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REVIEW ARTICLE

Apical surgery: A review of current techniques and outcome

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Abstract Apical surgery is considered a standard oral surgical procedure. It is often a last resort to surgically maintain a tooth with a periapical lesion that cannot be managed with conventional endodontic (re-)treatment. The main goal of apical surgery is to prevent bacterial leakage from the root-canal system into the periradicular tissues by placing a tight root-end filling following root-end resection. Clinicians are advised to utilize a surgical microscope to perform apical surgery to benefit from magnification and illumination. In addition, the application of microsurgical techniques in apical surgery, i.e., gentle incision and flap elevation, production of a small osteotomy, and the use of sonic- or ultrasonic driven microtips, will result in less trauma to the patient and faster postsurgical healing. A major step in apical surgery is to identify possible leakage areas at the cut root face and subsequently to ensure adequate root-end filling. Only a tight and persistent apical obturation will allow periapical healing with good long-term prognosis. The present paper describes current indications, techniques and outcome of apical surgery.

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Contents

Apical surgery belongs to the field of endodontic surgery, which also includes incision and drainage, closure of perforations, and root or tooth resections. The objective of apical surgery is to surgically maintain a tooth that primarily has an endodontic lesion that cannot be resolved by conventional endodontic (re-)treatment. It is therefore of clinical relevance to perform a thorough clinical and radiographic examination of the tooth before apical surgery (including adjacent and opposing teeth), in order to decide whether surgical or non-surgical endodontics should be considered. According to the updated guidelines by the European Society of Endodontology, indications for apical surgery comprise (1) radiological findings of apical periodontitis and/or symptoms associated with an obstructed canal (the obstruction proved not to be removable, displacement did not seem feasible or the risk of damage was too great), (2) extruded material with clinical or radiological findings of apical periodontitis and/or symptoms continuing over a prolonged period, (3) persisting or emerging disease following root-canal treatment when root canal re-treatment is inappropriate, and (4) perforation of the root or the floor of the pulp chamber and where it is impossible to treat from within the pulp cavity.

The use of a surgical microscope is strongly advocated in apical surgery since it allows inspection of the surgical field at high magnification with excellent and focused illumination, detection of microstructures (additional canals, isthmus) and root integrity (cracks, fractures, perforations), distinction between bone and root, and identification of adjacent important anatomical structures. The incision and flap design should be chosen according to clinical and radiographic parameters, including condition, biotype and width of gingival tissues, presence of a restoration margin, location and extent of the periapical lesion, and patient's esthetic demands. A small osteotomy is produced to locate the root-end that is resected by about 3 mm. The resection plane should be perpendicular to the long axis of the tooth. At this stage, all pathological tissue should be removed and adequate hemorrhage control be established. The application of 1–2% methylene blue dye aids in the careful inspection of the cut root face. It is important to identify possible areas of leakage such as root-fractures, un-negotiated accessory canals or isthmuses, and gaps between the existing root-canal filling and the root-canal walls. Root-end cavity preparation is performed with sonic- or ultrasonic driven microtips. The use of rotary instruments to prepare a root-end cavity is no longer recommended. The retrocavity should have a depth of 3 mm, follow the original path of the root canal, and also include accessory canals and isthmuses, if present. How to surgically manage dentinal cracks has not been clarified yet, but teeth with vertical root fractures must be extracted. With regard to the root-end filling material, mineral trioxide aggregate (MTA) appears to become the standard. Although it is a comparatively expensive material and the clinician has to become familiar with its handling, MTA has excellent biocompatibility, ideal adherence to the cavity walls, and low solubility. Clinical (comparative) studies have reported excellent success rates for MTA ranging from 90% to 92% (follow-up periods from 1 to 5 years).

With regard to healing outcome, the classification of healing should be based on defined clinical and radiographic healing criteria. Cases should be monitored at yearly intervals until a final diagnosis (success or failure) can be established. It has been shown that 95–97% of cases classified as successful at the 1-year control remain so over the long term (5 years). Generally, lower success rates have been reported for re-surgery cases, and for teeth with combined endodontic–periodontal lesions. For both problems, the indication to perform apical surgery must be carefully weighed against extraction and implant/prosthodontic rehabilitation.

1. Introduction

Apical surgery belongs to the field of endodontic surgery that also includes incision and drainage, closure of perforations, and root or tooth resections. The objective of apical surgery is to surgically maintain a tooth that has an endodontic lesion which cannot be resolved by conventional endodontic (re-) treatment (von Arx, 2005a,b). This goal should be achieved by root-end resection, root-end cavity preparation, and a bacteria-tight closure of the root-canal system at the cut root end with a retrograde filling. In addition, the periapical pathological tissue should be completely debrided by curettage in order to remove any extraradicular infection, foreign body material, or cystic tissue. Apical surgery has greatly benefited from continuing development and introduction of new diagnostic tools, surgical instruments and materials, making this method of tooth maintenance more predictable. Success rates approaching 90% or above have been documented in several clinical studies.

The objective of this review article is to give the reader an update about apical surgery. The most recent publications are highlighted, with a focus on clinical studies. The present paper is divided into three sections: indication for apical surgery, microsurgical technique, and treatment outcome.

2. Indication of apical surgery

The evaluation of a case referred for apical surgery must always include a careful weighing of the advantages and disadvantages of surgical and non-surgical intervention, i.e., the possibility of a conventional root-canal (re-)treatment should be considered as a therapeutic option. Advantages and disadvantages of all procedures should be discussed with the referring dentist and the patient. Written informed consent must be obtained from the patient prior to apical surgery. The indication for apical surgery must be based on a careful and thorough clinical and radiographic examination.

The introduction of cone beam computed tomography (CBCT), also called digital volume tomography (DVT), has had an enormous impact in dentistry, and particularly in surgical fields of dentistry. Whereas conventional computed tomography (CT) provides sliced-image data, CBCT captures a cylindrical volume of data in one acquisition and thus offers distinct advantages over conventional radiography. These advantages include increased accuracy, higher resolution, scan-time reduction, and dose reduction (Cotton et al., 2007). CBCT greatly aids in assessment prior to apical surgery.

Lofthag-Hansen et al. (2007) compared CBCT with intraoral periapical radiography in the diagnosis of periapical pathology. In 32 (= 70%!) of 46 cases, additional relevant information was obtained with CBCT, including presence and size of apical lesions or presence of an apico-marginal communication. Low et al. (2008) compared CBCT with intraoral periapical radiography (PA) in posterior maxillary teeth referred for apical surgery. CBCT showed significantly more lesions (34%, $p < 0.001$) than PA. Additional findings were seen more frequently with CBCT than PA, including missed canals, presence of apico-marginal communication, expansion of lesions into the maxillary sinus, and sinus membrane thickening. The study clearly showed the limitations of PA compared to CBCT for preoperative diagnosis of posterior maxillary teeth scheduled to undergo apical surgery. Hence, the use of CBCT has been recommended for presurgical planning, and in particular for planning of apical surgery in multi-rooted teeth (Lofthag-Hansen et al., 2007).

Indications for apical surgery have been recently updated by the ESE (European Society of Endodontology, 2006) and include the following:

(1) Radiological findings of apical periodontitis and/or symptoms associated with an obstructed canal (the obstruction proved not to be removable, displacement did not seem feasible or the risk of damage was too great).
(2) Extruded material with clinical or radiological findings of apical periodontitis and/or symptoms continuing over a prolonged period.
(3) Persisting or emerging disease following root-canal treatment when root canal re-treatment is inappropriate.
(4) Perforation of the root or the floor of the pulp chamber and where it is impossible to treat from within the pulp cavity.

Modified indications have been published by Wu et al. (2006). Post-treatment disease following root-canal treatment is most often associated with poor quality procedures that do not remove intra-canal infection. This scenario can be corrected via a non-surgical approach. However, infection remaining in the inaccessible apical areas, extraradicular infection including apically extruded dentin debris with bacteria present in dentinal tubules, true radicular cysts, and foreign body reactions require surgical intervention.

Kim and Kratchman (2006) argued that a surgical approach is more conservative than a non-surgical treatment for certain cases. A common example is a tooth with acceptable endodontics and a new post and crown restoration, but a persistent or enlarging periapical lesion. Breaking or disassembling the crown, removing the post and retreating the canals would be more dramatic, more time consuming, more costly and less predictable than a root-end microsurgical approach, they said.

Contraindications for apical surgery include the following: the tooth has no function (no antagonist, no strategic importance serving as a pillar for a fixed prothesis), the tooth cannot be restored, the tooth has inadequate periodontal support, or the tooth has a vertical root fracture. Additional general contra-indications may be an uncooperative patient or a patient with a compromised medical history for an oral surgical intervention.

3. Microsurgical technique

True progress in apical surgery resulted from the introduction of microsurgical techniques in the mid-1990s. Microsurgical principles in apical surgery include production of a small osteotomy for access to the root end, resection of the root end perpendicular to the long axis of the root, inspection of the resected root face for microstructures, and preparation of a root-end microcavity. These surgical steps are important to minimize surgical trauma and to create optimal conditions for the subsequent root-end filling. Technical requirements for the performance of apical microsurgery include the use of magnification/illumination and microsurgical instruments.

The utilization of a surgical microscope is today considered a must in endodontics. Teaching the use of magnification is now an accreditation requirement of the American Dental Association (ADA) for endodontic speciality programs (Kim and Kratchman, 2006). Several authors have described the benefits of using a surgical microscope in apical surgery as well (Kim, 1997; Rubinstein and Kim, 1999): inspection of the surgical field at high magnification, smaller osteotomy, identification of microstructures (additional canals, isthmus) and root integrity (cracks, fractures, perforations), distinction between bone and root, identification of adjacent important structures (roots of neighboring teeth, maxillary sinus, nasal cavity, mandibular canal, mental foramen, etc.). The use of a surgical microscope also requires an erect posture, thus reducing occupational and physical stress. In addition, video recordings of surgeries can be used for research, education or case documentation.

The incision technique and flap design should be chosen according to clinical and radiographic parameters (von Arx and Salvi, 2008). Clinical issues include: the patient's esthetic demands; condition, biotype and width of gingival tissues, and presence of a restoration margin. Radiographic parameters consist of location and extent of the periapical lesion and status of the marginal periodontium. Interestingly, soft tissue healing following apical surgery has rarely been addressed in the literature, where the focus has always been on the periapical healing. However, gingival recession – including papillae shrinkage and scar tissue formation – is frequent following apical surgery (von Arx et al., 2007a,b,c, 2009).

When apical surgery is planned, in particular in the anterior maxilla (esthetic zone), the patient must be informed about the potential consequences related to a specific incision and flap design. The author has a preference of using the so-called papilla-base incision, and in the esthetic zone, the submarginal incision. The latter avoids gingival recession but is associated with scar tissue formation within the band of keratinized mucosa. The issue of scarring should be discussed with patients who have a very high smile line. If an apico-marginal communication is present (endo-perio lesion), or a cystic lesion extends towards the alveolar crest, an intrasulcular incision is the flap design of choice.

Once the mucoperiosteal flap has been raised, the cortical bone over the root end is removed and the root end is located. The periapical pathological tissue is curetted out to enhance access and visibility of the surgical field. The next surgical step is the root-end resection. The resection plane should be as perpendicular as possible in relation to the long axis of the root. *In vitro* studies have shown that this measure effectively reduces leakage, although no clinical studies have proven such a correlation (Tidmarsh and Arrowsmith, 1989; Gilheany et al., 1994; Gagliani et al., 1998). It is generally suggested to resect the root 3 mm from the root tip to remove the apical delta. However, in re-surgery cases or teeth with long posts or screws, the length of root resection must be individually determined to provide an adequate depth for the root-end filling.

It has been shown that the smoothest surface and the least amount of gutta–percha disturbance were produced by a plain fissure bur in a low-speed handpiece (Nedderman et al., 1988). Another study reported that a multi-purpose bur produced the smoothest and most uniplanar resected root-end surface with the least root shattering compared to a Lindeman bur or a plain fissure bur (Morgan and Marshall, 1998). To ensure minimal disruption and distortion of the root filling and to prevent shredding of the gutta–percha interface, care should be taken to ensure that the final pass of the bur across the root canal is in the correct direction in relation to its direction of rotation (Weston et al., 1999). In roots close to the maxillary sinus or mandibular canal, it is suggested to grind down rather than cut the apical portion in order to avoid untoward displacement of the resected root tip.

Following apical resection, any residual pathological tissue, in particular on the lingual/palatal aspect of the root, is now removed. Prior to a careful inspection of the cut root face, it is important to achieve adequate hemorrhage control. Various hemostatic techniques and agents have been propagated, and all have their own characteristics, with advantages or disadvantages. The latter include insufficient hemostatic effect (collagen products, epinephrine, bone wax) or foreign body reactions (bone wax, aluminium-chloride, ferric sulfate) (Kim and Rethnam, 1997; von Arx et al., 2006). Once hemorrhage control within the bony crypt has been achieved, the surgical field and the exposed root surface as well as the resected root face are stained with 1–2% methylene blue (Cambruzzi et al., 1985). The dye marks organic tissue, but mineralized inorganic tissues are not stained. This measure aids in the identification of the circumference of the resected root end, of microstructures (see below) within the cut root face, and of the remaining pathological tissue.

The next critical step is the inspection of the resected root-end to identify any areas of possible leakage, such as an accessory canal, an isthmus, dentinal cracks, a gap between the existing root-canal filling and the pulp canal wall, and areas of the root canal that have not been negotiated or filled by the orthograde approach. Since the main objective of apical surgery is to avoid re-infection, the tight seal of the mentioned microstructures is essential to prevent egress of bacteria and toxins from the root-canal system into the periradicular tissues. The isthmus between two canals within the same root has been identified as a critical structure for the successful outcome of apical surgery (Weller et al., 1995; Hsu and Kim, 1997; von Arx, 2005a,b). With the help of a surgical microscope, the presence of an isthmus can be recognized and managed appropriately.

A more critical and difficult issue is the presence of dentinal cracks. The use of an (rigid) endoscope appears to be useful for the detection of dentinal cracks (or of other microstructures) at the cut root face (von Arx et al., 2002, 2003a,b; Slaton et al., 2003). However, the clinical relevance of dentinal cracks observed at the resected root surface has not yet been clarified (Morgan and Marshall, 1999). A recent *in vitro* study has found that the presence of cracks originating from the root canal negatively influences the seal of root-end filling materials, and is probably of major clinical importance (de Bruyne and de Moor, 2008).

After the careful check of the resection plane, a retrocavity is prepared into the root-end. This retrocavity should have a depth of 3 mm and should follow the original path of the root canal. The cavity should also include an isthmus or accessory canal, if present. While the conventional technique of root-end cavity preparation, i.e., the use of a small round bur or of an inverted cone bur in an angled micro-handpiece, was problematic with regard to direction and depth of the retrocavity, the development of sonic- or ultrasonic driven microtips (retrotips) was a major breakthrough in apical surgery, and has considerably simplified the technique of root-end cavity preparation (von Arx and Walker, 2000). The small and angled configuration of the microtips does not require an acute bevel of the resection plane; hence, fewer dentin tubules are exposed. In addition, the osteotomy (bony window and bony crypt) can be kept to a minimum with microtips, compared to with conventional rotary instruments. This also leads to less trauma for the patient and faster bony healing (von Arx et al., 2007a,b,c). Concern over the possibility of increased frequency of dentinal cracks following root-end cavity preparation by means of ultrasonic or sonic microtips has been refuted in several clinical and cadaver studies (Calzonetti et al., 1998; Morgan and Marshall, 1999; Gray et al., 2000; de Bruyne and de Moor, 2005).

For root-end filling, a variety of materials have been propagated in the past. Almost every material that was introduced in operative and restorative dentistry as a temporary (Super-EBA, IRM, Cavit, etc.) or permanent (gold, amalgam, resin composite, glass ionomere cement, compomere, etc.) restoration material was sooner or later also utilized in apical surgery. However, mineral trioxide aggregate (MTA) appears to have become the gold standard for a root-end filling material. All clinical comparative studies published to date have reported higher success rates for MTA than for the competitor material (Chong et al., 2003; Lindeboom et al., 2005a,b; von Arx et al., 2007a,b,c; Kim et al., 2008), although the differences were not found to be significant (probably due to the number of treated cases). Although MTA is an expensive material and the clinician has to become familiar with its handling, it has major advantages, including excellent biocompatibility (Camilleri and Pitt Ford, 2006), ideal adherence to the cavity walls and low solubility (Poggio et al., 2007), and cementogenesis at the cut root face, with deposition of new cementum onto the exposed dentin and MTA surfaces (von Arx et al., 2003a,b; Baek et al., 2005; Bernabé et al., 2007). The most recently published randomized clinical trial compared MTA to smoothing of the existing orthograde gutta–percha (GP) root filling. Teeth treated with MTA demonstrated a significantly ($p < 0.001$) better healing (96%) than teeth treated with the smoothening procedure only (52%) (Christiansen et al., 2009). The results emphasize the importance of placing a root-end filling after apical resection.

Before wound closure, the surgical field is carefully checked and rinsed. Adaptation of wound margins is accomplished with single interrupted sutures, preferably utilizing fine suture material (5-0, 6-0, 7-0). Slight compression with gauze is recommended to bring the periosteal tissue in contact with the bone. Sutures are normally removed within 3–5 days after surgery. The prescription of antibiotics has not shown any benefit for immediate postoperative healing (Lindeboom et al., 2005a,b) nor for the 1-year outcome after apical surgery (von Arx et al., 2007a,b,c).

4. Outcome after apical surgery

The treatment outcome of apical surgery should be assessed clinically and radiographically. Reporting the survival rates of apicoectomized teeth without periodic radiographic re-examination is of no clinical value. Only the combination of clinical and radiographic healing criteria is accepted today to determine the outcome of apical surgery (Zuolo et al., 2000). From a practical point of view, healing is normally evaluated 1-year postsurgery, although small (< 5 mm) periapical defects might heal within a few months (Rubinstein and Kim, 1999). Clinical healing is based on the absence of signs and symptoms such as pain, sinus tract, swelling, apico-marginal communication, and tenderness to palpation or percussion. Standard radiographic healing classes include complete healing, incomplete healing (“scar tissue formation”), uncertain healing (partial resolution of postsurgical radiolucency), and unsatisfactory healing (no change or an increase in postsurgical radiolucency). This classification is based on landmark studies that have compared radiographic findings with histopathologic results of periapical tissues of teeth that had to be extracted after apical surgery (Rud et al., 1972; Molven et al., 1987).

With regard to the value of the 1-year control, a few clinical studies have compared the long-term healing with the 1-year results (Halse et al., 1991; Jesslen et al., 1995; Yazdi et al., 2007). A consistently high predictive value (95–97%) was reported for cases successful at the 1-year follow-up remaining so after the long-term re-examination. As a consequence, cases classified as successful do not need to be monitored radiographically at yearly follow-ups unless clinical signs or symptoms are present. In contrast, cases with incomplete, uncertain or unsatisfactory radiographic healing should be re-evaluated clinically and with radiographs (normally at yearly intervals) until a final diagnosis can be made.

With regard to the outcome of apical surgery, inconsistent success rates ranging from 44% to 90% were reported prior to the introduction of microsurgical techniques (Hepworth and Friedman, 1997). However, recent studies have shown that the treatment outcome of apical surgery has considerably improved, and the success rates have approached or exceeded 90% (von Arx, 2005a,b). This tendency of consistently high healing rates after apical (micro-)surgery has been substantiated by several clinical studies published in the last 5 years (Lindeboom et al., 2005a,b; Tsesis et al., 2006; von Arx et al., 2007a,b,c; Kim et al., 2008; Saunders, 2008; Taschieri et al., 2008; Christiansen et al., 2009).

Several studies have also compared the healing outcome of re-surgery and first-time surgery cases (Schwartz-Arad et al., 2003; Wang et al., 2004a,b; von Arx et al., 2007a,b,c). For re-surgery cases, the healing outcome was 7% to 27% lower than for first-time surgery cases. A recent 5-year longitudinal study found a low success rate of 59% for re-surgeries compared to a high success rate of 86% for first-time surgeries (Gagliani et al., 2005).

Another important issue to consider in the healing outcome of apical surgery is the difficulties and challenges of combined endo-perio lesions, in particular the absence of the buccal bone plate with a completely exposed buccal root surface. Only a few clinical studies have compared the healing outcomes in apical surgery of teeth with intact and with missing buccal bone. Wesson and Gale (2003) determined the 5-year success rates associated with molar apical surgery in consideration of the width of the buccal “bone cuff” prior to wound closure. Teeth with a width of 3 mm or greater of cuff had a healing rate of 76%, whereas teeth with no buccal bone cuff had a significantly lower healing rate of 46% ($p < 0.0001$). Kim et al. (2008) reported a successful outcome of 77.5% in apicoectomized teeth with combined endodontic–periodontal lesions, compared to a successful outcome of 95.2% in teeth with isolated endodontic lesions. Teeth with an apico-marginal communication undergoing apical surgery may benefit from further advances and refinement of regenerative techniques. However, due to increased cost and surgical difficulty, regenerative techniques should only be incorporated in apical surgery when indicated, and should be performed by clinicians with appropriate training.

5. Conclusion

Apical surgery is now considered a predictable treatment option to save a tooth with apical pathology that cannot be managed by conventional, non-surgical endodontics. The use of magnification and illumination, preferably a surgical microscope, and the application of microsurgical principles are also important requirements for obtaining successful outcomes after apical surgery.

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