Modern Endodontic Microsurgery Concepts
A Clinical Update

Spyros Floratos, DMD*, Syngcuk Kim, DDS, PhD

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- Microsurgery • Magnification • Surgical operating microscope • Isthmus
- Inspection • Apical surgery

KEY POINTS
- Microsurgical technique is a minimally invasive procedure that results in faster healing and a better patient response.
- Inspection is the key stage of microsurgery that is completely missing from the older surgical technique.
- Untreated isthmuses frequently cause treatments to fail; therefore, they must be identified, cleaned, shaped, and filled as carefully as the root canals.
- By following a strict microsurgical protocol and careful patient selection, almost all lesions of endodontic origin can be successfully treated.

ENDODONTIC MICROSURGERY: PROCEDURAL STEPS

Flap Design

Semilunar incision was the most commonly used incision design in older surgical procedures, especially in the maxillary anterior area. This incision is no longer used, as it does not allow for an adequate access to the surgical site and is related to prolonged inflammation and scar formation on healing of the wound. Modern microsurgery is using the triangular flap with 1 vertical incision, the papilla base incision for preservation of the papillae and the Lübbe-Ochsbein submarginal flap. The last one is the most commonly used esthetic flap design especially in the maxillary anterior area. It is performed within the zone of the attached gingiva and results in almost zero recession of the gum margins and the interdental papillae postoperatively. Therefore, crown margin exposure and formation of “black triangles” in anterior teeth as well as food impaction in posterior teeth is prevented. In microsurgical technique, vertical incisions should be 1.5 to 2 times longer.
than in the traditional technique, so the flap is reflected far away from the light path of the microscope and adequate visibility of the surgical site is achieved.\textsuperscript{4}

**Osteotomy**

In microsurgery, osteotomy becomes more and more conservative thanks to the enhanced magnification and illumination offered by the microscope. The diameter of the osteotomy is only 3 to 4 mm, just enough to allow for a 3-mm ultrasonic tip to vibrate freely within the bone cavity (Figs. 1 and 5).\textsuperscript{5} To prepare a small-size osteotomy, the exact position of the root apex has to be identified. The clinician has to have in mind the following guidelines:

- Sometimes the cortical plate is perforated and the perforation can be identified with a microexplorer under the microscope. In that case, the osteotomy site is obvious. A microexplorer also can penetrate through a thin layer of cortical bone underneath which lies the lesion.
- If there is a sound cortical bone, the measurement of the tooth length by using digital radiograph or even better by using cone-beam computed tomography (CBCT) can give us a precise estimation of the root apex position.
- If there is a periapical lesion extending on both roots of a lower molar, then starting the osteotomy right at the center of the lesion will safely lead us to both mesial and distal root apex.
- If the osteotomy does not reveal the root apex at a depth of 2 to 3 mm, the placement of a radiopaque material on the cortical bone, for example, gutta percha, resilon, aluminum foil, and the acquisition of a periapical radiograph is a clinical technique for root apex identification.

A small-size osteotomy leads to reduced postoperative discomfort and faster healing. A clinical study on healing, as evidenced by radiographic changes, showed that there is a

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**Fig. 1.** Microsurgical technique on mandibular molars. The diameter of the osteotomy is only 3 to 4 mm, just enough to allow for a 3-mm ultrasonic tip to vibrate freely within the bone cavity. The root is resected at a $0^\circ$ to $10^\circ$ bevel.
direct relationship between the size of the osteotomy and the speed of healing: the smaller the osteotomy, the faster the healing. For instance, a lesion smaller than 5 mm would take an average of 6.4 months, a 6-mm to 10-mm-size lesion takes 7.25 months, and larger than 10 mm requires 11 months to heal. Therefore, the osteotomy should be as small as possible, but as large as necessary to accomplish the clinical objective.

**Root Resection**

After granulation tissue is removed to the extent where the root apex is clearly visible, 3 mm of the root tip is resected perpendicular to the long axis of the root (Fig. 4D). A Lindemmann bur should be used in any 45° angled handpiece using copious water spray. Some clinical guidelines during root resection are the following:

- 3 mm of root resection equals to approximately twice the width of a Lindemmann bur.
- After resecting the root end, complete removal of all granulation tissue is facilitated, as there is often remaining granulation tissue behind the root tip.

Endodontic literature over the past 2 decades supports several reasons for resection of the apical part of the root during periapical surgery:

- Removal of pathologic processes.
- Removal of anatomic variations (apical deltas, accessory canals, apical ramifications, severe curves).
- Removal of iatrogenic mishaps (ledges, blockages, perforations, strip perforations, separated instruments).
- Enhanced removal of the granulation tissue.
- Access to the canal system when the coronal access is blocked or when coronal access with nonsurgical retreatment is determined to be impractical, time-consuming, and too invasive.
- Evaluation of the apical seal.
- Creation of an apical seal.
- Reduction of fenestrated root apices.
- Evaluation for complete or incomplete vertical root fractures.

There is no consensus concerning the amount of root that has to be resected. An anatomic study of the root apex conducted at the University of Pennsylvania revealed that at least 3 mm of the root end must be removed to reduce 98% of the apical ramifications and 93% of the lateral canals.

To verify a complete resection of the root tip, the root surface has to be stained with methylene blue and inspected under a medium magnification (×10—×12) for the presence of the periodontal ligament (PDL). When a complete root-end resection has been done, the PDL appears as an uninterrupted circular line around the root surface (Fig. 2). Incomplete root resection is one of the most common reasons for failure of a surgery.

**Root-End Resection: Long Bevel Versus Short Bevel**

With traditional surgical technique, it was recommended that the angle of root-end resection should be 45° to 60° from the long axis of the root facing toward the buccal or facial aspect of the root. However, there is no biological justification for creating a steep bevel on the resected root end. The steeper the bevel, the more potential for one of the following complications to occur:

- Damage to or unnecessary removal of buccal supporting bone.
Incomplete root resection: This can occur particularly on roots that extend rather deep linguually, such as the roots of a mandibular molar.

Root canal anatomy missed on the lingual/palatal aspect of the root. The operator’s spatial disorientation regarding the true long axis of the canal system can be a result of the long bevel. This increases the risk of perforations of the lingual or palatal dentinal walls during root-end preparation (see section on root-end preparation). On the contrary, microsurgery suggests a 0° bevel, perpendicular to the long axis of the tooth (see Fig. 1).

Inspection under high magnification is the key stage of microsurgery that is missing from the traditional surgical technique. A careful inspection will identify the possible reason or reasons for failure of the nonsurgical treatment. Inspection uses the high magnification and illumination that the operating microscope offers. Magnification of the microscope should be set at the range of ×14 to ×25, higher than the rest of the surgical steps. During inspection, the resected root end is rinsed and dried with a Stropko Irrigator (Vista Dental, Racine, WI) (Fig. 3).

The dried surface is then stained with 1% methylene blue, which is applied to the root surface with a microapplicator tip.

Following that, a micromirror is placed at 45° to the resected surface and the reflected view of the root surface shows every anatomic detail of the canal system (Fig. 4A, B, and D).

The most common microfinding seen on inspection is a gap in the filling. That is essentially a space (stained with methylene blue) between the root canal filling material and the adjacent dentinal wall (Fig. 4C).

A complete evaluation involves not only the inspection of the cut root surface, but also of the whole root surface, particularly in cases in which there is a persistent lateral periradicular lesion evident on the radiograph or a lesion that extends alongside the entire length of the root. In this way, a vertical fracture, a perforation, or a lateral exit of an accessory canal may be found.

**Clinical Significance and Management of Isthmus**

An isthmus is a narrow, ribbon-shaped communication between 2 root canals that contains pulp, or pulpally derived tissue (see Fig. 2; Fig. 5). The isthmus is a part
Fig. 3. Tooth #19 apical surgery. The resected surface on the distal root is stained with methylene blue and inspected under a medium magnification (×12). During inspection, the resected root end is dried with a Stropko Irrigator.

Fig. 4. (A) Failed previous endodontic treatment with a periapical lesion on tooth #30. Preoperative radiograph. Apical surgery by use of the microsurgical technique was determined. (B) Inspection of the resected root surface on the distal root was performed by placing a micromirror at a 45° angle to the resected surface (magnification ×8). (C) Inspection revealed a gap in the filling on the distal canal and 3 accessory canals (white arrows) (magnification ×12). (D) By resecting the root face 0.5 mm more coronally, the accessory canals were eliminated (magnification ×12). (E) Root-end filling with MTA on the distal canal (magnification ×12). (F) Postoperative radiograph showing a 3-mm root-end filling coaxial to the distal canal.
of the canal system and not a separate entity. Therefore, it must be cleaned, shaped, and filled as thoroughly as possible. When performing apical surgery, the clinician should be aware that isthmuses are present in premolars and molars in approximately 80% to 90% of cases at the 3 mm level from the apex.\textsuperscript{5,15,16}

When the apical segments of mesial roots of mandibular molars after apical surgery were examined under transmission electron microscopy, in 10 of the 11 root tips that had an isthmus, there were microorganisms present within the isthmus area. These findings prove that the isthmus tissue appears to be the “Achilles' heel” of conventional endodontic treatment.\textsuperscript{17} Moreover, this is one of the reasons why apical root resection alone, without root-end preparation and root-end filling of canals and the isthmus, usually fails. Identification of unnegotiated canals and isthmuses is the first and most important step after root-end resection.

It is essential that the entire canal and isthmus be prepared to a depth of 3 mm. Clinical experience has shown that the main cause of failure after surgery in maxillary and mandibular premolars, mesiobuccal roots of maxillary molars, and mesial roots of mandibular molars, done with a bur and amalgam is the inability to treat the isthmus.\textsuperscript{5,16,18}

Root-End Preparation

Root-end preparation aims at removing the filling material, irritants, necrotic tissue, and remnants from the canals as well as the isthmus and creates a cavity that can be properly filled. The ideal root-end preparation is a class I cavity at least 3 mm
into root dentin (Fig. 4F), with walls parallel to and within the anatomic outline of the root canal space (see Fig. 5). This clinical demand can no longer be satisfied by use of rotary burs in a micro-handpiece, which was the common practice in traditional surgical techniques.

What is clinically important for an efficient ultrasonic preparation is not the brand or type of tip, but how the tip is used. In terms of pressure during ultrasonic preparation, the key is an extremely light touch in a repeated fashion. A lighter touch increases the cutting efficiency, whereas a continuous pressure, similar to the way a handpiece is used, decreases the cutting efficiency. That is because ultrasonics work through vibration, not through pressure. If resistance is met during ultrasonication, then a typical high-pitch sound is produced, indicating that the tip is cutting against dentin. At that point, the operator should stop the preparation, go to a low-range magnification of the microscope, realign the tip with the long axis of the root, and start again. If this step is not taken, then transportation or a perforation of the root might occur either on the lingual or distal dentinal wall.

The clinician should be aware of the following clinical concepts during root-end preparation:

- Root-end preparation begins with aligning a selected ultrasonic tip along the root prominence on the buccal plate under low magnification.
- \( \times 4 \text{–} 8 \) to ensure that the preparation follows the long axis of the root.
- Once the ultrasonic tip is aligned, the preparation is carried out under midrange magnification \( \times 10 \text{–} 12 \).
- Ultrasonic tips are used in a light, sweeping motion: short forward/backward and upward/downward strokes result in effective cutting action.
- Interrupted strokes are more effective than a continuous pressure on the dentin surface.

Once the apical preparation has been completed, gutta percha should be compacted with a microcondenser and the preparation should be dried and inspected with a micromirror. There should be a dry and clean class I cavity coaxial to the root, with no debris or tissue remnants and no filling material left on the axial walls (Fig. 6). Modern ultrasonic tips can facilitate the preparation of a 4-mm, 5-mm, 6-mm, or even 9-mm root-end cavity depending on the length of the unprepared canal space.

**Root-End Filling**

Root-end filling is the last part of the surgical procedure and adequate hemostasis in the bone crypt as well as dryness in the root-end cavity is extremely important. For this reason, an epinephrine-impregnated cotton pellet is left at the depth of the osteotomy to maintain hemostasis as well as to prevent particles of the root-end filling material from falling at the periradicular bone or PDL.

Various materials have been used as root-end filling materials over the past few years: amalgam, gold foil, zinc oxide eugenol cements, Diaket (ESPE GmbH, Seefeld, Germany), glass ionomer cements, composite resins, intermediate restorative material (Caulk/Dentsply, Milford, DE), SuperEBA (Bosworth, Skokie, IL), and mineral trioxide aggregate (MTA; ProRoot MTA; Dentsply, Tulsa, OK). Although none of these satisfy all the requirements of an ideal repair material, MTA has been the material of choice for root-end filling (Fig. 4E, F).

MTA was developed at Loma Linda University in the 1990s as a root-end filling material for endodontic surgery and is now indicated in many clinical settings. MTA demonstrates superior biocompatibility compared with other materials.
promotes tissue regeneration when placed in contact with the periradicular tissues.22

Recently, a number of new bioactive materials based on tricalcium silicate cement have been introduced as potential root-end filling materials due to their ability to release calcium hydroxide in solution.23 Such materials include Biodentine (Septodont, Saint-Maur-des-fosses, France), Bioaggregate (Innovative Bioceramix Inc, Vancouver, Canada) and EndoSequence Root Repair Material (RRM) and Root Repair Putty (RRP) (Brasseler USA, Savannah GA) (see Fig. 5). According to manufacturers, both ERRM and ERRP are produced as premixed, homogeneous and consistent materials. Their physical properties include exceptional dimensional stability, high mechanical bond strength, high pH, and radiopaque and hydrophilic setting properties.24 In vitro studies conclude that ERRM and ERRP have statistically similar levels of cytotoxicity to MTA, thus rendering them biocompatible materials for safe use.24,25 Additional in vitro studies showed that bioceramic RRMs possess antibacterial properties26 and sealing ability,27 similar to those of MTA.

In a recent animal model study, RRM achieved a better tissue healing response adjacent to the resected root-end surface histologically compared with MTA. The superior healing tendency associated with RRM could be detected by CBCT and micro CT but not periapical radiography.28

The main differences between the traditional surgical technique and modern microsurgery are summarized in Table 1.
MICROSURGICAL TECHNIQUE: PROGNOSIS AND TREATMENT OUTCOMES

Until a few years ago, endodontic surgery was faced with skepticism due to the insufficient knowledge of the apical anatomy as well as the reported limited success rate that the older surgical technique offered.

Modern microsurgical periradicular surgery uses certain technical advances, mainly the dental operating microscope, ultrasonics, modern microsurgical instruments, and biocompatible root-end filling materials and has obtained highly successful treatment outcomes. These higher success rates were attributed to a superior inspection of the surgical site and to precise preparation of root-ends with microinstruments using high magnification and enhanced illumination. The clinical success of microsurgically approached cases is reported to be as high as 96.8% and 91.5% at the short-term follow-up after 1 year and the long-term follow-up after 5 to 7 years, respectively. Recent prospective studies with long-term follow-up have presented similar results.

To obtain a successful outcome in terms of healing of the existing periapical pathology, along with a good long-term prognosis in microsurgery, the strict case selection is of paramount importance. Kim and Kratchman suggested a surgical classification A to F for proper case selection. Classes A to C were primarily endodontic lesions; classes D to F were cases with associated periodontal involvement. In a comparison of surgical outcome of these classes, Kim and colleagues found a successful outcome of 95.2% for cases classified as A to C, compared with a success rate of 77.5% for classes D to F. Regenerative methods such as calcium sulfate and collagen membranes were used in the cases with a periodontal component in the pathology. Further investigation should be conducted in treatment of teeth with perio-endo communication via microsurgical and regenerative techniques. The current evidence though shows that microsurgery with regenerative techniques when indicated should be presented to the patient as a treatment option and a predictable and viable solution especially when the tooth is scheduled for an unnecessary extraction and implant placement.

SUMMARY

With a high percentage of successful treatment outcomes of conventional endodontics together with high success of surgical endodontics, almost all teeth...
with endodontic lesions can be successfully treated. The challenge for the future will be the successful and predictable management of perio-endo lesions.

Further well-controlled experiments, clinical as well as biological, need to be conducted on many new techniques and materials to meet the present and future challenges. On the basis of published research, MTA is the material of choice for use in microsurgery, but new bioactive materials, such as bioceramic, seem to be equally reliable and probably more user friendly in clinical practice.

REFERENCES