Introduction

By Surgical Endodontics one refers to that branch of Dentistry that is concerned with the diagnosis and treatment of lesions of endodontic origin that do not respond to conventional endodontic therapy or that cannot be treated by conventional Endodontic therapy. The scope of Surgical Endodontics is to achieve the three dimensional cleaning, shaping and obturation of the apical portion of the root canal system which is not treatable via an access cavity, but only accessible via a surgical flap (Fig. 1). For this reason it is preferable to use the term Surgical Endodontics rather than Endodontic Surgery, in as much as the procedure should be planned and carried out as an endodontic procedure via surgical access and not a surgical procedure done for endodontic reasons.

Once a diagnosis of Endodontic failure has been made, it is necessary to understand what the cause of the failure was so that successively the possibility of correcting the failure by orthograde retreatment can be evaluated.

Only in the case where this possibility does not exist or better still after failure of the non-surgical therapy carried out to resolve the problem, only then is one authorized to intervene surgically. Apical Surgery in other words is not a substitute for incomplete debridement and poor endodontics (Fig. 2).

In agreement with what Nygaard-Ostby and Schilder confirmed, Surgical Endodontics must be reserved for those cases in which the preparation and obturation of the root canal appear impossible right from the beginning or when the non-surgical retreatment attempts have failed.

Nevertheless, even in such cases, the authors recommend filling as much of the root canal by conventional method as possible.

Currently the technique and instruments for clinical retreatment of endodontic failures are so refined that the cases that for certain have to be treated surgically because they cannot be retreated by orthograde means are becoming fewer. Often a high level of Surgical Endodontics experience masks the operators inability to carry out a correct cleaning, shaping and three dimensional obturation of the root canal system by non-surgical means.
Ultimately even after the indication for surgery has been established, in agreement with Weine and Gerstein, it is recommended to remove as much as possible of the inadequate preceding canal obturation material and replace it with well compacted gutta-percha: in this way lateral canals, forgotten additional canals can be filled, often removing the need for surgery (Fig 3).

Nevertheless, in those cases which still have the indication for surgery it is currently possible to have a notably increased percentage of success with the treatment of surgical cases compared with what could be attained up until a few years ago, and this is thanks to recent technological progress that has happened in the field of Surgical Endodontics. In the last 10-15 years two important developments have been introduced in surgical endodontics: the ultrasonic root end preparation and the surgical operating microscope.

Fig. 2
A typical example of Endodontic Surgery: the procedure was carried out after failure of a poorly executed orthograde therapy. a. Preoperative radiograph. b. Postoperative radiograph after orthograde retreatment. c. After a few months the patient presented with a fistula: now there is an indication for surgical retreatment. d. Postoperative radiographs: Super EBA was used as a retrofilling material. e. Two year recall.

Fig. 3a
Due to presence of material beyond the apex and the closeness of the preceding root canal obturation to the bifurcation, there could be an indication for surgical retreatment.
The ultrasonic preparation

For many years the root end has been surgically prepared drilling a class 1 preparation into the dentin, using a straight slow-speed handpiece or a so called “miniature” contra-angle handpiece (Fig. 4) with small round or inverted-cone carbide burs. This approach had many disadvantages, mainly the impossibility to create a preparation in the longitudinal axis of the root canal and to clean the buccal surface of the root end. Trying to give enough retention to the cavity, the risk of a palatal or lingual perforation was always present and the procedure was more and more difficult as the root canal was more and more difficult to reach from the operator. The smallest burs were always too big compared with the diameter of the root canals and the big cavities were therefore more difficult to seal. For the same reason, retropreparations often failed to include isthmus areas.

The introduction of the ultrasonic root end preparation made possible to obtain what is defined as the ideal retropreparation: a class 1 preparation at least 3 mm into the root dentin with walls parallel to and coincident with the anatomic outline of the pulpal space. In order to do this, special ultrasonic tips were developed to enable the clinician to reach every root in all clinical situations. The use of the specifically designed retrotips allows the operator to clean the root canal from an apical approach, leaving clean dentinal walls not only on the lingual or palatal side, but also on the buccal aspect, which was impossible to clean with the previous techniques. The cavity now can be made 3 mm deep, without the necessity of making undercuts, since there is no need of further retention.

The retrotips are of the same size or even smaller compared to the original size of the root canal, so that the retropreparation can be easily and predictably sealed in the maximum respect of the original anatomy. The isthmus area can now be included into the preparation, without damaging or weakening the root, while being extremely conservative in the mesio-distal dimension.
The surgical operating microscope

The introduction of the surgical operating microscope (Fig. 5) represents the other important development in surgical endodontics.2,10 For many years periapical surgery has been performed without any magnification, using the dental light as the only light source to illuminate the surgical field. No surprise therefore if until recently the success rate after surgery was much lower compared to nonsurgical endodontics.4 To increase visibility, surgical telescopes or loops and surgical headlamps became available. Loops are available in a variety of configurations and magnifications, starting from 2x up to 6x, with Galileian optics or prismatic optics. When a fiberoptic headlamp is added to the loops, a coaxial light is projected into the surgical field, so that both magnification and illumination are enhanced. On the other hand, how much magnification is enough? Clinicians who have benefited from the use of loops and headlamps soon understand the limitations of this system. Magnification of 6x sooner or later is not enough anymore and the headlamp is not capable to send the light deep into the canal in surgical and nonsurgical endodontics. The right answer to the previous question is: “enough to see and solve the problem”. The surgical operating microscope has a range of magnifications from 2.5x to 25x and the illumination is coaxial with the line of sight. The coaxial illumination has two advantages:

a) the clinician can look into the surgical field without any shadows (which means that it is possible to examine the cleanliness of the retropreparation during surgical endodontics);

b) since the coaxial illumination is made possible because the operating microscope uses Galileian optics, and since Galileian optics focus at infinity and send parallel beams of light to each eye,
the operator’s eyes are also focusing at infinity and every procedure can be performed without any eye fatigue.

As far as the magnification is concerned, there is no need to go beyond 25-30x. Lower and medium magnifications are used for operating; higher magnifications are used only for observing fine details. Working at high magnifications means to have a very limited depth of field and limited illumination, and therefore is not practical.

The use of the surgical operating microscope has several advantages in surgical endodontics: a) better visualization of the surgical field; b) better evaluation of the surgical technique; c) better accuracy during the entire procedure; d) better predictability of long term results.

For these reasons, the author is firmly convinced that surgical endodontics should not be performed without the use of the microscope, from the incision to the removal of sutures.

Under the microscope, the incision made with the microsurgical scalpel is more accurate, with less trauma to the soft tissue, a more passive flap elevation and later reapproximation is simplified.

At minimum magnification, the entire surgical field can be observed (Fig. 6), looking for the mental nerve (Fig. 7), for instance. The size of the osteotomy is usually small (usually less than 5 mm), big enough to accommodate the ultrasonic tips, which have a tip length of 3 mm. Working at 10x to 20x magnifications, the small osteotomy allows a perfect control of the entire surgical procedure.

Microsurgical technique

Anesthesia

In surgical endodontics the goals in anesthesia are to provide profound anesthesia not only for the procedure, but also for a prolonged period of time following the surgery and also to provide a good hemostasis. For this purpose, the anesthesia of choice is 2% lidocaine with 1:50,000 epinephrine. Other anesthetic solutions with less epinephrine are contraindicated, because the excessive bleeding of the surgical site will compromise surgical visibility. The slow administration of anesthetic solution with 1:50,000 epinephrine has no contraindication even in medically compromised patients. The use of the microscope during the administration of the anesthetic solution is helpful to avoid the injection near bigger capillary vessels and can guarantee almost no bleeding once the needle is removed.

Incision

Using microsurgical scalpel blades...
The microsurgical scalpel blade CK2 by Analytic Endodontics compared with the Bard-Parker #15.

(Fig. 8) under the microscope even at minimum magnification, the surgeon can make a very precise incision with minimum damage to the soft tissue. If enough attached gengiva is present, the mucogengival incision is preferable, in order to preserve the existing epithelial attachment. If there is limited attached gengiva or if there are short roots or large periapical lesions or when the cervical aspect of the root must be examined because for instance a vertical root fracture is suspected, the flap of choice is the triangular or rectangular flap with sulcular incision. In both flaps, the elevation must be undermined, to reduce the trauma to the soft tissue: the elevation begins at the vertical releasing incision and continues to the coronal margins in an apical-coronal direction. The mucogengival incision is scalloped, to facilitate reappraisal.

Osteotomy

With a round surgical bur mounted on a straight slow speed handpiece and under copious irrigation with saline solution the surgeon starts the removal of bone to isolate the root apex. If the cortical plate has been perforated by the lesion, the location of the root apex is very easy and the removal of bone is minimum. If the cortical plate is still intact, the gentle removal continues until a difference in color is appreciated: the yellowish dentin can be easily recognized against the white bone. The osteotomy must be large enough to provide good visibility and to allow the use of all necessary instruments: curettes, retrotips, micropluggers. Once the root apex is identified, the lesion is removed in toto to provide a better control of the bleeding and later a faster healing. The complete removal of the lesion is contraindicated if the aggressive curette-

Apical resection

The apical resection is made using a Lindemann bone-cutting bur on a high speed handpiece specifically designed for oral surgery: it has no air out-put to eliminate the danger of air embolism and the bur is mounted at a 45° angle to enhance visibility under the microscope, especially in posterior teeth. The apical resection is made almost perpendicular to the long axis of the root and must be complete both in bucco-lingual and in mesio-distal directions. The microscope is very helpful in locating the root canal, to evaluate the presence of multiple portals of exit, to locate and then eliminate the extruded filling material and the old and failing amalgam retrograde, the apical root fracture, and the accessory canal on the root surface.

The best way to inspect the surface of the beleved root is painting a small amount of methylene blue dye: it will...
be a lot easier to verify that the root has been completely sectioned, that an isthmus is present, and that a vertical root fracture is present (Figs. 9-16).

Bleeding control

It is imperative that the retrofilling procedure is made in a dry field. For this purpose, the bleeding inside the bony cript must be totally eliminated and totally under control. The dental assistant uses a small suction tip and follows the entire procedure using the assistant scope. She will help to main-

Fig. 9
The methylene blue dye is used to detect an apical root fracture.

Fig. 10
The apical vertical root fracture is now evident.

Fig. 11
After the removal of about 1 mm of root structure and a second application of methylene blue the fracture disappeared: the prognosis is now very good.

Fig. 12
The retropreparation has been completed with ultrasonic tips.

Fig. 13
Fitting the microplugger.

Fig. 14
The retrofilling material (Super EBA) is now carried to the apical preparation.
tain a dry field and a good visibility for the surgeon. If the suction is not enough to keep the blood away from the beveled root surface, a few drops of anesthetic solution with 1:50,000 epinephrine are placed on a sterile gauze and then pushed against the walls of the bony crypt for a few minutes. Another more efficient method to completely eliminate the bleeding from inside the crypt is the use of ferric sulfate, which causes instantly a very good hemostasis, having an extremely low pH (0.21) and causing rapid intravascular coagulation. The use of ferric sulfate has no contraindications, but it must not be used in contact with important anatomic structures, like mandibular or mental nerve, maxillary sinus or floor of the nose. Its use is also to be avoided on the cortical bone and on soft tissues. When the retrofilling procedure is completed and before suturing, it is also imperative to completely remove it in order to avoid a delay in the healing process.6,7

**Apical retropreparation**

A large variety of retrotips are today available to make what has been defined as the ideal retropreparation. Several ultrasonic units specifically designed for root end preparation are also commercially available. The first retrotips introduced into the market were designed by Gary Carr3 and were available in different sizes, the standard CT Tips (Fig. 17) and the smaller SLIM JIM tips (Fig. 18). A special tip to work in roots with a very pronounced lingual inclination is

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**Fig. 15**
The retrograde has been finished.

**Fig. 16**
A. Preoperative film. The first right upper premolar has a broken instrument in the palatal root and guttapercha extruded from the buccal root. During the surgical procedure appeared evident that the guttapercha was extruded through an apical fracture caused during the obturation made with lateral condensation. B. Postoperative film. C. Two year recall.
the Back Action Tip, designed by Gary Carr (Fig. 19).

Recently, Syngcuk Kim designed new tips made in stainless steel coated with zirconium nitride (Fig. 20a). They are called KiS Microsurgical Ultrasonic Instruments and they have several advantage:

a) they are more aggressive and cut dentin faster, without need for repeated ultrasonics
b) the irrigation port has been placed near the working tip, with increased efficiency and more abundant irrigation during the retropreparation (Fig. 20b)

The retrotips should be placed perpendicular to the long axis and then activated. The tips should penetrate the old filling material without resistance. They should be disactivated before their removal from the root canal. This is done to avoid a scratch or any kind of damage to the surface of the root bevel. The removal of the previous failing amalgam retrofill is also facilitated by the use of the retrotips which many times can remove the old filling in one single piece, without risk of tattoo. If the root to be treated has two or more canals, the surgeon must be very careful and look for the isthmus, which contains pulp tissue and debris as any other endodontic space and therefore must be cleaned and incorporated into the retropreparation (Fig. 23). Failure to prepare and seal the isthmus is an invitation for failure. The isthmus sometimes can be so narrow that it is difficult to see even under the microscope. Therefore, as a general rule, in all roots with multiple canals the isthmus must always be prepared, even though we cannot see it with the microscope!

Once the ultrasonic preparation is com-
completed, it is examined for completeness. If debris are still present, the surgeon can use again the retrotip, irrigate and reexamine the retropreparation. The cavity should be 3 mm deep and the walls completely free of the old gutta-percha or sealer (Fig. 24). The operating microscope is crucial to examine the accuracy of the retropreparation and this is done with the use of the micromirror (Fig. 25) after the cavity has been irrigated with saline solution and dried with a light system of air using the Stropko surgical irrigator\textsuperscript{12} (Fig. 26).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{20a}
\caption{The KiS Microsurgical Ultrasonic Tips designed by Syngcuk Kim. Note the irrigation port very close to the working tip.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{20b}
\caption{The KiS Microsurgical Ultrasonic Tips designed by Syngcuk Kim. Note the irrigation port very close to the working tip.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{21}
\caption{The retrotips designed by Elio Berutti are diamond coated (EMS).}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{22}
\caption{The retrotips BK3 designed by Bertrand Khayat (Analytic Endodontics) have three bends specifically made to work easily in posterior teeth.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{23}
\caption{Stereo-microscopic view of the retropreparation made in a third molar by a dental student: the isthmus has been incorporated into the retropreparation, with the maximum respect of the root canal anatomy.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{24}
\caption{Stereo-microscopic view of a clean retropreparation. Stropko surgical irrigator.}
\end{figure}
Root end filling materials

Historically, amalgam has been the retrofilling material of choice for many years, but today it is not used anymore since it has several disadvantages, like corrosion, expansion, and leakage. The most widely accepted retrofilling materials today are zinc oxide-eugenol cements, like IRM and Super EBA. They are easy to manipulate, have adequate working time, dimensionally stable, biocompatible, unaffected by moisture, bacteriostatic, radiopaque, don’t discolor the tooth or the surrounding tissues and are easy to remove.

The Super EBA cement is mixed to a putty consistency, shaped into a narrow cone, attached to the end of a spoon excavator or a little spatula and carried to the apical preparation (Fig. 27). The cone of material reaches the base of the preparation and the sides of the cone contact the walls. Between each aliquot of material, a pre-fitted plunger is used to condense the Super EBA. The material is condensed in excess on the beveled surface of the root using a ball burnisher (Fig. 28). When the cement has set, a finishing bur is used to finish the retrofilling (Fig. 29). The integrity of Super EBA is then examined at high magnification after the surface has been dried with the Stropko irrigator (Fig. 30). A post-operative radiograph is now exposed and then the surgeon is ready to suture the flap.

As an alternative to ZOE cements, a new material has been recently introduced in endodontic surgery as a retrofilling material (Fig. 31). Mineral Trioxide Aggregate is a powder consisting of fine hydrophilic particles of tricalcium silicate, tricalcium aluminate, tricalcium oxide and silicate oxide. It also contains small amounts of other mineral oxides, which modify its chemical and physical properties and make the material radiopaque. Hydration of the powder results in a colloidal gel that solidifies to a hard structure in approximately three hours. MTA has several advantages:

1) easy to mix and place into the cavity with a small carrier...
b) since it sets in the presence of moisture, it is not moisture sensitive
c) seals better than amalgam or Super EBA
d) has a better adaptation to the surrounding dentin
e) has excellent biocompatibility
f) activates cementogenesis (Figs. 32-33).

MTA can be difficult to manipulate in narrow retropreparation and the long setting time could be considered a disadvantage.

Suture
Suturing under the operating microscope has the advantage of being more accurate in repositioning the flap, allowing a
perfect healing by primary intention, without any scar tissue. The author disagrees with people who recommend the use of the microscope for osteotomy, curettage, apicectomy, apical preparation, retrofilling and documentation but not for suturing as well as for the incision. Suturing under the microscope can be difficult sometimes, especially in posterior regions, but the accuracy in reapproximation provided by the microscope cannot be compared with that provided by the use of loops.

Ideally, the suture must keep the soft tissue in place during the time of healing and should not encourage colonization of bacteria. If repositioning has been accurate as it should be, healing occurs by primary intention in 24-48 hours and this is the reason why suture removal is indicated after 24-48 hours. When left in place for a longer period of time, the suture has no function and is simply an irritant: soon it will be completely covered by bacteria and will cause inflammation and delayed healing by secondary intention.

Many suture materials are commercially available today. Silk is not recommended anymore because it encourages colonization by bacteria. Nylon is colonized more slowly, but is too rigid and often patients complain because the suture is irritating the lip or the cheek. Tevdek is a newly introduced suture made of a polytetrafluoroethylene impregnated polyester material. It is very resistant to bacterial colonization and is nonirritating. The suggested size of the suture is 6-0 (Figs. 34 and 35).

Conclusion

Endodontic surgery can today be performed with an accuracy and predictability.
lity of results that were not possible to reach 10 or 15 years ago. Magnification and illumination together with the new instruments and materials provide a higher success rate than ever before (Fig. 36).

Using the microscope, the incision is more accurate, the elevation of the flap is less traumatizing for the soft tissues, the osteotomy and the apicectomy are more conservative. Using the ultrasonic tips the retropreparation is more precise, coaxial with the root canal, the entire circumference is cleaner, the retrofill is also more accurate, and the exact repositioning of the soft tissue guarantees a perfect healing without any scar. For all these reasons, the surgical procedure is more predictable and the success rate is very high.

Fig. 36
A. Preoperative film. B. Two year recall. Note the retrofilling made in Super EBA, 3 mm long, in the long axis and of the same size like the original root canal.
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BIBLIOGRAPHY


