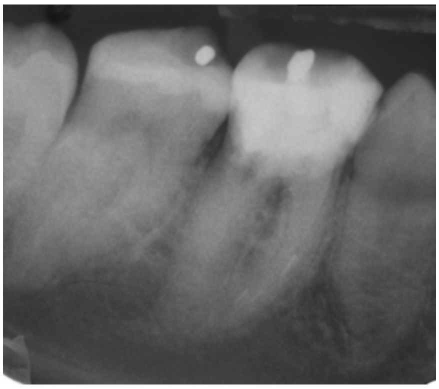

Fig.10 Radiograph of composite restoration

September 27, 2005

The patient returned to the clinic three weeks later. The tooth was asymptomatic. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. Access cavity was irrigated with 1% sodium hypochlorite. The working length was found with K-Flex nr 15 and the help of an apex locator (Root ZX), and verified by a working length radiograph (Fig.11).

Fig.11 Working length

The working lengths were: MB canal 16mm. Last instrument size NiTi nr 50
ML canal 14mm. Last instrument size NiTi nr 50
DB canal 21mm. Last instrument size NiTi nr 60
DL canal 21mm. Last instrument size NiTi nr 60

The MB cusp was the reference point for all the canals.
The separated instrument in the ML canal was localized after instrumentation. It was tried to bypass without success. A staging platform was created with Gates and modified Gates bur (Fig.12).

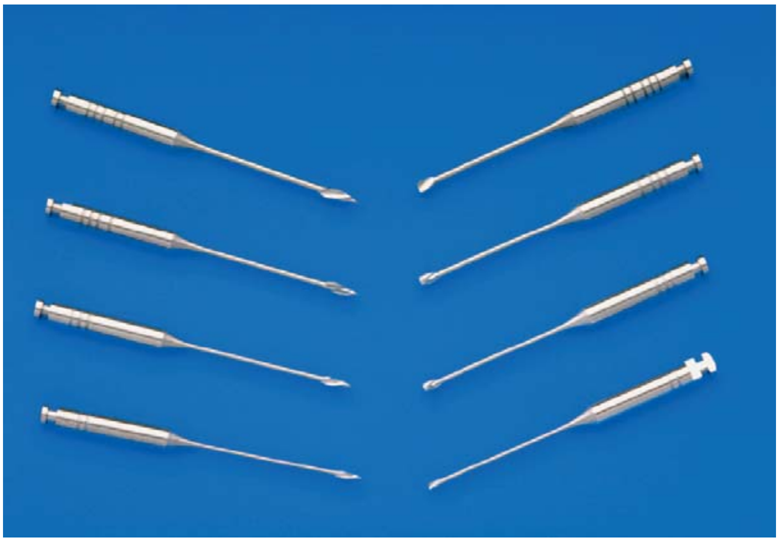

Fig.12 Gates and modified gates to create a staging platform.

Then the separated instrument was attacked with an ultrasound instrument laterally. The ultrasonic instrument maintains contact with the broken file, precisely sands away dentin, and progressively exposes the coronal part of the broken file (Fig.13, 14).

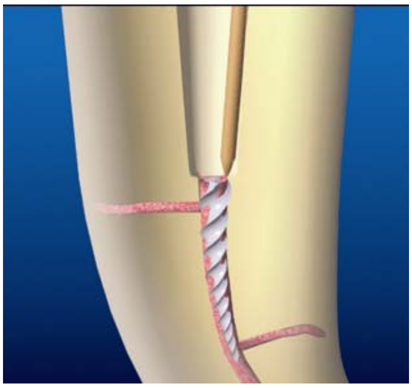

Fig.13 After making a platform ultrasound was applied to remove the instrument.

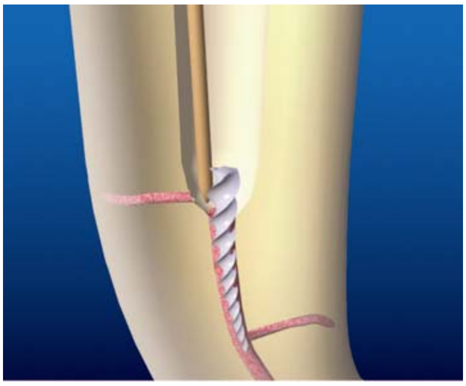

Fig.14 The ultrasonic tip is working around the fractured instrument.

Even tough visibility was achieved with the help of Gates bur I had problem with the visibility and control of the ultrasonic instrument. Continuing without removing too much of the root was difficult, and it was decided to leave the fractured instruments.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and dressed for 5 min. with 2% chlorhexidine digluconate. The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

October 05, 2005

The patient returned one week later. The tooth was asymptomatic. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi instruments, and irrigation with 1% sodium hypochlorite, 17% EDTA and dressed for 5 min. with 2% chlorhexidine digluconate. Master gutta-percha cones were tried in and a master cone radiograph was taken (Fig.15).

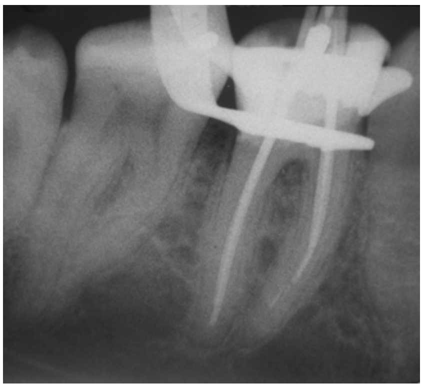

Fig.15 Master cone

The root canals were dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. The access cavity was filled with IRM (Fig.16, 17).

Fig.16 Final radiograph **Fig.17** Mesioeccentric image

Evaluation

The goal was to remove the most coronal separated instrument in the mesio-lingual canal. I achieved good visibility with the technique described by Dr. Ruddle (Fig.12, 13, 14). It was difficult to be in control when working with the ultrasound. Therefore I decided to stop being afraid of weakening or perforate the root. This was a non-reversible pulpitis in the beginning, and the impact of instrument fracture on the outcome of the endodontic treatment should be minor.However in this case, multiple treatments sessions, a fracture of the lingual part of the tooth, and a fractured temporary filling were not the perfect scenario for maintenance of the aseptic chain throughout the endodontic treatment.
The patient was referred back to her GP for crown treatment as soon as possible to make sure no leakage would take place from the composite build-up, and eventually periapical pathology could be solved surgically. The patient was informed that a follow-up of the tooth would be done after 6 months and the need of surgery evaluated.

Prognosis

Endodontic treatment is considered uncertain.

6 months follow-up

March 21, 2005

The patient returned to the clinic 6 months later. The GP had made a PFM crown on the tooth. The tooth was asymptomatic. Clinical and radiographic exams revealed no pathology (Fig.18, 19).

Fig. 18 PFM crown in place on tooth 46

Fig.19 Six months follow-up

Discussion

When an endodontic instrument fractures during use in a root canal, the best option is to remove it (Machtou & Reit 2003). Only after removal of the fractured instrument can the root canal be negotiated, cleaned and shaped optimally. If the root canal cannot be cleaned and shaped successfully, remnants of pulp tissue and bacteria may remain and compromise the outcome of root canal treatment (Sjøgren et al. 1990, Rocke & Guldener 1993).
However, attempts to remove fractured instruments may lead to ledge formation, overenlargement and transportation of the prepared root canal or perforation. Thus, the clinician has to evaluate the options of attempting to remove the instrument, bypassing it or leaving the fractured portion in the root canal. This decision should be made with consideration for the pulp status, canal infection, the canal anatomy, the position of the fractured instrument and the type of the fractured instrument (Rocke & Guldener 1993).

NiTi rotary instruments have become an important and popular technique for root canal preparation. Some of the instruments may fracture if used inappropriately (Suter 1999, Saunders & Saunders 2003). Due to their increased flexibility and elasticity the removal of fractured NiTi instruments may be more difficult compared with stainless steel instruments. An additional factor may be that when ultrasonic vibration is used in an attempt to loosen the fractured instruments from the root canal, the NiTi instruments have a greater tendency to fracture repeatedly. A further reason for the more difficult removal may be that many of the fractured NiTi instruments are 'locked' into the canal because they may screw in.

The introduction of new devices such as the operating microscope, ultrasonic devices, Cancelliers (Carr 1992), hypodermic needles (Eleazer & O`Connor 1999), blunt needle and core paste (Machtou & Reit 2003), Instrument Removal System (IRS) (Ruddle 2003) or the Tube-and-Hedström file-Technique (Suter 1998) may result in easier and more controlled removal of fractured instruments. Indeed the experience developed during the study of Suter (1998) showed that the use of the operating microscope was essential for the removal of fractured instruments.
Hülsmann & Schinkel (1999) report a 68% overall success rate for removing or bypassing fractured instruments from root canals *in vivo*. Ward *et al.* (2003) using more modern techniques introduced by Carr (1992) reported an overall success rate of 73% for complete removal of broken instruments *ex vivo*.

Suter (2005) recommended the treatment steps in the following strict orders.

1. Where possible, straight-line access to the coronal portion of the fractured instrument was created. The intention of this first step was to visualize the fractured instrument under the operating microscope. Straight-line access was created using the SonicFlex Endo System (KaVo, Biberach, Germany) with tip types 67, 68 and/or 70 (Suter 2001). In some cases Gates Glidden burs (Dentsply Maillefer, Ballaigues, Switzerland) were used.

2. An attempt was made to create a groove around the coronal end of the fractured instrtument using a size 25 K-File mounted on a ultrasonic handpiece (Satelec, Merignac, France) and/or to bypass it with K-Files.

3. The fractured instrument was loosened with an ultrasonically activated file and flushed out of the root canal. At any stage if visualization was impossible, an attempt was made to remove the fractured instrument using tactile sense. In this way the instrument was bypassed using precurved ultrasonic files; when successful, the instrument was flushed out of the canal.

4. If ultrasonic vibration was ineffective, an attempt was made to remove the fractured instrument with the Tube-and-Hedström file-Method (Suter 1998).

5. If possible, at all stages, an attempt was made to remove a loosened and bypassed instrument with the help of a microdebrider, a Hedström file, a Masserann trephine or with pliers.

Hülsmann & Schinkel (1999) did not describe the time required for instrument removal. Suter (2003) demonstrated that success rates may drop with increased time of treatment. This may be related to operator fatigue, or overenlargement of the root canal owing to ultrasonic abrasion. This in turn may correspond with a higher risk for perforation. The difficulty of the case may also explain the reduction in success rates. Attempts to remove fractured instrumnets from root canals should not take longer than 45–60 min. It is recommended that after this period of time serious consideration is given to other treatment options.

Hülsmann & Schinkel (1999) reported fracture in mesial roots mandibular molars in 34% of all cases. Suter (2003) the figure was 50% of all instruments and was comprised as follows: 58% of all NiTi rotary instrument fractures, 26% of all steel instrument fractures, 64% of all Lentulo spiral fractures and 50% of all other instrument fractures located in mesial roots of mandibular molars. It seems therefore that the use of rotary instruments (i.e. NiTi rotary and Lentulo spirals) in mesial canals of mandibular molars may lead to a higher risk of instrument fracture.

Some cases Suter (2005) demonstrate more than the preferred enlargement of the root canal after removal of the instrument. The clinical experience was that the power setting and the working time may be more critical for root canal over enlargement than the design of the ultrasonic tip. The potential for excess dentine removal through lateral cutting by the ultrasonically activated K-Files is minimized using visual control with the operating microscope (Zaugg *et al.* 2004). It should be noted that K-Files for the ultrasonic unit are more cost-effective, versatile and could be pre-bent more easily than ultrasonic tips.

There was an increased failure rate when treatment time exceeded 45–60 min. The deeper within the root canal that the fragment was located and the longer ultrasonic vibration was used in order to loosen it, the greater potential for perforation resulted. The use of the operating microscope was a prerequisite for the techniques applied to remove the fractured instrument (Suter 2005).

Only a few small studies have evaluated the effect of a retained fractured endodontic instrument on the outcome of endodontic treatment (summarized in Table 1). Those that have been regularly cited include two early studies, which reported that the retained fragment reduced healing, particularly in the presence of a preexisting periapical radiolucency (Strindberg 1956, Grossmann 1969) and others, which stated that it had no influence on healing (Ingle 1965, Crump 1970). Some of these studies further suggested that in most cases the retained fractured instrument can be incorporated into the final root canal filling (Crump1970, Fox 1972), although recently developed techniques have made removal more predictable (Ward 2003, Ward 2003, Ruddle 2004).

Fractured root canal instruments may include endodontic files, lateral or finger spreaders, spiral fillers, or Gates-Glidden burs, and can be nickel-titanium (NiTi), stainless steel (SS), or carbon steel. The prevalence of retained fractured endodontic hand instruments (mostly SS files) has been reported to range from 1 to 6%. The fracture incidence of rotary NiTi files, based on only a small number of very recent investigations, has been shown to lie in the range 0.4 to 5% (Pettiette 2002, Schafer 2004); the higher figure represented fractures only in molar teeth (Al-Fouzan 2003). In most circumstances fracture results from incorrect use or overuse of an endodontic instrument, and occurs most commonly in the apical third of a root canal. Although there is a perception that rotary NiTi instruments may fracture without warning, recent work indicates that fracture involves many factors the most important of which seems to be the clinician's skill (Parashos 2004).
Evaluation of fractured-instrument cases versus matched controls Spili (2005) revealed that the overall success rate of endodontic treatment and retreatment when a fractured instrument was left within a root canal (91.8%) was not significantly different from that of the controls (94.5%). When the data were analyzed according to the absence or presence of a preoperative periapical lesion, again no statistically significant effect of a fractured instrument was found. Healing in both groups was lower in teeth with a preoperative periapical radioluceny 86,7% versus 92,9%. Overall, success rates were very high, but within the range of previously reported studies for overall success and failure of endodontic treatment (Friedmann 1998).
The overall frequency of fractured endodontic instruments left in the root canal after treatment was found to be 3.3% of treated teeth and comprised 78.1% rotary NiTi files, 15.9% SS hand files, 4.0% paste fillers, and 2.0% lateral spreaders. The frequency of rotary NiTi instrument breakage was comparable to that previously reported for hand files.
In the hands of experienced operators, endodontic instrument fracture, in particular rotary NiTi, had no adverse influence on the outcome of nonsurgical root canal treatment and retreatment when the instrument remained in the root canal. The presence of preoperative periapical radiolucency, rather than the fractured instrument per se, was a more clinically significant prognostic indicator.

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Case number 13

Retreatment of endodontically treated mandibular right first molar with exacerbation

Patient

A 63-year-old white Norwegian male (Fig.1) was referred to the Department of Endodontics, University of Oslo, by his general practioner October 26, 2004 for treatment of mandibular right first molar.

Fig.1 Frontal view

Medical history

Non-contributory.

Dental History & Chief Complaint

Patient consulted his general practioner in September 2004 because of pain in his right lower jaw. The GP had done endodontic treatment of tooth 46 5 years earlier. The GP referred the patient for further treatment to the Department of Endodontics.
It had been swelling and pain when he consulted his GP. He got an antibiotic treatment. The swelling and pain had disappeared after some days, and today it was just not comfortable chewing on his right side.

Clinical Examination

Preoperative photograph showed the region from mandibular right second molar to canine (Fig.2).

No pathology was found extra-orally.

A normal oral mucosa was observed.

Fig.2 Buccal view

Mandibular right second molar: A MO composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Mandibular right first molar: A MOD composite restoration was seen and the tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to percussion and palpation.
Mandibular right second premolar: An OD composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from maxillary right second molar to second premolar (Fig. 3).

Mandibular right second molar: A MO radiopaque restoration was seen and lamina dura could be followed around the entire root.
Mandibular right first molar: A radiopaque restoration was seen in the crown and lamina dura could be followed around the entire mesial root. Around the distal root it could be seen a radiolucent area of approximately 10 mm in diameter. A radiopaque root filling material can be observed in all roots. In the coronal part of distal root the radiopaque material was missing.
Mandibular right second premolar: An OD radiopaque restoration was seen and lamina dura could be followed around the entire root.

The height of the marginal bone was within normal limits

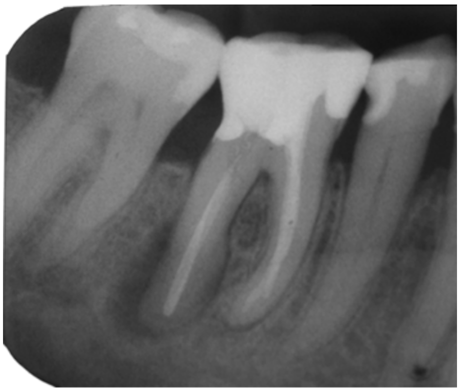

Fig.3 Huge build up of the crown, radiolucent
area coronal in distal root

Diagnosis

Chronic apical periodontitis mandibular right first molar

Treatment Plan

Retreatment of an endodontically treated mandibular right first molar
Root canal disinfection and filling

Treatment

October 26, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The access cavity was prepared. Four canals were found filled with gutta-percha.
Gutta-percha was removed with the help of ProTaper F3 and F2.
Irrigation was done with 1% sodium hypochlorite and 17% EDTA. A nr 15 K-Flex was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig.6).
Working length was 23 mm with the buccal cusp as a reference point in both DL and DB canal.The last instrument was NiTi nr 60 in both canals.

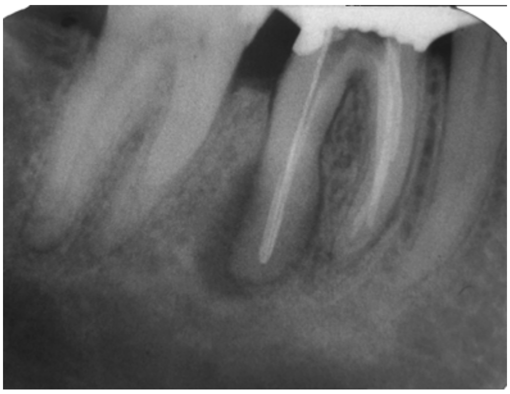

Fig.4 Working length distal canal

Working length was 21 mm with the buccal cusp as a reference point in both ML and MB canal. The last instrument was NiTi nr 45 in both canals.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and the canals were dressed for 5 min. with 2% chlorhexidine digluconate. The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

October 17, 2004

The patient returned to the clinic three weeks later with no symptoms from the tooth. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi nr 60 in the distal canals and NiTi nr 45 in the mesial canals, and irrigation was done with 1% sodium hypochlorite, 17% EDTA and the canals were dressed for 5 min. with 2% chlorhexidine digluconate.
Master gutta-percha cones were tried in, and a master cone radiograph was taken (Fig.5).
The root canals were dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. Access cavity was filled with IRM (Fig.6).

Fig.5 Master cone

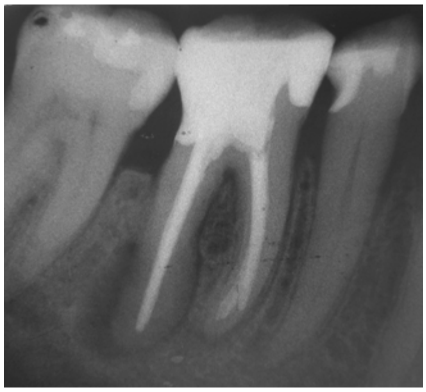

Fig.6 Final radiograph

August 31, 2005

The patient returned to the clinic 10 months later with pain from the tooth. 5 weeks earlier he had an emergency dental treatment because of severe swelling and pain. The GP had started to remove the root filling and given the patient antibiotic. 5 weeks later the swelling had disappeared but the tooth was still sore. The GP had removed most of the restoration and started to remove gutta-percha from all the canals. IRM was used as a temporary filling. The radiolucent area around the distal root seemed to have enlarged compared with 10 months earlier (Fig.7).
Differential diagnosis was vertical root-fracture. It was decided to try to retreat one more time.

Fig.7 GP had started retreatment, radiolucent area enlarged

September 4, 2005

The patient returned one week later. The tooth was still sore. A composite restoration was done before treatment was started. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. It was observed a perforation in the floor of the pulp chamber close to the DB canal towards the furcation area. This had probably been made by the GP under the retreatment. Gutta-percha was removed with the help of ProTaper F3 and F2. Irrigation was done with 1% sodium hypochlorite and 17% EDTA.
Working length was 23 mm with the buccal cusp as a reference point in both DL and DB canal. The last instrument was NiTi nr 60 in both canals.
Working length was 21 mm with the buccal cusp as a reference point in both ML and MB canal. The last instrument was NiTi nr 45 in both canals.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and the canals were dressed for 5 min. with 2% chlorhexidine digluconate. The root canals were dried with sterile paper points, and filled with MTA. MTA was condensed with the help of LM Endo-Plugger, and sterile paper points. MTA was also filled in the perforation. A radiographic control of the filling of MTA was done
A wet cotton pellet was applied in part of the pulp chamber to facilitate solidification of MTA. Access cavity was sealed with IRM (Fig8)

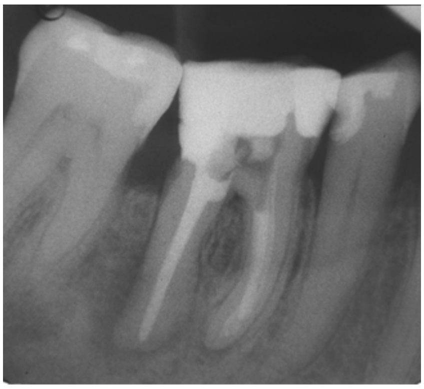

Fig.8 MTA with wet cotton pellet and IRM
Note perforation repair in floor of pulp-chamber

October 04, 2005

The patient returned to the clinic 4 weeks later. The tooth was asymptomatic. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. IRM and the wet cottonpellet were removed. A composite restoration was done all the way down to the MTA to tray to strengthen the tooth (Fig.9)

Evaluation

The apical lesion on the distal root was pear shaped and differential diagnosis was vertical root-fracture. No fracture line was visible. It was decided to fill all the canals with MTA because of the perforation and a very uncertain prognosis. Surgery would be easier if that was needed at a later stage. Adaptation between MTA and composite in the mesial canals were not satisfying (Fig.9)

Prognosis

Endodontic prognosis was considered uncertain

5 months follow-up

March 14, 2006

The patient returned for a 5 months follow-up to evaluate if surgery had to be done.
The tooth had been asymptomatic. Radiographic exam was done and it seemed that healing was in progress (Fig.10). A one year follow-up was scheduled.

Fig.9 Composite restoration occlusal

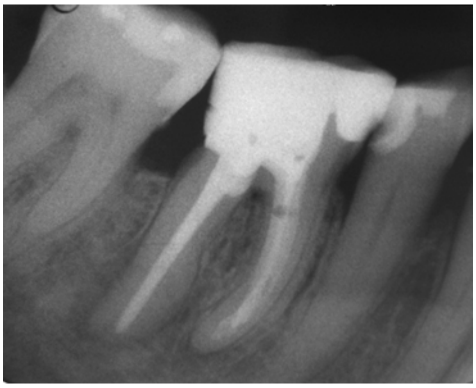

Fig.10 Five months follow-up

Discussion

The patient experienced flare-up and swelling several months after the endodontic retreatment of the tooth. A flare-up may be defined as the occurrence of severe pain and/or swelling following an endodontic treatment appointment, requiring an unscheduled visit and active treatment (Walton & Fouad 1992).
The interappointment flare-up can also be defined as follows: Within a few hours to a few days after a root canal treatment procedure a patient has either pain or swelling or a combination of both. The problem must be of sufficient severity that there is disruption of the patient's lifestyle such that the patient initiates contact with the dentist. Required then are both

an unscheduled visit and active treatment (incision for drainage, canal debridement, opening for drainage, etc.).

The study results by (Imura & Zuolo 1995) indicated that flare-ups were found to be positively correlated with multiple appointments, retreatment cases, periradicular pain prior to treatment, presence of radiolucent lesions, and patients taking analgesic or anti-inflammatory drugs. In contrast, there was no correlation between flare-up, and age, sex, different arch/tooth groups and the status of the pulp.
There were significantly more flare-ups in cases exhibiting apical lesions than those showing radiographically normal apical bone. Teeth which show apical bone loss must be assumed to have infected root canals (Moller et al. 1981); therefore, the higher incidence of severe acute reactions in these cases could be explained by the presence of bacteria or their byproducts which may have been forced into the periradicular region during instrumentation procedures. Trope (1991) reported similar findings where all the cases of flare-up were related to teeth showing apical periodontitis.
Another important diagnostic factor is the presence of pre-operative pain. There were significantly more flare-ups in teeth presenting with pain and/or swelling with periradicular origin. These findings are in agreement with other studies. Torabinejad et al. (1988) showed that patients with pain, or pain and swelling, before treatment were highly susceptible to flare-ups, whereas patients without pre-operative complaints were the least susceptible group. Walton & Fouad (1992) also reported an incidence of flare-ups in more than 19% of patients with pain prior to treatment.
Taking this information into account, the clinician should be aware of the possibility of flare-up when treating cases of infected canals exhibiting radiolucent areas, especially when pre-treatment symptoms are present.
This study also showed a statistically significantly higher incidence of flare-ups in patients taking analgesics and anti-inflammatory drugs. Walton & Fouad (1992) also reported these findings. They concluded it was not probably that the therapeutic agent was the cause of a flare-up. They felt it more reasonable to assume that patients with adverse symptoms are usually taking these drugs before the appointment.
Some authors (Mata et al. 1985; Morse et al. 1990) have advocated the use of antibiotics in the prevention of flare-ups, but well designed and controlled studies have concluded that prophylactic use of drugs such as penicillin (Walton & Chiappinelli 1993) and amoxicillin (Pickenpaugh et al. 1992) is unrelated to the incidence of post treatment symptoms.
Retreatment cases showed a significantly higher incidence of flare-ups than conventional. Trope (1991) had a 13.6% incidence of flare-ups in retreatment teeth with apical periodontitis. A factor that can contribute to this is the fact that retreatment cases are technically more difficult to treat and there is a tendency to push fragments of gutta-percha and other canal contents into the periapical tissues. The use of a solvent to soften the gutta-percha may contribute to the increased incidence of pain, since organic solvent, is toxic to living tissues (Wolfson & Seltzer 1975).

Inter-appointment flare-up is characterized by the development of pain, swelling or both, following endodontic intervention. The causative factors of flare-ups encompass mechanical, chemical and/or microbial injury to the pulp or periradicular tissues. Of these factors, microorganisms are arguably the major causative agents of flare-ups. Even though the host is usually unable to eliminate the root canal infection, mobilization and further concentration of defense components at the periradicular tissues impede spreading of infection, and a balance between microbial aggression and host defenses is commonly achieved. There are some situations during endodontic therapy in which such a balance may be disrupted in favor of microbial aggression, and an acute periradicular inflammation can ensue. Situations include apical extrusion of infected debris, change in the root canal microbiota and/or in environmental conditions caused by incomplete chemo-mechanical preparation, secondary intraradicular infections and perhaps the increase in the oxidation-reduction potential within the root canal favoring the overgrowth of the facultative bacteria. Based on these situations, preventive measures against infective flare-ups are proposed, including selection of instrumentation techniques that extrude lesser amounts of debris apically; completion of the chemo-mechanical procedures in a single visit; use of an antimicrobial intracanal medicament between appointments in the treatment of infected cases; not leaving teeth open for drainage and maintenance of the aseptic chain throughout endodontic treatment. Knowledge about the microbial causes of flare-ups and adoption of appropriate preventive measures can hopefully reduce the incidence.

The reasons for such exacerbations are not always clear, a number of hypotheses, some of which may be interrelated, will be offered and discussed. Among these are:

Alteration of the local adaptation syndrome

Chronic inflammation persists if the irritant is not removed, there is a local adaptation. However, when a new irritant is introduced to inflamed tissue, a violent reaction may occur (Selye 1953).

The inflammatory lesion may be adapted to the irritant, and chronic inflammation may exist without perceptible pain or swelling. However, when endodontic therapy is performed, new irritants in the form of medicaments, irrigating solutions, or chemically altered tissue proteins may be introduced into the granulomatous lesion. A violent reaction may follow, leading to liquefaction necrosis, indicative of an alteration of the local adaptation syndrome.

Microbial factors

The study by (Sundqvist 1976), showed that in all of the teeth with painful symptoms, Bacteroides melaninogenicus, an anaerobic, Gram-negative rod, was present in combination with other microorganisms.

Griffee et al. 1980 demonstrated a significant relationship between the presence of B. melaninogenicus and pain.

The presence of bacterial endotoxins in infected root canals and periapical lesions has been demonstrated by (Schein and Schilder 1975) and by (Schonfeld et al. 1982). More endotoxin was found in the periapical areas of painful teeth than in those of asymptomatic teeth.

A recent study revealed that F. nucleatum, Prevotella species and Porphyromonas species were frequently isolated from flare-up cases (Chavez et al. 2002).

Fusobacterium nucleatum appears to be associated with the development of the most severe forms of interappointment endodontic flare-ups (Villanueva 2002).

Two-visit endodontic treatment with intracanal medication was found to be effective in reducing postoperative pain of previously symptomatic teeth and decreased the number of flare-ups in all retreatment cases (Yoldas et al. 2004).

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Case number 14

Endodontic treatment of maxillary left canine with internal resorptions

Patient

A 23-year-old white Norwegian female was referred to the Department of Endodontics, by her GP December 07, 2004 (Fig. 1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patient had received orthodontic treatment approximately 10 years earlier because of dens ret. maxillary canines. Her GP had noticed a small shift in colour, and a decrease in reaction to the electric pulp test on maxillary left canine.
The patient had no complaint.

Clinical Examination

Preoperative photograph showed the region from maxillary left central incisor to maxillary left second premolar (Fig.2).

Fig.2 Buccal view, slightly discolouration 23

No pathology was found extra-orally.

A normal oral mucosa was observed.

Maxillary left central incisor: The tooth responded positively to the sensibility test with Endo Ice.
Maxillary left lateral incisor: The tooth responded positively to the sensibility test with Endo Ice.
Maxillary left canine: The tooth responded negatively to the sensibility test with Endo Ice. Slightly discolouration was seen compared to the canine on the right side.

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from maxillary left central incisor to maxillary left first premolar (Fig.3)

Maxillary left central incisor: Lamina dura could be followed around the entire root.
Maxillary left lateral incisor: Lamina dura could be followed around the entire root.
Maxillary left canine: Lamina dura could be followed around the entire root. An enlarged canal space was observed mid root.

A periapical radiograph was taken of the maxillary right canine to compare the two canines canal space (Fig.4).

Fig.3 Note the enlarged canal space mid root

Fig.4 Right maxillary canine

The height of the marginal bone was within normal limits.

Diagnosis

Necrotic maxillary left canine with internal resorption

Treatment Plan

Necrotic treatment of maxillary left canine
Root canal disinfection and filling

Treatment

December 7, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol.
The access preparation was done and the canal was localized.
Irrigation was done with 1% sodium hypochlorite and 17% EDTA. A nr 15 K Flex was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig.5). The root was necrotic.
Working length was 19.5 mm with the incisal edge as a reference point.
The last instrument was NiTi nr 60.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and the canal was dressed for 5 minutes with 2% chlorhexidine digluconate.
Ultrasound with a nr. 25 K-Flex was used together with sodium hypoclorite to get a better cleaning of the irregular canal.
The root canal was dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canal with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

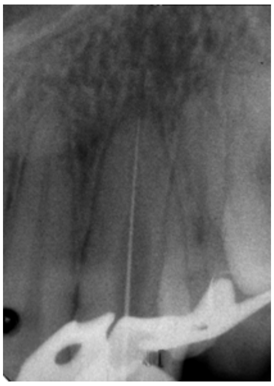

Fig.5 Working length

February 15, 2005

The patient returned nine weeks later. The tooth was asymptomatic. Rubber dam was applied, and the area was disinfected with a chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi instrument nr 60, and irrigation with 1% sodium hypochlorite and 17% EDTA and the canal was dressed for 5 minutes with 2% chlorhexidine digluconate. Master gutta-percha cone was tried in, and a master cone radiograph was taken (Fig.6).
The root canal was dried with sterile paper points Application of AH Plus with a Lentulo spiral. The master cone was cut 3 mm long and applied with a LM Endo Plugger. Back fill with gutta-percha from an Obtura II gun. The access cavity was filled with IRM. A final radiograph was taken after removal of the rubber dam (Fig.7, 8).
The patient was referred back to her GP.

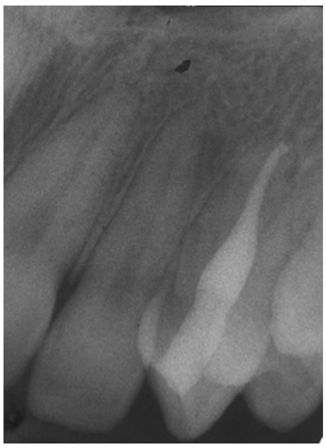

Fig.6 Master cone

Fig.7 Final radiograph

Fig.8 Disto-eccentric view

Evaluation

I was uncertain if it was an internal resorption or just the tooth angel giving the enlarged canal apperance. Not much difference was seen comparing the two canines. A slightly difference in colour, and the GP`s results of the sensitivity tests over a long period of time was important in decision making. No anesthesia was given so sensibility could be controlled during access preparation.
To improve obturation of the irregular canal it was used a warm gutta-percha technique.

Prognosis

Endodontic prognosis was considered good

One year follow –up

April 15, 2006

The patient returned to the clinic for a one year follow-up.The tooth was asymptomatic.
Her GP had placed a composite restoration palatally.
Both clinical and radiographic exams were satisfactory (fig.9, 10).

Fig.9 One year follow-up palatal view

Fig.10 One year follow-up

Discussion

Root resorption is a dental complication that can lead to tooth extraction. The etiology of root resorption requires two phases: injury and stimulation (Tronstad 1988, Trope 1988). Injury is related to non-mineralized tissues covering the external surface of the root, the precementum, or internal surface of the root canal, the predentin. The injury is similar to several types of root resorption and may be mechanical following dental trauma, surgical procedures, and excessive pressure of an impacted tooth or tumor. It may also occur, following chemical irritation, during bleaching procedures using hydrogen peroxide 30% or other irritating agents (Friedman 1988). Denuded mineralized tissue is colonized by multinucleated cells, which initiate the resorption process. However, without further stimulation of the resorption cells, the process will end spontaneously. Repair with cementum-like tissue will occur within 2–3 weeks if the damaged surface does not cover a large surface area. If the damaged root surface is large, bone cells will be able to attach to the root before the cementum-producing cells; ankylosis is the result of this process. Continuation of the active resorption process is dependent on a common stimulation factor of the osteoclastic cells, either infection or pressure. Its origin is different for each type of root resorption. Therefore, the various types of root resorption should be identified according to the stimulation factors (Fuss 2003). When these stimulating factors are identified, it will be possible to reverse the process by removing the etiological factor.

Pulpal infection root resorption - internal root resorption

- external root resorption

Periodontal infection root resorption - invasive cervical resorptions

Orthodontic pressure root resorptions

Impacted tooth or tumor pressure root resorptions

Ankylotic root resorption

Invasive cervical resorption is an insidious and often aggressively destructive form of external root resorption that is characterized by invasion of the cervical region of the root by fibrovascular tissue derived from the periodontal ligament. This pathologic process progressively resorbs cementum, enamel, and dentin, to eventually involve the pulp space late in the process. The pulp is not at least initially involved (Heithersay 1999)
A clinical classification had been developed by Heithersay both for research purposes and also to provide a clinical guide in the assessment of cases of invasive cervical resorption.
.
Class 1 – Denotes a small invasive resorptive lesion near the cervical area with shallow penetration into dentine.
Class 2 – Denotes a well-defined invasive resorptive lesion that has penetrated close to the coronal pulp chamber but shows little or no extension into the radicular dentin.
Class 3 – Denotes a deeper invasion of dentine by resorbing tissue, not only involving the coronal dentine but also extending into the coronal third of the root.
Class 4 – Denotes a large invasive resorptive process that has extended beyond the coronal third of the root.

Three types of external root resorptions have been recognized: surface, inflammatory, and replacement resorption.
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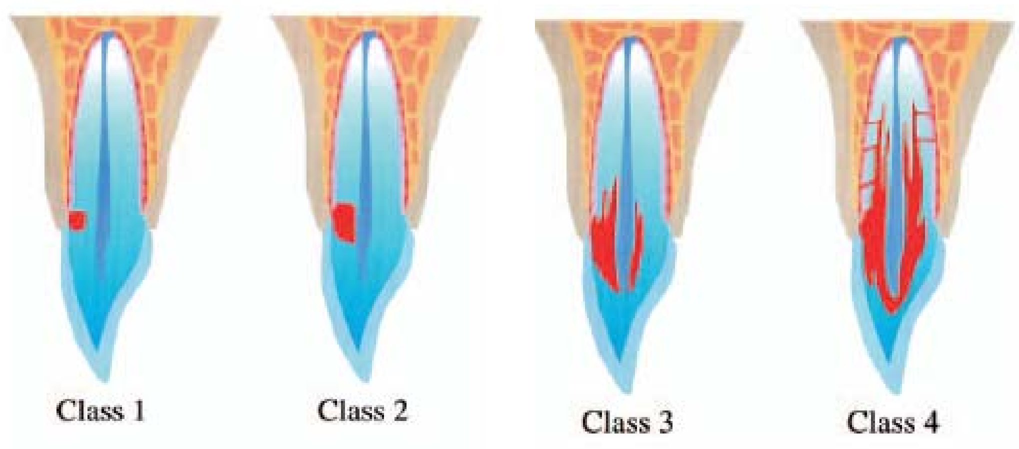

Fig.16 Clinical classification of invasive cervical resorption

Inflammatory resorption is another type of extern root resorption. The pulp is necrotic and infected bacterial by-products escape by way of the dentinal tubules and become the stimulus for ongoing phagocytosis, causing inflammation and further root and bone resorption. If the process is not stopped, the resorptive process may destroy the root and adjacent alveolar bone. The resorption is arrested by early endodontic treatment (Cvek 1973, Trope et al. 1995). The lesion of extern inflammatory root resorption has usually not well-defined margins. The lesion may be superimposed over the canal and the canal can be followed unaltered through the defect area. The lesions position will shift on different radiographic angulations (Gartner et al. 1976).

Replacement resorption can be seen after luxation injuries with loss of viability of PDL cells or in cases of tooth avulsion in which extensive damage to the ligament occurs because of drying or inappropriate storage, healing occurs without an intervening periodontal attachment. Depending on the extent of injury, cell lysis will occur on the root surface where the PDL has become necrotic. Mild tissue damage (less than 20% of root surface involved): gives Transient Resorption and may repair itself with cells from adjacent healthy PDL. More severe damage (long extra oral time lead to dessication and death of root surface cells or more than 20% of root surface involved): gives Progressive Resorption. Cells of the alveolar bone replace the periodontal attachment and continue to resorb the root, gradually replacing it with alveolar bone (Gunraj 1999).

Internal root resorption occurs rarely in the permanent teeth (Trope 1998). Internally, from pulpal side, dentin is lined by the odontoblasts and predentin. The odontoblasts have no resorbing ability and in combination with the unmineralized predentin, apear to form a barrier against dentin resorption. Progressive internal root resorption continues where dentin is exposed after loss of odontoblasts and predentin (Tronstad 1988, Wedenberg & Lindskog 1985). Internal root resorption requires that vital pulp tissue must be connected to necrotic pulp tissue. Tronstad states that resorptive activity is sustained by infection of the necrotic pulp tissue in the root canal coronal to the area where resorption takes place.

The sensitivity testing are often negative, since the coronal pulp is infected while the apical pulp-which includes the resorptive defect-remains vital (Trope 1998). The resorption of exposed dentin may continue until the necrotic process overtakes the vital tissue in the remainder of the pulp space, thus depriving the tissue of needed blood supply, at which time the internal resorptive process ceases (Bakland 1992). Barclay suggested a number of etiological factors for internal root resorption (Barklay 1993):

- Chronic pulp inflammation
- Trauma

- Pulpotomy
- Restorative procedures
- Hereditary
- Cracked tooth syndrome
- Invaginated cingulum
- Orthodontic tooth movement
- Herpes Zoster

Radiographically, internal root resorption tends to have a more sharply outlined appearance than does external root resorption. The outline of the root canal is lost in the lesion. Radiographs taken at various angles tend to show the internal root resorption lesion in a central location. In contrast, external root resorption lesions tend to move with the various angles, at which radiographs are exposed (Bakland 1992).
Standard treatments of internal root resorption include pulpectomy which removes the blood supply to the granulomatous tissue and the rest of the treatment is concentrated on removing tissue from the irregular resorptive defect and obturating the space (Trope 1998).
Ultrasonic root canal preparation combinated with irrigation has an important roll to expose and clean the granulation tissue in the lesion. The antibacterial effect of ultrasonic instrumentation in the treatment of infected root canals was clinically evaluated by Sjogren & Sundqvist 1987. Sodium hypochlorite solution (0.5%) was used as an irrigant. The ultrasonic technique eliminated the bacteria from the canals more efficiently than hand instrumentation alone. Even though ultrasonication definitely improves the procedure of root canal disinfection, the use of an antibacterial dressing between appointments is necessary to achieve as complete a reduction in bacterial levels as possible (Sjogren & Sundqvist 1987).

When resorption has progressed to involve an external communication with the PDL space, this complication is often so serious that the tooth cannot be maintained. In some situations, complex surgical procedures may be used to gain access for repair (Gunraj 1999).
Three-dimensional obturation of the root-canal system to the canal apex is fundamental for successful endodontic therapy (Schilder 1974). Inadequate apical seal is a major cause of failure in non-surgical endodontic treatment (Harty et al. 1970).
In vertical condensation methods using warm gutta-percha, there is an increased risk of overextension in apical and eventual perforation areas on the root (Yared et al. 1994a, Yared et al 1994b).
Root canal filling materials are intended to prevent microorganisms and toxins in the canal from passing along the root canal space and into the periradicular tissues (Nguyen 1994). Difficulty obliterating accessory canals, fins, anastomoses, apical deltas, and other irregularities of the root canal space and failure to adequately seal the apical foramen have, been reported to account for a large percentage of root canal failures (Dow & Ingle 1955). When a perforation of the apical third of the canal space occurs, the ability to obtain an adequate seal is further compromised by the irregular shape and increased size of the area to be sealed.
MTA powder consists of fine hydrophilic particles that set in the presence of moisture. Hydration of the powder results in a colloidal gel that solidifies to a hard structure in less than 4h (Torabinejad et al. 1993).
Mineral trioxide aggregate (MTA) has been shown to be very effective in sealing the pathways of communication between the root canal system and the external surface of the tooth (Torabinejad et al. 1995).
Mineral trioxide aggregate (MTA) is biocompatible (Koh et al. 1998, Holland et al. 1999), bacteriostatic (Torabinejad et al. 1995a), and has a good sealing ability (Torabinejad et al

1995b). Mineral trioxide aggregate (MTA) has cement-conductive properties (Thomson et al. 2003) and there is neoformation of bone and periodontal ligaments in direct contact with it (Torabinejad et al. 1997). Cement forms around any minimum extrusion of MTA beyond the apex (Koh et al. 1998, Holland et al. 1999, Torabinejad et al. 1995a & b, Thomson et al 2003, Torabinejad et al. 1997, Shabahang et al. 1999).

Orthograde positioning of MTA in the root canal and in the apical third provides an adequate apical seal in cases of apices that are located at the side, resorbed, or irregular in shape. In these cases, the outcome of gutta-percha seal may be uncertain because of the apex architecture and the presence of humidity, whereas MTA might provide predictable results (Leiss de Leimburg et al. 2004).

When using gray MTA, one is instructed to limit the material to the confines of the canal and/or pulp chamber area, not above the crestal bone level, because the material by nature of its component parts may lead to discoloration (Dentsply, Tulsa Dental 1998).

Both gray and off-white MTA are marketed as ProRoot MTA. The principal components of the gray-colored formula are tricalcium silicate, bismuth oxide, dicalcium silicate, tricalcium aluminate, tetracalcium aluminoferite, and calcium sulfate dehydrate. Notably, the off-white-colored formula lacks the tetracalcium aluminoferrite. The lack of this iron-containing compound may account for its off-white appearance. Both formulae are 75% Portland cement, 20% bismuth oxide, and 5% gypsum by weight (Dentsply, Tulsa Dental 1998).

Study by Ferris and Baumgartner (2004) used an anaerobic bacterial leakage model testing teeth with furcation perforations repaired with the two types of MTA. The results showed that there was no significant difference between the gray type of MTA and the off-white type of MTA in allowing the passage of *F. nucleatum*.

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Case number 15

Endodontic treatment of three mandibular teeth with external root resorption

Patient

A 39-year-old white Norwegian male (Fig.1) was referred to the Department of Endodontics, University of Oslo, by his GP December 15, 2004 for treatment of mandibular right first premolar.

Fig.1 Side/frontal view

Medical history

Non-contributory.

Dental History & Chief Complaint

Patient consulted his general practioner in November 2004 because of pain in his right lower jaw. During the root canal therapy the GP failed to negotiate the canal, and separated two instruments.
The tooth was left open and the patient was given antibiotic therapy Apocillin 660 mg 1+1+2 for 7 days, and referred to the Department of Endodontics, UIO.
10 years ago he was involved in a car accident. He got a fracture of the mandible and the mandibular right second premolar had to be extracted. Some teeth were mobile after the accident, and he was under orthodontic treatment for almost 2 years after the accident.
He had no experience of pain before 2 weeks earlier when he consulted his GP.
He was still in pain from the tooth.

Clinical Examination

Preoperative photo showed the region from mandibular right first molar to mandibular left central incisor (Fig.2).

No pathology was found extra-orally.

A normal oral mucosa was observed.

Mandibular right first molar: A MO composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Mandibular right first premolar: An open access cavity was seen and the tooth responded negatively to the sensibility test with Endo Ice. The tooth was tender to palpation and percussion, and discolouration was seen.

Fig. 2 The region from mandibular right first molar to mandibular left central incisor.

Mandibular right cuspid: The tooth responded negatively to the sensibility test with Endo Ice.
Mandibular right lateral incisor: The tooth responded negatively to the sensibility test with Endo Ice.
Mandibular right central incisor: The tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower left and right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from mandibular right first molar to mandibular right lateral incisor (Fig.3).

Mandibular right first molar: A MO radiopaque restoration was seen and lamina dura could be followed around the roots. Two radiopaque elements located over the apices of the mesial roots were seen.
Mandibular right first premolar: A radiolucent area in the access cavity was visible. Two small fragments of files were located in the middle of the root. A radiolucent area apical of the separeted files was seen. Lamina dura could be followed on the mesial side of the root. Apical it widened to a radiolucent area of 4 mm in diameter. On the distal side of the root it was observed a widening of the lamina dura to a radiolucent area of 1 mm in diameter lateral to the radiolucent area on the root.
Mandibular right canine: Lamina dura could be followed around the entire root. In the middle of the root it was observed a radiolucent area.
Mandibular right lateral incisor: Lamina dura could be followed around the entire root. In the apical 1/3 of the root it was observed a radiolucent area.

Fig.3 Periapical radiograph showed right mandibular first premolar with separated instruments, and radiolucent areas both in the root and in the bone.

The radiographic angulations technique was performed to evaluate the localization of the resorptions. Because of the accident and resorptions a full mouth radiographic examination was done.

The height of the marginal bone was within normal limits, except distaly on mandibular right first premolar.

Diagnosis

Acute apical periodontitis mandibular right first premolar with external root resorption
Necrotic mandibular right canine with external root resorption
Necrotic mandibular lateral incisor with external root resorption

Treatment Plan

Necrotic treatment of mandibular right first premolar
Necrotic treatment of mandibular right canine
Necrotic treatment of mandibular right lateral incisor
Canal disinfection and root-filling

Treatment

December 15, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. Access cavity was irrigated with 1% sodium hypochlorite. The cavity was dried with sterile paper points. The fractured instruments were localized and were removed with the help of an ultrasonic device (fig.4) and nr 25 K-flex ultrasonic instrument (Fig.5) and microscope. Irrigation was done with 1% sodium hypochlorite and 17% EDTA. Working length was achieved with an nr 10 K-flex using balanced force technique. Control of working length with an apex locator (Root ZX) (Fig.6), and verified by a working length radiograph (Fig. 7).
The working length was 20.5 mm with the B cusp as a reference point. The last instrument was NiTi nr 55.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and the canal was dressed for 5 minutes with 2% chlorhexidine digluconate.
The root canal was dried with sterile paper points. There was blood on the paper point in the area were the resorption was located. Calcium hydroxide intracanal dressing was packed into the canal with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

Fig.4 Ultrasonic device: Satelec P5

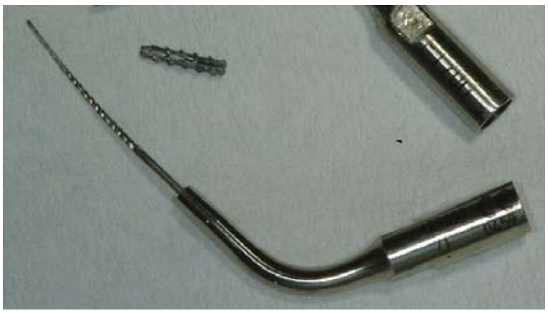

Fig.5 Ultrasonic instrument #25 K-flex

Fig.6 Apex locator Root ZX

Fig.7 Working length

January 25, 2005

The patient returned to the clinic five weeks later. The tooth was asymptomatic. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi nr 55, and irrigation with 1% sodium hypochlorite, 17% EDTA and the canal was dressed for 5 minutes with 2% chlorhexidine digluconate.
The root canal was dried with sterile paper points, and filled with grey MTA.
MTA was condensed with the help of LM Endo- Plugger, and sterile paper points. A radiographic control of the filling of MTA was done
(Fig.8). A wet cotton pellet was applied in the pulp chamber to facilitate solidification of MTA. The access cavity was sealed with IRM (Fig.9).

Fig.8 Control of MTA packing

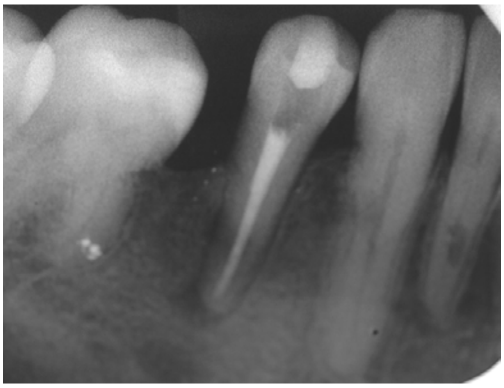

Fig.9 MTA with wet cotton pellet and IRM

February 2, 2005

Treatment of mandibular right canine and lateral incisor was started, and the treatment protocol was the same as for the mandibular right first premolar (Fig.10).

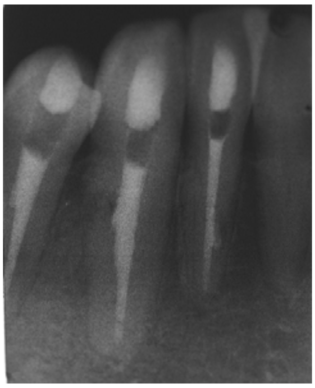

Fig.10 Canine and lateral incisor filled with MTA and wet cotton pellet/IRM

March 15, 2005

The patient returned to the clinic two months after the mandibular right first premolar was filled with MTA. All the teeth were asymptomatic. Rubber dam was applied on mandibular right first premolar, canine and lateral incisor, and the area was disinfected with chlorhexidine-ethanol solution. The IRM temporary fillings and the cotton pellets were removed. The cavities were etched with 35% phosphoric acid, rinsed with water, and application of bonding material. The bonding was light cured.
Hybrid composite material was applied with the help of the microscope to prevent a gap between MTA and the composite filling.
Radiograph showed good adaptation between MTA and composite on mandibular right first premolar, and apical healing in progress (Fig11).
Radiograph showed a gap between MTA and composite on canine and good adaptation on lateral incisor (Fig.12).

Fig.11 Final radiograph

Fig.12 Final radiograph

Evaluation

MTA was chosen as root-filling material to prevent extrusion of material in the resorptions areas and in case of surgery. Healing was already in progress on mandibular right first premolar. The fill in the resorptions areas in both canine and lateral incisor was not satisfying. The gap between composite and MTA in the canine was a disappointment.

Prognosis

Endodontic prognosis is considered favourable mandibular right first premolar
Endodontic prognosis is considered uncertain for canine and lateral incisor

One year follow-up

January 31, 2006

The patient returned to the clinic one year after treatment was completed. The teeth have remained asymptomatic.
The control radiograph showed successful outcome on the mandibular right first premolar. (Fig.13). There was uncertainness about the prognosis for the canine and lateral incisor (Fig.14). It might bee that the resorptions have expanded. The patient was scheduled for a follow-up in 6 months to further evaluate the outcome of the treatment.

Fig.13 Healing of mandibular right first premolar.

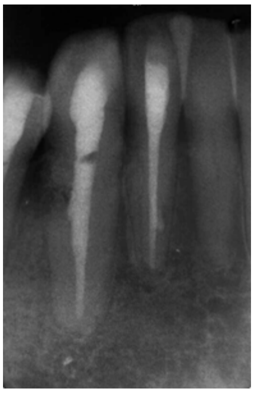

Fig.14 Healing more uncertain of canine and lateral incisor

Discussion

Root resorption is a dental complication that can lead to tooth extraction. The etiology of root resorption requires two phases: injury and stimulation (Tronstad 1988, Trope 1988). Injury is related to non-mineralized tissues covering the external surface of the root, the precementum, or internal surface of the root canal, the predentin. The injury is similar to several types of root resorption and may be mechanical following dental trauma, surgical procedures, and excessive pressure of an impacted tooth or tumor. It may also occur, following chemical irritation, during bleaching procedures using hydrogen peroxide 30% or other irritating agents (Friedman 1988). Denuded mineralized tissue is colonized by multinucleated cells, which initiate the resorption process. However, without further stimulation of the resorption cells, the process will end spontaneously. Repair with cementum-like tissue will occur within 2–3 weeks if the damaged surface does not cover a large surface area. If the damaged root surface is large, bone cells will be able to attach to the root before the cementum-producing cells; ankylosis is the result of this process. Continuation of the active resorption process is dependent on a common stimulation factor of the osteoclastic cells, either infection or pressure. Its origin is different for each type of root resorption. Therefore, the various types of root resorption should be identified according to the stimulation factors (Fuss 2003). When these stimulating factors are identified, it will be possible to reverse the process by removing the etiological factor.

Pulpal infection root resorption - internal root resorption

- external root resorption

Periodontal infection root resorption - invasive cervical resorptions

Orthodontic pressure root resorptions

Impacted tooth or tumor pressure root resorptions

Ankylotic root resorption

Invasive cervical resorption is an insidious and often aggressively destructive form of external root resorption that is characterized by invasion of the cervical region of the root by fibrovascular tissue derived from the periodontal ligament. This pathologic process progressively resorbs cementum, enamel, and dentin, to eventually involve the pulp space late in the process. The pulp is not at least initially involved (Heithersay 1999)
A clinical classification had been developed by Heithersay both for research purposes and also to provide a clinical guide in the assessment of cases of invasive cervical resorption (Fig.15).
.
Class 1 – Denotes a small invasive resorptive lesion near the cervical area with shallow penetration into dentine.
Class 2 – Denotes a well-defined invasive resorptive lesion that has penetrated close to the coronal pulp chamber but shows little or no extension into the radicular dentin.
Class 3 – Denotes a deeper invasion of dentine by resorbing tissue, not only involving the coronal dentine but also extending into the coronal third of the root.
Class 4 – Denotes a large invasive resorptive process that has extended beyond the coronal third of the root.

Three types of external root resorptions have been recognized: surface, inflammatory, and replacement resorption.
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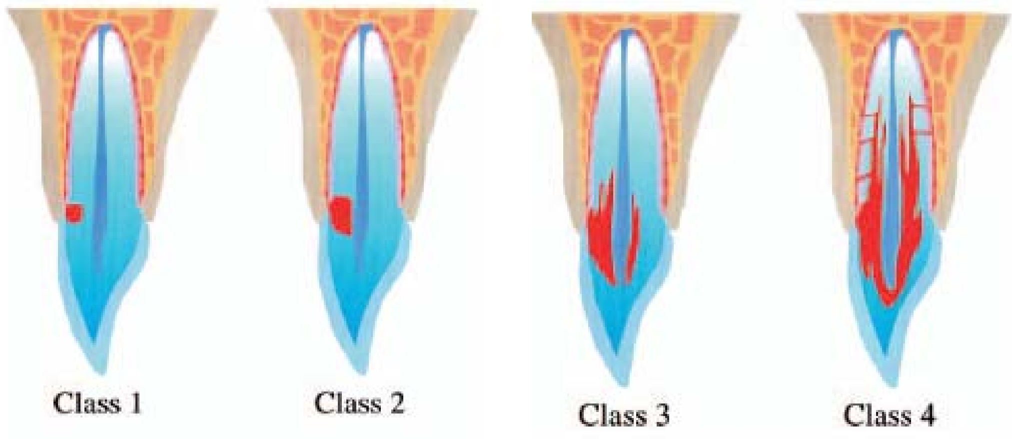

Fig.15 Clinical classification of invasive cervical resorption

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- Hereditary
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Radiographically, internal root resorption tends to have a more sharply outlined appearance than does external root resorption. The outline of the root canal is lost in the lesion. Radiographs taken at various angles tend to show the internal root resorption lesion in a central location. In contrast, external root resorption lesions tend to move with the various angles, at which radiographs are exposed (Bakland 1992).
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Case number 16

Endodontic retreatment of maxillary right first molar with invasive cervical resorption

Patient

A 22-year-old white Norwegian female was referred to the Department of Endodontics, University of Oslo by her GP August 25, 2004 for treatment of maxillary right first molar (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The maxillary right first molar was endodontic treated Mai 2002 by her GP because of acute apical periodontitis. She had pain again in December 2003, and visited her GP again. Her GP diagnosed resorption on the mesial root. The GP removed explorative the mesial composite restoration. An IRM temporary filling was placed and he referred her to the Department of Endodontics. The patient had intermediate pain from the tooth and especially after the temporary filling had broken.

Clinical Examination

No pathology was found extra-orally

A normal oral mucosa was observed.

Maxillary right second molar: A MO composite restoration was seen and the tooth responded positively to the sensitivity test with electric pulp test and Endo Ice.

Maxillary right first molar: An OD composite restoration was seen and IRM was placed as a temporary filling in the access preparation. The IRM was broken and lost in the mesial part. The tooth was tender to percussion and responded negatively to the sensibility test with the electric pulp test, and Endo Ice.
Maxillary left second premolar: The tooth responded positively to the semnsibility test with the electric pulp test and Endo Ice.

Two preoperative photographs showed the region from maxillary right second molar to canine (Fig.2, 3).

Fig.2 Buccal view

Fig.3 Occlusal view

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The preoperative radiograph showed the region from maxillary right second molar to canine (Fig.4).

Maxillary right second molar: A MO radiopaque restoration was seen and lamina dura could be followed around the entire roots without disruption.
Maxillary right first molar: An OD radiopaque restoration was seen and lamina dura could be followed around the entire roots. A radiopaque root filling material could be seen in MB, DB and P root. In the MB root the radiopaque material was 3 mm short of apex. In the MB root it was seen a radiolucent area in the cervical part. This was clearly seen in the BW (Fig.5)
Maxillary right second premolar: Lamina dura could be followed around the entire root without disruption.

The marginal bone level was within normal limits except mesialy tooth 16.

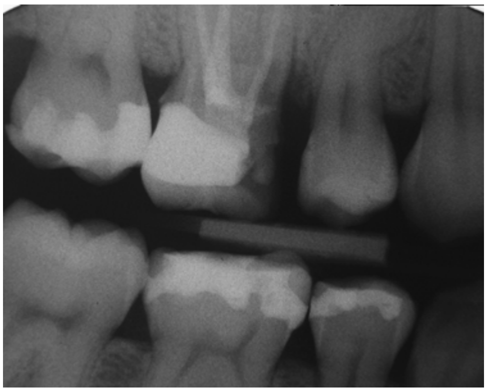


Fig.4 Note breakdown of marginal bone mesial maxillary first molar

Fig.5 Note breakdown of marginal bone and radiolucent area cervical mesial root

Diagnosis

Invasive cervical resorption maxillary right first molar

Treatment plan

Retreatment of an endodontically treated maxillary right first molar
Restore cervical resorption

Treatment

August 25, 2004

The access cavity was prepared and three canals were localized (Fig.6). Mesial resorption was localized and it was done a gingivectomi with Odontosurge. Granulation tissue was removed with curettes. Bleeding was stopped with ferric sulphate. The resorption was filled with grey MTA (Fig.7, 8, 9). A wet cotton pellet was placed in the pulp chamber and IRM was placed as a temporary filling (Fig.10).

Fig. 6 Localization of three canals

Fig.7 Granulation tissue

Fig.8 Granulation tissue removed and bleeding stopped

Fig.9 MTA in resorption

Fig.10 Cervical resorption filled with MTA

September 21, 2004

The patient returned to the clinic 4 weeks later. A MOP composite restoration was placed (Fig.11).

Fig.11 Different views of composite restoration

Rubber dam was applied, and the area disinfected with chlorhexidine-ethanol solution. The working length was reached by using K-flex nr 20. A working length radiograph was taken with a K-Flex nr 20 in the distal canal, NiTi nr 25 in the mesial canal, and NiTi nr 30 in the

palatale canal (Fig.11). The lengths were controlled with an apex locator (Root ZX, J. Morita, Japan).
The root canals were instrumented up to NiTi nr 45 in the MB canal and a length of 16 mm with B cusp as a reference point. The DB canal was instrumented up to NiTi nr 50 and a length of 17.5 mm with the B cusp as a reference point. P canal was instrumented up to NiTi nr 60 and a length of 21 mm with the B cusp as a reference point. Irrigation was done with 1% sodium hypochlorite and 17% EDTA. A MB 2 canal was not localized.
The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

October 12, 2004

The patient returned to the clinic 3 weeks later. The tooth was asymptomatic.
Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. IRM and Cavit G were removed, and calcium hydroxide was removed with irrigation with 1% sodium hypochlorite and 17% EDTA. The root canals were dried with sterile paper points. Master gutta-percha cones were tried in and a master cone radiograph was taken (Fig.12). The root canals were dried with sterile paper points, and filled with AH Plus and master gutta-percha cones with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the orifices and sealed with IRM plugs. The access cavity was sealed with IRM. A final radiograph was taken after removal of the rubber dam (Fig.13).

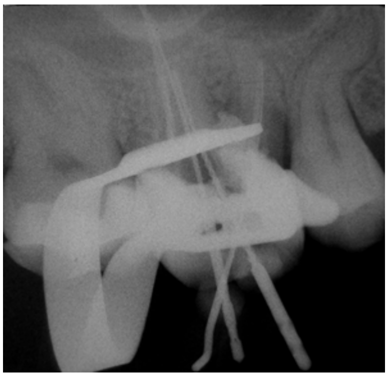
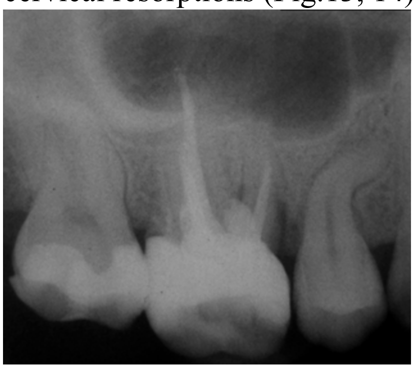


Fig.12 Master cone

Fig.13 Final radiograph

January 12, 2005

The patient returned 3 months later. The tooth was asymptomatic. A composite restoration was placed in the access preparation. Radiology revealed some radiolucency around the cervical resorptions (Fig.13, 14).



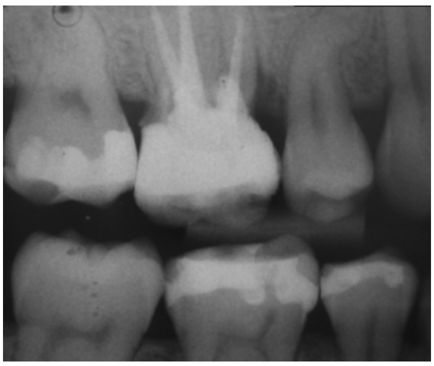


Fig.13 Three month follow-up **Fig.14** Three month follow-up

Evaluation

This cervical resorption was very inaccessible. Surgery would not help a lot to get better access. Alternative treatment plans was radisectomi of mesial root or extraction.
A step formation was made in the MB root, and I was not able to bypass. An MB 2 root was not localized. Maybe it would be better to do the radisectomi or extraction when the prognosis to achieve a favourable result was minor. It was the patient aged that was the most important factor to try to rescue this tooth hopefully for some years to postpone a more final treatment.

Prognosis

The endodontic and tooth prognosis was considered to be uncertain.

One year follow-up

09.02.06

The patient returned to the clinic for a one year follow-up. Periodically the patient felt some irritation from the area around the tooth.
Clinical a pocket depth of 6 mm mesial on maxillary right first molar was found with bleeding on probing. Radiology revealed possible continuing resorptions (Fig.15).
A new follow-up in six months was scheduled.

Fig.15 One year follow-up

Discussion

Root resorption is a dental complication that can lead to tooth extraction. The etiology of root resorption requires two phases: injury and stimulation (Tronstad 1988, Trope 1988). Injury is related to non-mineralized tissues covering the external surface of the root, the precementum, or internal surface of the root canal, the predentin. The injury is similar to several types of root resorption and may be mechanical following dental trauma, surgical procedures, and excessive pressure of an impacted tooth or tumor. It may also occur, following chemical irritation, during bleaching procedures using hydrogen peroxide 30% or other irritating agents (Friedman 1988). Denuded mineralized tissue is colonized by multinucleated cells, which initiate the resorption process. However, without further stimulation of the resorption cells, the process will end spontaneously. Repair with cementum-like tissue will occur within 2–

3 weeks if the damaged surface does not cover a large surface area. If the damaged root surface is large, bone cells will be able to attach to the root before the cementum-producing cells; ankylosis is the result of this process. Continuation of the active resorption process is dependent on a common stimulation factor of the osteoclastic cells, either infection or pressure. Its origin is different for each type of root resorption. Therefore, the various types of root resorption should be identified according to the stimulation factors (Fuss 2003). When these stimulating factors are identified, it will be possible to reverse the process by removing the etiological factor.

Pulpal infection root resorption - internal root resorption

- external root resorption

Periodontal infection root resorption - invasive cervical resorptions

Orthodontic pressure root resorptions

Impacted tooth or tumor pressure root resorptions

Ankylotic root resorption

Invasive cervical resorption is an insidious and often aggressively destructive form of external root resorption that is characterized by invasion of the cervical region of the root by fibrovascular tissue derived from the periodontal ligament. This pathologic process progressively resorbs cementum, enamel, and dentin, to eventually involve the pulp space late in the process. The pulp is not at least initially involved (Heithersay 1999)
A clinical classification had been developed by Heithersay both for research purposes and also to provide a clinical guide in the assessment of cases of invasive cervical resorption.
.
Class 1 – Denotes a small invasive resorptive lesion near the cervical area with shallow penetration into dentine.
Class 2 – Denotes a well-defined invasive resorptive lesion that has penetrated close to the coronal pulp chamber but shows little or no extension into the radicular dentin.
Class 3 – Denotes a deeper invasion of dentine by resorbing tissue, not only involving the coronal dentine but also extending into the coronal third of the root.
Class 4 – Denotes a large invasive resorptive process that has extended beyond the coronal third of the root.

Three types of external root resorptions have been recognized: surface, inflammatory, and replacement resorption.
Surface resorption can be transient or progressive. In the transient variety, the tooth has a vital, healthy pulp. This type of resorption is usually not of clinical significance. In such cases, the resorbed area will be restored partially or completely too normal surface contour by deposition of new cementum (Bakland 1992). If there is injury or irritation to the dentin, cementum, or PDL, clastic (resorbing) cells will be attracted to the affected areas of the root surface, and resorption will occur as part of the normal scavenging function of the cells. There are usually no symptoms or radiographic signs (Gunraj 1999). In the progressive type, the surface resorption is the beginning of more destructive resorption.

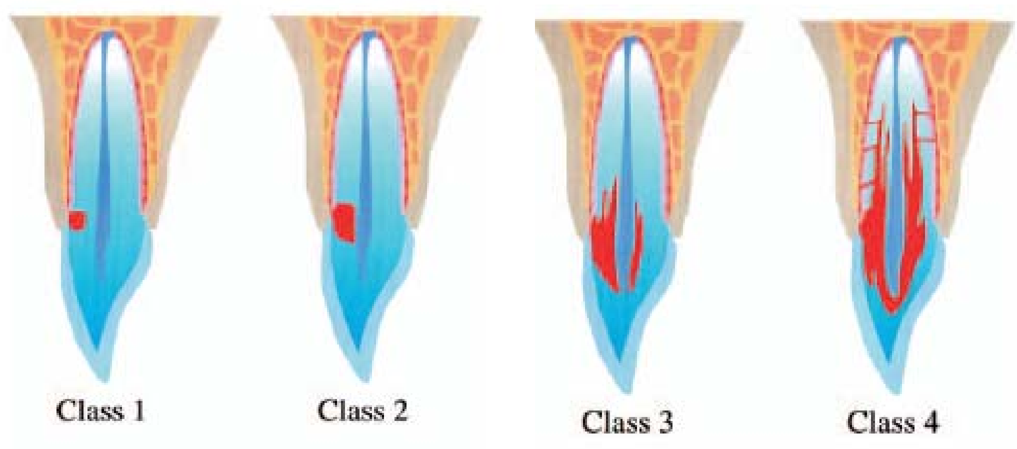


Fig.16 Clinical classification of invasive cervical resorption

Inflammatory resorption is another type of extern root resorption. The pulp is necrotic and infected bacterial by-products escape by way of the dentinal tubules and become the stimulus for ongoing phagocytosis, causing inflammation and further root and bone resorption. If the process is not stopped, the resorptive process may destroy the root and adjacent alveolar bone. The resorption is arrested by early endodontic treatment (Cvek 1973, Trope et al. 1995). The lesion of extern inflammatory root resorption has usually not well-defined margins. The lesion may be superimposed over the canal and the canal can be followed unaltered through the defect area. The lesions position will shift on different radiographic angulations (Gartner et al. 1976).

Replacement resorption can be seen after luxation injuries with loss of viability of PDL cells or in cases of tooth avulsion in which extensive damage to the ligament occurs because of drying or inappropriate storage, healing occurs without an intervening periodontal attachment. Depending on the extent of injury, cell lysis will occur on the root surface where the PDL has become necrotic. Mild tissue damage (less than 20% of root surface involved): gives Transient Resorption and may repair itself with cells from adjacent healthy PDL. More severe damage (long extra oral time lead to dessication and death of root surface cells or more than 20% of root surface involved): gives Progressive Resorption. Cells of the alveolar bone replace the periodontal attachment and continue to resorb the root, gradually replacing it with alveolar bone (Gunraj 1999).

Internal root resorption occurs rarely in the permanent teeth (Trope 1998). Internally, from pulpal side, dentin is lined by the odontoblasts and predentin. The odontoblasts have no resorbing ability and in combination with the unmineralized predentin, apear to form a barrier against dentin resorption. Progressive internal root resorption continues where dentin is exposed after loss of odontoblasts and predentin (Tronstad 1988, Wedenberg & Lindskog 1985). Internal root resorption requires that vital pulp tissue must be connected to necrotic pulp tissue. Tronstad states that resorptive activity is sustained by infection of the necrotic pulp tissue in the root canal coronal to the area where resorption takes place.

The sensitivity testing are often negative, since the coronal pulp is infected while the apical pulp-which includes the resorptive defect-remains vital (Trope 1998). The resorption of exposed dentin may continue until the necrotic process overtakes the vital tissue in the remainder of the pulp space, thus depriving the tissue of needed blood supply, at which time the internal resorptive process ceases (Bakland 1992). Barclay suggested a number of etiological factors for internal root resorption (Barklay 1993):

- Chronic pulp inflammation
- Trauma

- Pulpotomy
- Restorative procedures
- Hereditary
- Cracked tooth syndrome
- Invaginated cingulum
- Orthodontic tooth movement
- Herpes Zoster

Radiographically, internal root resorption tends to have a more sharply outlined appearance than does external root resorption. The outline of the root canal is lost in the lesion. Radiographs taken at various angles tend to show the internal root resorption lesion in a central location. In contrast, external root resorption lesions tend to move with the various angles, at which radiographs are exposed (Bakland 1992).
Standard treatments of internal root resorption include pulpectomy which removes the blood supply to the granulomatous tissue and the rest of the treatment is concentrated on removing tissue from the irregular resorptive defect and obturating the space (Trope 1998).
Ultrasonic root canal preparation combinated with irrigation has an important roll to expose and clean the granulation tissue in the lesion. The antibacterial effect of ultrasonic instrumentation in the treatment of infected root canals was clinically evaluated by Sjogren & Sundqvist 1987. Sodium hypochlorite solution (0.5%) was used as an irrigant. The ultrasonic technique eliminated the bacteria from the canals more efficiently than hand instrumentation alone. Even though ultrasonication definitely improves the procedure of root canal disinfection, the use of an antibacterial dressing between appointments is necessary to achieve as complete a reduction in bacterial levels as possible (Sjogren & Sundqvist 1987).

When resorption has progressed to involve an external communication with the PDL space, this complication is often so serious that the tooth cannot be maintained. In some situations, complex surgical procedures may be used to gain access for repair (Gunraj 1999).
Three-dimensional obturation of the root-canal system to the canal apex is fundamental for successful endodontic therapy (Schilder 1974). Inadequate apical seal is a major cause of failure in non-surgical endodontic treatment (Harty et al. 1970).
In vertical condensation methods using warm gutta-percha, there is an increased risk of overextension in apical and eventual perforation areas on the root (Yared et al. 1994a, Yared et al 1994b).
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Case number 17

Treatment of maxillary front after traumatic avulsions in cooperation with oral surgeon and prosthodontist

Patient

A 21-year-old white Norwegian female was referred to the Department of Endodontics by an oral surgeon September 15, 2004 for treatment of the maxillary right canine and central incisor (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The patient was involved in a biking accident July 22, 2004. The teeth 13, 11 and 21 were all avulsed. The patient was treated at the hospital 1 hour later and the teeth 13 and 11 were replanted.
She got a semi rigid fixation. She returned to the hospital after 3 weeks for a follow-up.
She was informed of getting in touch with her dentist for continuing treatment.
She consulted an oral surgeon almost two months after the accident because of the missing 21. The oral surgeon referred the patient to the Departments of Endodontic to handle the treatment of 13 and 11 before starting with implant treatment.
The patient felt that her front teeth were sore, but did not feel any pain.

Clinical Examination

Preoperative photos showed the region from maxillary right first premolar to maxillary central incisor (Fig.2, 3).

Fig.2 Buccal view **Fig.3** Palatal view

No pathology was found extra-orally

A normal oral mucosa was observed.

Maxillary right first premolar: The tooth responded positively to the sensibility test with Endo Ice.
Maxillary right canine: The tooth responded negatively to the sensibility test with Endo Ice and was tender to both palpation and percussion. A sinus tract could be observed in the buccal fold. A periodontal pocket 8mm was detected mesial.
Maxillary right central incisor: A MIB composite restoration was seen and the tooth was tender to palpation and percussion. A sinus tract could be observed in the buccal fold and the tooth responded negatively to the sensibility test with Endo Ice. It was splinted to a temporary crown on 21.
Maxillary left central incisor: The tooth was missing. Temporary crown splinted to both neighboring teeth.

The other teeth in the upper and lower left quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits except mesially 13.

The tooth 12 and 22 was missing from earlier.

Radiographic Examination

The periapical radiograph showed the region from maxillary right first premolar to maxillary left central incisor (Fig.4, 5)

Maxillary right first premolar: Lamina dura could be followed around the entire root. .
Maxillary right canine: Lamina dura could be followed on the distal side until the apical area where a circumscribed radiolucency of 3 mm in diameter could be seen. On the mesial side a bone pocket could be seen down to the apical 1/3 of the root. Also possibly external resorptions could be seen on the mesial side of the root.

Fig.4 Note bone pocket mesial 13 Fig.5 Tooth 21 was lost

Maxillary right central incisor: Lamina dura could be followed on the mesial side until the apical area where a circumscribed radiolucency around 1 mm in diameter could be seen. On the distal side some breakdown of the bone had occurred in the cervical area.
Maxillary left central incisor: The tooth was missing.

Diagnosis

Apical periodontitis with sinus tract, bone pocket and external resorption maxillary right canine
Apical periodontitis with sinus tract maxillary right central incisor

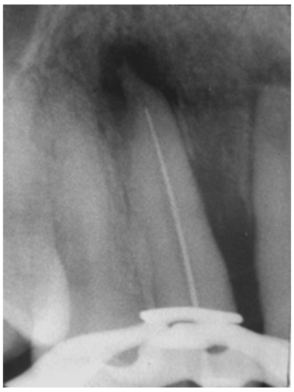
Treatment Plan

Endodontic treatment of necrotic maxillary right canine
Endodontic treatment of necrotic maxillary right central incisor
Root canal disinfection and filling

Treatment

September 15, 2004

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The access cavity was prepared on tooth 13,
Irrigation was done with 1% sodium hypochlorite and 17% EDTA. An nr 15 K-Flex was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig.6).
Working length was 24.5 mm with the incisal edge as a reference point.
The last instrument was NiTi nr 55. The root canal was dried with sterile paper points, and filled with UltraCal XS (calcium hydroxide paste-Ultradent) intracanal dressing. The access cavity was sealed with IRM.
The same procedure was done with tooth 11. Working length was 23 mm with the incisal edge as a reference point (Fig.7). The last instrument was NiTi nr 55. The root canal was dried with sterile paper points, and filled with UltraCal XS. The access cavity was sealed with IRM.



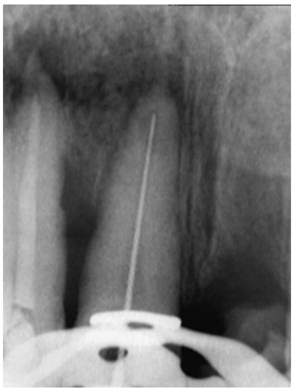


Fig.6 Working length 13

Fig.7 Working length 11

September 29, 2004

The patient returned to the clinic two weeks later. She had lost the temporary tooth 21. A new temporary crown was made in composite and splinted to neighboring teeth.

October 13, 2004

The patient returned to the clinic 4 weeks later. The teeth were still symptomatic, and a sinus tract could be observed on tooth 13. The sinus tract from tooth 11 had closed, but the area was still tender to palpation (Fig.8, 9).

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. Irrigation was done with 1% sodium hypochlorite, 17% EDTA and dressed for 5 min. with 2% chlorhexidine digluconate. A master cone radiograph was taken of both teeth to verify correct working length (Fig.10, 11). The root canals were dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canals with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with IRM.

Fig.8 Buccal view

Fig.9 Palatal view

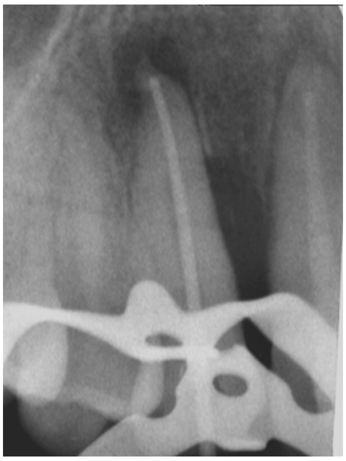


Fig.10 Master cone 13

Fig.11 Master cone 11

November 03, 2004

The patient returned to the clinic 3 weeks later. Both sinus tracts had closed, but still the were tenderness on palpation on both teeth (Fig.12, 13). The radiographs revealed healing in progress apical on both teeth, but not in the bony defect mesially 13 (Fig.14, 15).

Fig.12 Still some irritation buccal 13

Fig.14 Apical healing in progress

Fig.13 Still some irritation buccal 11

Fig.15 Apical healing in progress

January 12, 2005

The patient returned to the clinic 2 months later. The area buccal on tooth 13 was still sore. No healing of the bony defect, but in the apical area on both teeth the healing was in progress (Fig.16, 17).
It was decided together with the oral surgeon and prosthodontist that because of the lack of healing of the bony defect mesialy on tooth 13 the tooth was going to be extracted.
The tooth 11 should be evaluated furtherat a later stage in the treatment.

Fig.16 Healing in progress in the apical area.

Fig.17 Complete healing of the apical area.

March 21, 2006

The patient returned to the clinics 14 months later. The tooth 13 had been extracted and an implant was placed in regio 13 and 21.
The tooth 11 was asymptomatic (Fig.18, 19). The temporary IRM filling was in place. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi instruments and irrigation with 1% sodium hypochlorite, 17% EDTA and dressed for 5 min. with 2% chlorhexidine digluconate. Master gutta-percha cone nr 60 was tried in, and a master cone radiograph was taken (Fig.20).
The root canal was dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-filling was removed 2 mm apical to the orifice and sealed with an IRM plug. The access cavity was filled with IRM (Fig.21).

Evaluation

The teeth were replanted one hour after avulsion. Endodontic treatment should have started 1-2 weeks after replantation. All the parameters for a successful replantation were not present. Conservative treatment was initiated in spite of bad prognosis. This could be justified with a close monitoring of the patient together with oral surgeon to be sure not risking loss of bone. This was done because implants in the estethic zone can be difficult toachieve satisfying result, especially when loss of bone hight is present.

Prognosis

Endodontic prognosis is considered favourable.

Fig.18 Healing was seen

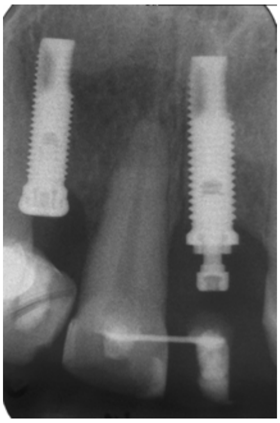


Fig.19 Complete healing

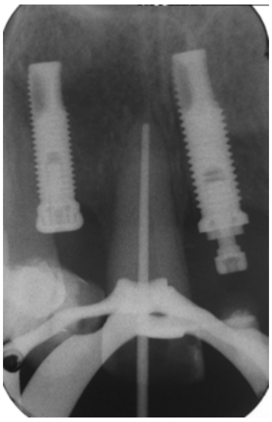


Fig.20 Master cone

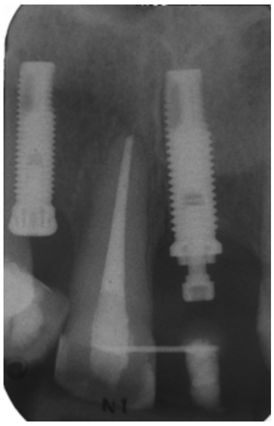


Fig.21 Final radiograph

Discussion
Avulsion of teeth with closed apices

In this trauma type the tooth is displaced totally out of its socket. Clinically the socket is found empty or filled with a coagulum.
Immediately after injury, the PDL and pulp in the avulsed tooth begin to suffer ischemic injury, which is soon aggravated by drying, exposure to bacteria or chemical irritants. These events can kill PDL and pulpal cells even after a short extra-alveolar period.
Treatment outcome is strongly dependent on the length of the dry extra-alveolar period and storage media. If the extra-alveolar period is less than 1 hour, complete or partial PDL healing is possible. However, total PDL death can be expected after more than 1 hour of drying, and progressive root resorptions will be the result.
In these cases the indication for replantation should be considered. Thus in cases of young individuals, where considerable alveolar growth has to take place (i.e. 7-13 years of age), and replantation is generally not indicated due to ankylosis and subsequent interference with alveolar growth. In older individuals, where limited alveolar growth is to be expected, replantation can be performed.

Replantation of an avulsed tooth preferably should be done at the site of injury in order to minimize extra-alveolar time. In these cases the tooth should be immediately replanted in its socket or, if obviously contaminated rinsed for 10 seconds in cold running tap water.
The patient should then seek an emergency service or dental office for further treatment including splinting and antibiotic prophylaxis.
If immediate replantation is not possible, the avulsed tooth should be stored in milk or in the mouth.
Tooth replantation which is performed in a dental office should consist of the following procedures: Assess extra-alveolar period and storage medium.

Immediat replantation:

1. Rinse the tooth surface carefully with physiological saline. All obvious contaminants should be removed.
2. Flush the socket coagulum with saline.
3. Replant the tooth slowly with gentle pressure. The tooth must not be forced in place.
4. Splint the tooth with semi-rigid splint.
5. Antibiotic coverage should be given.
6. Tetanus prophylaxis is assessed according to the immunization status of the patient.

In the extended extra-alveolar periods in adults, an alternative replantation procedure is possible. The replantation becomes implantation in that the root surface is treated with a fluoride solution to make the root surface partly osteoclast resistant, and thereby protract the replacement process of any later ankylosis.

Alternative replantation or implantation:

1. Remove the necrotic PDL from the avulsed tooth with scalers and pumice.
2. Extirpate the pulp.
3. Place the tooth ion a 2% NaF solution for 20 minutes.
4. Root-fill the tooth with sealer and gutta-percha.
5. Rinse the tooth surface for 2 minutes with saline.
6. Replant the tooth after removing the coagulum from the socket.
7. Splint the tooth for 6 weeks.

If a fluoride treatment is used a doubling of the tooth survival time can be expected in these cases.

The splint is removed after 1 week (immediate replanation). If pulpal revascularization is not to be expected the pulp is extirpated prior to splint removal, and calcium hydroxide is placed in the root canal as interim dressing. The tooth should be permanently root-filled after 2-4 weeks, provided there is no sign of inflammatory resorptions and there is periapical healing.
In all cases a radiograph control should be made after 2-3 weeks. At this time signs of inflammatory resorption may be present, which will dictate pulpal extirpation even in teeth with incomplete root formation.
Further radiographic and clinical controls should be done after 2 and 6 months, 1, 2 and 5 years at which time ankylosis can usually be demonstrated if it is going to occur.

Pulpal and periodontal healing has been found to be dependent on three factors:

1. Length of extra-alveolar storage
2. Extra-alveolar storage medium
3. Stage of root development

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Case number 18

Endodontic retreatment of maxillary right lateral incisor with chronic apical periodontitis and iatrogenic root perforation

Patient

A 54-year-old white Norwegian female was referred to the Department of Endodontics, University of Oslo, by an undergraduate dental student January 20, 2004 for treatment of the maxillary right lateral incisor (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The maxillary right lateral incisor had an old crown with a post, and a chronic apical periodontitis. The crown and post were removed and endodontic retreatment started by an undergraduate dental student (Fig.2). Removal of gutta-percha was problematic, and it was used a drill to remove the gutta-percha (Fig.3). With the drill a perforation was made buccaly in the middle of the root (Fig.4). The patient was referred to the post-graduation program. The patient only concern was if the temporary crown would be in place after my treatment.

Fig.2 After removal of crown and post

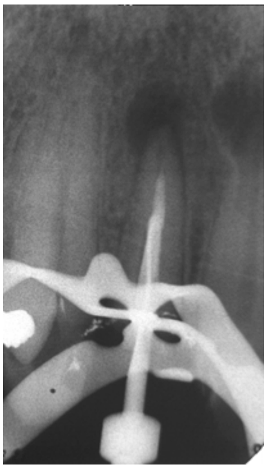

Fig.3 Removal of gutta-percha

Fig.4 Perforation buccal

Clinical Examination

The photos showed the region from maxillary right canine to maxillary right central incisor (Fig.5, 6).

Fig.5 Temporary crown on tooth 12

Fig.6 Palatal view IRM in access cavity

No pathology was found extra-orally.

A normal oral mucosa was observed.

Maxillary right canine: A MDP composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Maxillary right lateral incisor: A temporary crown with a palatal IRM temporary filling was seen and the tooth responded negatively to the sensibility test with Endo Ice. The tooth was discoloured gray-bluish in the gingival part,and was tender to palpation.
Maxillary right central incisor: A D composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from maxillary right canine to maxillary right central incisor (Fig.7)

Maxillary right canine: Lamina dura could be followed around the entire root.
Maxillary right lateral incisor: Lamina dura could be followed to the apex where it widened into a circumscribed radiolucent area 3 mm in diameter.
Maxillary right central incisor: Lamina dura could be followed around the entire root. A radiolucent area can be seen over the apex approximately 6mm in diameter.

Fig.7 Start of treatment

The height of the marginal bone was within normal limits.

Diagnosis

Chronic apical periodontitis maxillary right lateral incisor with an accidential perforation

Treatment Plan

Close accidential perforation
Retreatment of an endodontically treated maxillary right lateral incisor
Root canal disinfection and filling

Treatment

January 20, 2004

Rubber dam was applied, and the area was disinfected with a chlorhexidine-ethanol solution. The access preparation was done and the canal with gutta-percha and the perforation buccal was localized. Irrigation was done with 1% sodium hypochlorite and 17% EDTA. The canal space down to the perforation was cleaned with the help of ultrasound, Hedstrøm files and irrigation. The perforation was closed with grey MTA. Application of wet cotton pellet in the canal and sealed off with an IRM filling (Fig.8).

February 2, 2004

The patient returned to the clinic 2 weeks later. The tooth was asymptomatic. Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution.
An nr 15 KFlex was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig.9).
Working length was 21 mm with the incisal edge as a reference point.
The last instrument was NiTi nr 60.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. The root canal was dried with sterile paper points. Calcium hydroxide intracanal dressing was packed into the canal with the help of a Lentulo spiral and sterile paper points. The access cavity was sealed with Cavit G and IRM.

Fig.8 MTA in perforation

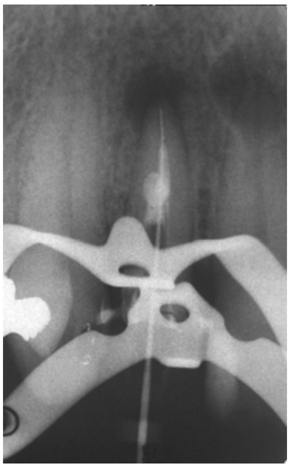

Fig.9 Working length

February 25, 2004

The patient returned three weeks later. The tooth was asymptomatic. Rubber dam was applied and the area was disinfected with chlorhexidine-ethanol solution. The calcium hydroxide was removed with NiTi instrument nr 60 and irrigation with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. Master gutta-percha cone nr 60 was tried in and a master cone radiograph was taken (Fig.10).
The root canal was dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-filling was removed 2 mm apical to the orifice and sealed with an IRM plug. The access cavity was filled with IRM. A final radiograph was taken after removal of the rubber dam (Fig.11).

Fig.10 Master cone

Fig.11 Final radiograph

Evaluation

The iatrogenic root perforation was done under aseptic conditions and the perforation was in the apical third. Visibilty was good and the perforation was closed with MTA.
This was done before starting the retreatment procedure.

Prognosis

Endodontic prognosis was considered favourable

One year follow-up

February 10, 2005

The patient returned to the clinic for a one year follow-up. The tooth was asymptomatic. The patients GP had made a PFM crown. Radiographic exam showed no pathology at the site of perforation, and apical healing in progress (Fig.12).

2 year follow-up

April 5, 2006

The patient returned to the clinic for a 2 year follow up. The tooth was asymptomatic. Radiographic exam showed apical healing in progress (Fig.13, 14).

Fig.11 Final radiograph

Fig.12 One year follow-up

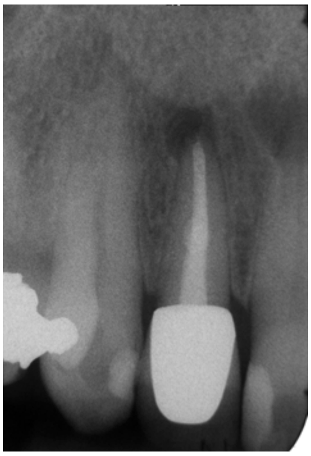

Fig.13 Two year follow-up

Fig.14 Two year follow-up

Discussion

Successful root canal treatment is dependent on cleaning, shaping, and filling of the root canal system. There is increasing realization that coronal seal is important in root canal treatment (Beckham et al. 1993). Coronal leakage leads to canal contamination, preventing the satisfactory completion of each stage in root canal treatment.

The use of intracanal medication to prevent canal contamination is ineffective in the presence of coronal leakage (Chong & Pitt Ford 1992). IRM, reinforced zinc oxide-eugenol cement was used as part of the double-seal to ensure a bacteria-tight coronal seal. Zinc oxide eugenol cements have antibacterial properties and are effective in preventing bacterial microleakage (Browne & Tobias 1986, Hume 1988).

It is important to insure that existing coronal restorations of the tooth under endodontic treatment are sound and caries free. The basic principle of caries control in dentistry also applies to root canal access cavity preparation. If a filling or crown is carious, deficient, or leaky, it must be replaced as appropriate. The integrity of the coronal seal is vital, even with completed root fillings. Coronal leakage may jeopardize the success of root canal treatment (Madison & Wilcox 1988, Torabinejad et al. 1990, Khayat et al. 1993).

Root canal filling materials are intended to prevent microorganisms and toxins in the canal from passing along the root canal space and into the periradicular tissues (Nguyen 1994). Difficulty obliterating accessory canals, fins, anastomoses, apical deltas, and other irregularities of the root canal space and failure to adequately seal the apical foramen have, been reported to account for a large percentage of root canal failures (Dow & Ingle 1955). When a perforation of the apical third of the canal space occurs, the ability to obtain an adequate seal is further compromised by the irregular shape and increased size of the area to be sealed. Most often the root filling material is going to extend out to the periradicular tissues because of the earlier apical perforation.

Perforations are regarded as serious complications in dental practice and pose a number of diagnostic and management problems. However, when teeth are of strategic importance perforation repair is clearly indicated whenever possible. Unfortunately, however, there is a paucity of evidence-based research upon which treatment decisions can be based.

Traditionally, the presence of radicular perforations has been both difficult to determine and manage. Most frequently, they were managed surgically, but in recent years non-surgical correction of many perforations has been facilitated by the use of improved magnification and illumination provided by the use of loupes or the surgical operating microscope (SOM). In practice, however, the indications for surgical correction of root perforations are being eroded from two directions: on the one hand by the improved non-surgical management of perforations and on the other by the use of implants.

Perforations occur primarily through three possible mechanisms: procedural errors occurring during root canal treatment or post-space preparation, resorptive processes and caries. Most perforations result from procedural errors. Errors leading to these defects include bur perforation during access opening or during the search for canal orifices, excessive removal of dentine in the danger zone, either with hand or rotary instruments, misdirected files during canal negotiation, unsuccessful attempts at bypassing separated instruments and misaligned instruments during post-space preparation.

When treatment planning for perforation repair, the location of the perforation is probably the most important and overriding factor in the decision-making process. Fuss & Trope (1996) presented a classification that emphasized the relationship of the perforation site to the 'critical crestal zone.' This classification divides the root into *coronal*, *crestal* and *apical* portions: *coronal* being defined as 'coronal to the crestal bone and epithelial attachment'; *crestal* being defined as 'at the level of the epithelial attachment and crestal bone' and *apical* being defined as 'apical to the crestal bone and epithelial attachment.' In addition to considering the position of the perforation in relation to the 'critical crestal zone,' its position in the mesial distal and facial lingual planes must also be taken into account..

Non-surgical treatment is indicated, whenever possible, in the management of perforations. Surgical intervention is reserved for cases not amenable to, or which have not responded to, non-surgical treatment, or in which the concomitant management of the periodontium is indicated (Gutmann 1991). There is no clear-cut distinction between those cases that are best treated non-surgically and those treated surgically, and, frequently, creative combinations of both non-surgical and surgical approaches must be adopted. The decision to repair perforations surgically can only be made when a number of considerations have been addressed.

Perforations in the apical third of the root can be considered simply as an extra exit from the canal system and managed either non-surgically or surgically (Heithersay G). If the defect cannot be managed non-surgically, resection of the root apex is usually the most efficacious method for repair provided that the crown–root ratio remains favorable. These types of perforation include apical perforation of the root during instrumentation of the canal system or placement of a post, perforation following zipping of the apical portion of the canal, deviation of the root canal instrument during cleaning and shaping or in an attempt to bypass an obstruction in the canal system. Perforations in the apical portion of the root rarely communicate with the oral cavity and are therefore not exposed to constant microbial contamination (Martin LR 1982).

MTA powder consists of fine hydrophilic particles that set in the presence of moisture. Hydration of the powder results in a colloidal gel that solidifies to a hard structure in less than 4h (Torabinejad et al. 1993).
Mineral trioxide aggregate (MTA) has been shown to be very effective in sealing pathways of communication between the root canal system and the external surface of the tooth (Torabinejad et al. 1995).

To investigate the biocompatibility of MTA, Holland et al. (1999) conducted an in vivo study to observe the reaction of dog periapical tissues to root canal filling with gutta-percha using either MTA or a commercial glass ionomer (Ketac-endo; ESPE Co., Seefeld, Oberbay, Germany) as a sealer. The results showed that MTA exhibited better biological properties, including the ability to stimulate hard tissue deposition at the root apex and no tendency to produce an inflammatory reaction in the periapical tissues.

When a perforation occurs in the middle or apical third of the root, instrumentation and control of the repair materials is very difficult. A biocompatible material that could repair the perforation and obdurate the canal simultaneously would be highly desirable (Vizgirda et al. 2004).
Although MTA has been shown experimentally to prevent microleakage, to be biocompatible, and to promote regeneration of the periradicular tissues, it has not been investigated or advocated for use as a root canal filling material. These favorable clinical and laboratory studies suggest that MTA might be used for simultaneous perforation repair and root canal space obturation (Vizgirda et al.2004).

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Case number 19

Endodontic treatment of a taurodont mandibular left second molar

Patient

A 53-year-old white Norwegian male was referred to the Department of Endodontics, University of Oslo, by an undergraduate dental student September 06, 2005 for treatment of the maxillary left second molar.

Medical History

Non-contributory

Dental History & Chief Complaint

The maxillary left second molar was treated by an undergraduate dental student for asymptomatic pulpitis. The tooth was severely broken down. To accomplish an aseptic treatment with rubber dam a copper-band/ring was cemented with glass ionomer. A perforation was made buccal under access preparation. The canals were not localized. The patient was referred to the post-graduation endodontic program.
The patient did not have any problem from the tooth.

Clinical Examination

No pathology was found extra-orally

A normal oral mucosa was observed.

Mandibular left second premolar: A MODP composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Mandibular left first molar: A MODP composite restoration was seen and the tooth responded positively to the sensibility test with Endo Ice.
Mandibular left second molar: A cemented copper band was seen and the tooth responded positively to the sensibility test with Endo Ice

The other teeth in the upper and lower right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from mandibular left second premolar to second molar (Fig.1).

Mandibular second premolar: A radiopaque restoration in the crown was seen and lamina dura could be followed around the entire root.
Mandibular first molar: A radiopaque restoration in the crown was seen and lamina dura could be followed around the entire root
Mandibular second molar: A radiopaque restoration in the crown was seen and lamina dura could be followed around the entire root

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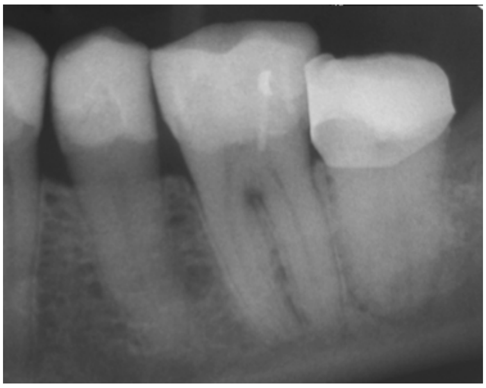

Fig.1 Start of treatment

The height of the marginal bone was within normal limits.

Diagnosis

Asymptomatic pulpitis with iatrogenic perforation mandibular left second molar

Treatment Plan

Perforation closure
Pulpectomi of mandibular left second molar
Root canal disinfection and filling

Treatment

September 06, 2005

Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution. The access preparation was done, and the "perforation" was the pulp chamber, Irrigation was done with 1% sodium hypochlorite and 17% EDTA. After removing the pulp in the pulp chamber it was possible to localize three canals.
An nr 15 KFlex was taken to working length in all three canals. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig.2).

Working length was 18.5 mm with the occlusal plane as a reference point for all the canals. The last instrument was NiTi nr 45 in MB and ML canal and NiTi nr 60 in D canal. Irrigation was done with 1% sodium hypochlorite and 17% EDTA.Master gutta-percha cones were tried, and a master cone radiograph was taken (Fig.3).The root canals were dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a cold lateral condensation technique. The root-fillings were removed 2 mm apical to the CEJ and sealed with IRM plugs. The access cavity was filled with IRM. A final radiograph was taken after removal of the rubber dam (Fig.4).

Fig.2 Working length

Fig.3 Master cone

Fig.4 Final radiograph

Evaluation

The undergraduate dental student and the instructor thaught they had perforated buccaly. They had actually just entered a huge pulp chamber.
A lot of bleeding from the pulp did visualization difficult, but after most of the pulp from the pulp chamber was removed, bleeding almost stopped and visualzation with microscope was possible. Three canals were found and cleaned. Looking at the final radiograph it looks like it was also a forth canal present. Some sealer has come into the opening of the fourth canal and

the canal itself was evident on the radiograph. This could also be seen in the master cone radiograph.
Because of some problems with cooperation in the undergraduate student clinic the patient was remised, and it has not been possibly for me to come in contact with the patient for a follow-up or retreat to clean and fill the fourth canal.

Prognosis

Endodontic prognosis was considered favourable

Discussion

Taurodontism is a morphologic variation in which the body of the tooth is enlarged and the roots are reduced in size. Taurodont teeth have large pulp chambers and apically positioned furcation (AAE 1998). The term taurodontism was coined by Sir Arthur Keith to describe the "bull-like" condition in teeth (from Latin *tauro*: "bull" and *dont*: "tooth" from Greek) in which the tall root trunk encloses a high pulp chamber and short roots (Keith 1911).

The etiology of taurodontism is unclear. It is thought to be caused by the failure of Hertwig's epithelial sheath diaphragm to invaginate at the proper horizontal level, resulting in a tooth with short roots, elongated body, an enlarged pulp, and normal dentin (Hamner 1964). Previously, taurodontism was related to syndromes such as Down's and Klinefelter's (Regezi 1999). Today, it is considered as an anatomic variance that could occur in a normal population (Shifman 1978).

Taurodontism has been graded according to its severity (Shaw 1928): least pronounced (hypotaurodontism), moderate (mesotaurodontism), and most severe (hypertaurodontism). Shifman and Chanannel (Shifman 1978) also included an index to calculate the degree of taurodontism as shown radiographically (Fig.1).

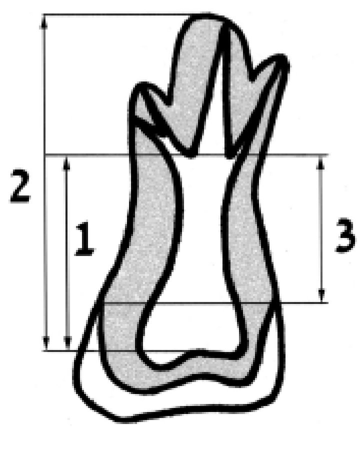

Fig 1. Variable dimensions for establishing the taurodontism index: vertical height of the pulp chamber (V1), distance between the lowest point of the roof of the pulp chamber to the apex of the longest root (V2), and distance between the baseline connecting the two CEJ and the highest point in the floor of the pulp chamber (V3). Establishing a condition of taurodontism is made when V1 is divided by V2 and multiplied by 100 if above 20, and V3 exceeds 2.5 mm: (V1/V2) * 100 > 20 and V3 > 2.5 mm. Taurodontic index (TI) = V1/V2 × 100. Taurodontism is diagnosed in molars in which TI is above 20 and

variable 3 exceeds 2.5 mm. Degrees of taurodontism were determined as: hypotaurodontism: TI 20–30, mesotaurodontism: TI 30–40, and hypertaurodontism: TI 40–75 (5).

Taurodontism refers to a condition in which the pulp chamber of molar teeth is enlarged apico-occlusally. The floor of the pulp chamber and the furcation area are situated more apically, resulting in shortened root canals. Clinically, the crowns of these teeth have normal characteristics; therefore, taurodontism may be diagnosed only radiologically. In this case, all taurodontic molar teeth had normal clinical morphology.

Several reports have been published in which taurodontism appears as a part of various syndromes, such as Klinefelter's (Goldstein 1973, Kamatz 1978, Yeh 1999), trisomy 21 (Jaspers 1981, Alpoz 1997), and trichodento-osseous syndromes (Wright 1994). Some reports suggest that taurodontism may be genetically transmitted (Witkop 1971).

Laatikainen and Ranta (1996) found that taurodontism was symmetrical in 91% of the affected molar pairs. They observed that taurodontism and hypodontia were together in 8 of 16 taurodontic twin pairs. In our patient, taurodontism in the maxillary and mandibular molars were symmetrical; taurodontism and hypodontia occurred together. The presentation of taurodont forms complicates nonsurgical, endodontic procedures because of the impact of the morphology on location of orifices and instrumentation and obturation (Tsesis 2003).

Shifman and Channanel (1978) reported that the mandibular second molar was the most prone, being involved in two thirds of all cases found. In this case, we observed hypertaurodontism in four maxillary molars and two mandibular second molars. Clinicians should be alerted to the possibility of taurodontism with its accompanying clinical difficulties in patients with hypodontia.

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Case number 20

Endodontic retreatment of dens invaginatus maxillary right later incisor with chronic apical periodontitis

Patient

A 25-year-old white Swedish female was referred to the Department of Endodontics, University of Oslo, by an undergraduate dental student March 02, 2004 for treatment of the maxillary right lateral incisor (Fig.1).

Fig.1 Frontal view

Medical History

Non-contributory

Dental History & Chief Complaint

The maxillary right lateral incisor was endodontic treated at the age of 9 because of acute apical periodontitis. No previous history of trauma or caries was recorded according to the patient. Two years ago a Procera crown was made by her GP in Sweden. January 13, 2004 was the patient treated by a dental student because of acute apical periodontitis. Retreatment was started, and puss was evacuated true the canal. Gutta-percha was removed and calcium-hydroxide was placed in the canal (Fig.2, 3, 4). The tooth was asymptomatic today.

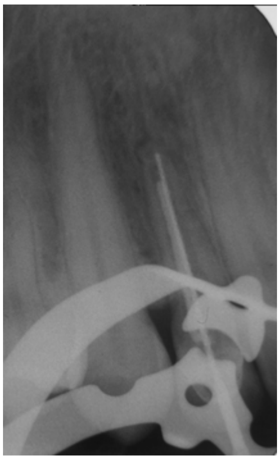

Fig.2 Start of treatment Fig.3 Working length Fig.4 Gutta-percha removed

Clinical Examination

The photo showed the region from maxillary right first premolar to maxillary left central incisor (Fig.5).

Fig.5 Procera crown on tooth 12

No pathology was found extra-orally.

A normal oral mucosa was observed.

Maxillary right canine: The tooth responded positively to the sensibility test with Endo Ice.
Maxillary right lateral incisor: A Procera crown with a palatal IRM filling was seen and the tooth responded negatively to the sensibility test with Endo Ice.
Maxillary right central incisor: The tooth responded positively to the sensibility test with Endo Ice.

The other teeth in the upper and lower right quadrants showed no signs relevant to the chief complaint.

The gingival margin was healthy, and the probing depths were within normal limits.

Radiographic Examination

The periapical radiograph showed the region from maxillary right canine to maxillary right central incisor (Fig.6), and a radiograph on the maxillary left lateral incisor was taken for comparison (Fig.7).

Maxillary right canine: Lamina dura could be followed around the entire root.
Maxillary right lateral incisor: Lamina dura could be followed to the apex where a widening of the periodontal ligament was seen.
Maxillary right central incisor: Lamina dura could be followed around the entire root.

Fig.6 Start of treatment

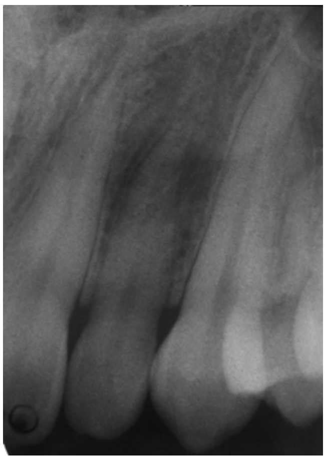

Fig.7 The tooth 22

The height of the marginal bone was within normal limits.

Diagnosis

Dens invaginatus maxillary right lateral incisor with chronic apical periodontitis

Treatment Plan

Retreatment of an endodontically treated maxillary right lateral incisor
Root canal disinfection and filling

Treatment

March 02, 2004

The tooth was asymptomatic. Rubber dam was applied, and the area was disinfected with chlorhexidine-ethanol solution.
A nr 30 NiTi was taken to working length. Control of working length with an apex locator (Root ZX), and verified by a working length radiograph (Fig.8).
Working length was 20.5 mm with the incisal edge as a reference point.
The last instrument was K-Flex nr 80.
Irrigation was done with 1% sodium hypochlorite, 17% EDTA and dressed for 5 minutes with 2% chlorhexidine digluconate. The root canal was dried with sterile paper points.
Master gutta-percha cone nr 100 was tried in and a master cone radiograph was taken (Fig.9).
The root canal was dried with sterile paper points. The tooth was root-filled with AH Plus and gutta-percha with a 4 mm apical plug of gutta-percha (Fig.10) The rest of the canal was back-filled with Obtura II gun (Fig.11). The root-filling was sealed with IRM.

Fig.8 Working length

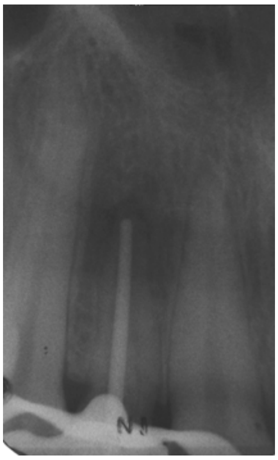

Fig.9 Master cone

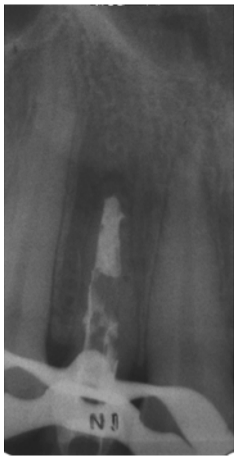

Fig.10 Apical plug

Fig.11 Backfilling with Obtura

March 24, 2004

The patient returned to the clinic 3 weeks later. The tooth was asymptomatic. IRM was removed from the access cavity and etched, primed, bonded and Bisfil 2B (Chemical cured composite - Bisco, USA) was applied with a Centrix needle tip.
Tetric Ceram was applied as a top layer (Fig.12).

Fig.12 Final radiograph

Evaluation

It was speculated that this could be a dens invaginatus type II. It was difficult because no radiology from earlier treatment was present, and the retreatment was started by an undergraduate student. According to the patient no caries or trauma had happened before endodontic treatment at the age of nine. Crown treatment two years ago may have induced necrosis of the main canal.
The be sure of proper cleaning in an irregular shaped canal a lot of irrigation, calcium hydroxide and ultrasound was used.
A warm hybrid gutta-percha technique was used to get a good flow of gutta-percha in the canal without using too much pressure. A cold lateral technique may lead to infraction and vertical root-fracture. A chemical cured composite was used down to bone level to hopefully strengthen the root-crown system.

Prognosis

Endodontic prognosis is considered good
Vertical root fracture or fracture of the crown is likely to happen

One year follow-up

28.04.05

The patient returned to the clinic for a one year follow-up. The tooth was asymptomatic. Radiographic exam showed no pathology (Fig.13).

Two year follow-up

05.04.06

The patient returned to the clinic for a two year follow-up. The tooth was asymptomatic. Clinical and radiographic exams showed successful endodontic outcome (Fig.14).

Fig.13 One year follow-up

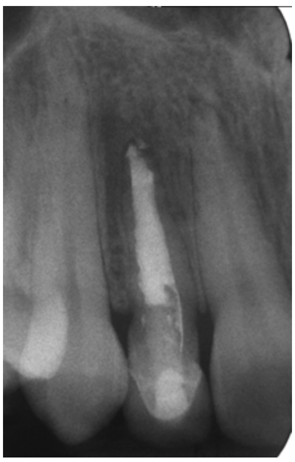

Fig.14 Two year follow-up

Fig.15 Buccal view

Fig.16 Palatal view

Discussion
Dens invaginatus

Dens invaginatus has been defined as a defect in tooth development, characterized by invagination of the enamel organ before the calcification phase. Other names for this type of malformation are dens in dente, invaginated odontoma and tooth inclusion,

Several theories have illustrated the etiology of dens invaginatus, however at the present time they remain unclear. Kronfeld (1934) speculated that dens invaginatus is caused by a failure in growth of the internal dental epithelium while at the same time there is also a proliferation of the surrounding normal epithelium, producing a static area of engulfing. Oehlers (1957) considered that the distortion of the enamel organ during tooth development and the subsequent protrusion of a part of this can lead to a formation of a lineal enamel canal that ends at the cingulum and in some cases at the incisal border, producing an irregular crown shape.

The incidence of dens invaginatus has been reported to be in a range of 0.04% and 10%, Pindborg (1970), Rotstein (1987) with the upper lateral incisors the teeth most commonly involved. Isolated cases have been reported in the mandibular region and in the deciduous dentition.

Dens invaginatus has been classified by Oehler (1957) into the following 3 types according to the depth of the invagination and the degree of communication with the periodontal ligament or the periradicular tissue.

- Type I: invagination confined inside the crown, not extending beyond the cementum enamel- junction (CEJ).

- Type II: invagination extending beyond the CEJ, it may or may not communicate with the pulp and not reach the periradicular tissue.

- Type III: invagination extending beyond the CEJ penetrating the root and exhibiting second foramina in the apical third within the periradicular tissue.

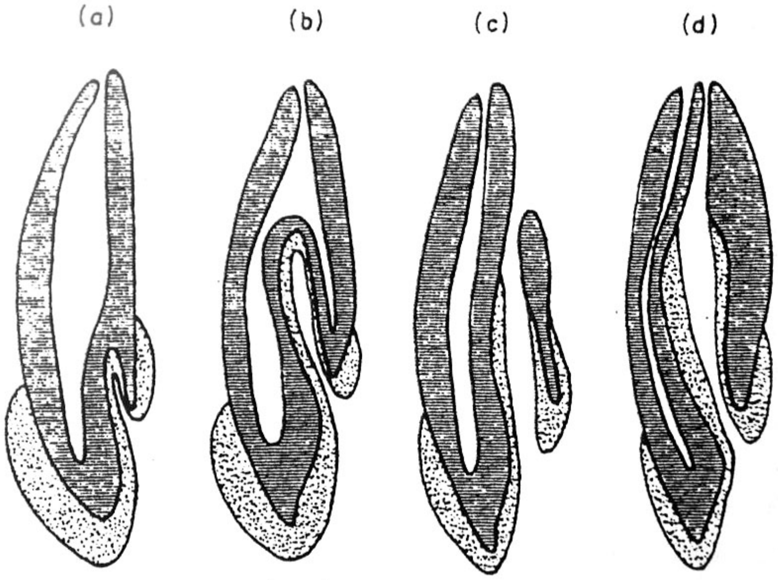

Fig. 3 Classification of invaginated teeth by Oehlers (1957).

Most cases of dens invaginatus are detected after a routine radiographic evaluation with a panoramic x-ray and confirmed with a periapical film. Clinically, a morphologic alteration of the crown or a deep foramen coecum can serve as an indication for the diagnosis of dens invaginatus. On the other hand, the main reasons for consultation are acute pain and inflammation. Histological, fragile hypomineralized enamel is frequently seen at the site of the invagination; this condition facilitates the formation of dental caries and the penetration of microorganisms from the saliva directly into the pulp, leading to pulp necrosis and the development of a periradicular inflammatory process (Hulsmann 1997).

Root canal treatment of teeth with dens invaginatus can be difficult because of the unpredictable shape of the internal anatomy and the fact that the dens tract is lined with enamel. The large and irregular volume of the root canal system makes proper shaping and cleaning difficult. Calcium hydroxide is helpful as an interappointment dressing because of its antimicrobial and tissue-dissolving properties (Hasselgen 1988). Several changes are sometimes necessary to get adequate tissue debridement. Ferguson et al (1980) also described the use of calcium hydroxide in teeth with dens tracts for apexification. Irrigation supported by ultrasonics has been recommended as another method to enhance disinfection (Cunningham 1982).

Khabbaz et al. (1995) described treatment of the dens tract as a separate canal. A warm gutta-percha obturation technique as recommended by Rottstein et al. (11) was used in this case as an effective method to fill the irregular root canal space.Nonsurgical treatment sometimes fails because it is difficult to gain access to all parts of the root canal system (1987). In many teeth with dens tracts, surgery may become necessary for a successful outcome.

In some cases, the anomalous structure of dens invaginatus is internal and a separate entity from the rest of the tooth. In these instances, the complete removal of the central-anomalous structure and total removal of pulp tissue can be accomplished with the use of ultrasonics and a surgical operating microscope (Girsch 2002).

Andreasen et al. (1993) have shown periodontal tissue regeneration including cementogenesis adjacent to retrograde composite fillings. It can be used only in the presence of excellent hemostasis.

Calcium sulfate can be used to aid in hemostasis and crypt control during surgery. It also acts as a soft tissue barrier (Sottosanti 1992) and has been shown to aid in rapid bone regeneration (Pecora 2001).It is absorbed by the body within a few weeks after it is placed in the crypt.

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