Contemporary Endodontic Surgery

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ABSTRACT

During the past decade, endodontics has seen a dramatic shift in the application of periradicular surgery and the role it plays in endodontic treatment. With the introduction of enhanced magnification, periradicular ultrasonics and other associative technologies, teeth that might otherwise be extracted now have a chance for retention. This article describes the role of these advances in contemporary endodontic surgery.

Nonsurgical root canal therapy is a highly successful procedure if diagnosis and technical aspects are carefully performed. There is a common belief that if root canal therapy fails, surgery is indicated for correction. This is not always true; most failures are best corrected by retreatment. Studies have shown that a majority of retreated cases are successful following retreatment.[1-5] There are, however, situations in which surgery is necessary to retain a tooth that would otherwise be extracted. The purpose of this article is to briefly describe indications and contraindications as well as the steps involved and new advances in periradicular surgery. The details for this procedure can be found in surgical and nonsurgical endodontic text books.[6-8]

Indications and Contraindications for Periradicular Surgery

The main indications for periradicular surgery are: complex root canal anatomy, procedural accidents (**Figure 1**), irretrievable materials in the root canal (**Figure 2**), symptomatic cases, horizontal apical fracture, biopsy (**Figure 3**) and corrective surgery (**Figure 4**). Contraindications are relatively few. There are four major categories: (1) anatomic factors, (2) medical or systemic complications, (3) indiscriminate use of surgery, and (4) unidentified cause of treatment failure.

Steps in Periradicular Surgery

The typical sequence of procedures used in periradicular surgery are flap design, incision and reflection, apical access, periradicular curettage, root-end resection, root-end cavity preparation, root-end filling, flap replacement and suturing, postoperative care and instructions, suture removal and evaluation.

Recent Advances in Endodontic Surgery

Many advances in surgical technique and instrumentation have occurred over the past decade. They include enhanced magnification and illumination, ultrasonic tips, micro-

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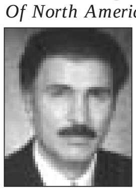

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Figure 1a. A separated file is present in the mesial root of the first mandibular molar.

Figure 1b. Presence of symptoms required to perform an apical surgery and placement of MTA as a root-end filling material.

Figure 1c. Complete periradicular healing is observed three years following surgery.

Figure 2a. A failing root canal treatment required surgery.

Figure 2b. The root end is resected, a cavity is prepared and is filled with MTA.

Figure 2c. A post-operative film after one year showing complete healing.

Figure 3. Periradicular radiolucency simulates a periapical lesion of pulpal origin. A biopsy showed presence of squamous cell carcinoma.

instruments and newer root-end filling materials.

Enhanced Illumination and Magnification Magnification and Illumination

Perhaps the most important development in surgical endodontics in recent years has been the introduction of the surgical operating microscope (SOM). A few years ago, a handful of endodontists throughout the United States and Europe began experimenting with the SOM to determine whether any of its applications could be used in endodontic surgery.[9-14] They believed they could achieve better results if they were able to further magnify and illuminate the surgical field beyond what was available with conventional loupes and surgical headlamps. After using the SOM, they realized cases that once seemed impossible became easier and more exciting to operate. Otologists were the first medical specialists to introduce the SOM in the early 1940s. Initially, loupes seemed adequate, and emphasis was placed on improving their function. At that time, many clinicians felt the SOM would make highly successful operations complicated and time consuming. Over time, they recognized advantages such as wider fields, variable magnification, better depth of focus, and coaxial illumination. Slowly, the use of the SOM was introduced into ophthalmology, and finally into neurosurgery in 1967, when UCLA's Dr. Peter Jannetta devised a microscopic procedure called micro-vascular decompression to treat trigeminal neuralgia.[15]

Most dentists have had clinical expe-

Figure 4a. An off-centered post has perforated the root and has caused a bony lesion. Internal and external perforation repairs with MTA resulted in complete repair of the bony lesion in three years (C).

Figure 4b. Internal and external perforation repairs with MTA resulted in complete repair of the bony lesion in three years (C).

Figure 4c. *Courtesy of Dr. Noah Chivian.*

rience with conventional surgical telescopes or loupes and surgical headlamps, which are commonly available in a variety of configurations and magnifications. When a fiber optic headlamp system is added to the armamentarium, white light is projected coaxially with the line of sight into the surgical field, and surgical and nonsurgical endodontic procedures can be performed with less eyestrain and fatigue. Clinicians who have used surgical telescopes and surgical headlamps have benefited from the expanded use of magnification and illumination. But how much magnification is enough? Most microscopes have the ability to go to magnifications of x 40 and beyond (**Figure 5**). However, limitations in depth of field and illumination make this impractical. Therefore, magnifications in the range of x 2.5 to x 30 are recommended. The lower magnifications (x 2.5 to x 8) are used for orientation to the surgical field and allow a wide field of view. Midrange magnifications (x 10 to x 16) are used for operating. Higher range magnifications (x 20 to x 30) are used for examining fine detail.

Areas in which the SOM can have its greatest impact include the following: visualizing the surgical field; evaluating the surgical technique; reducing the number of radiographs needed; expanding patient education through video use; providing reports to referring dentists

Figure 5. JEDMED/KAPS SOM 62 (Jedmed Instrument Company, St. Louis, Mo.) power zoom and power focus microscope, with 35 mm and video cameras.

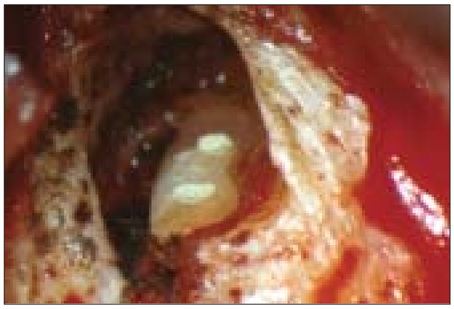

Figure 6. Final retrofills on the beveled surface of a maxillary right first bicuspid (x 13).

and insurance companies as well as creating documentation for legal purposes.

The most significant advantage of using the SOM is in visualizing the surgical field. It is truly educational to enlarge the periradicular region before our eyes. **Figure 6** shows SuperEBA retrofills in the buccal and lingual canals of the resected root surface of a maxillary right first bicuspid. They clearly illustrate the benefits of enhanced magnification and illumination achieved with an SOM. If you can see a task better, you can do it better, and performing endodontic surgery is no exception. Fractures, accessory canals, canal isthmuses, and fins can readily be observed and dealt with accordingly (**Figures 7 and 8**).

Microsurgical Technique

With the SOM, we can better locate surgical access entry sites and remove osseous tissue with more precision. Periapical curettage is facilitated because bony margins can be scrutinized for completeness of tissue removal (**Figure 9**). More efficient removal of granulomatous tissue can aid wound healing.

Root-end resection is performed with a 170L tapered fissure bur in an Impact Air 45 handpiece (SybronEndo; Orange, Calif.) (**Figures 10-12**). This handpiece was originally designed for oral surgeons who needed more access when sectioning third molars. Because the turbine is offset at 45 degrees, the operator can use this handpiece to gain better access to the

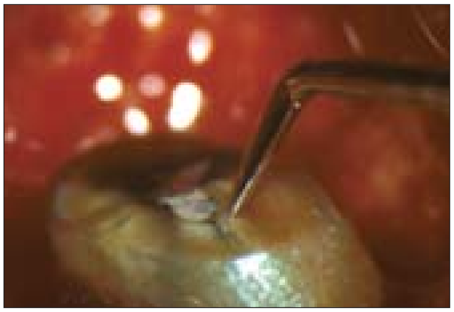

Figure 7. A microsurgical explorer pointing out a microfracture on the beveled surface of a maxillary left lateral incisor (x 20).

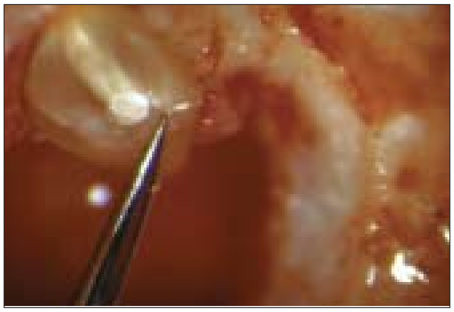

Figure 8. A microsurgical explorer pointing out an accessory canal on the beveled surface of a mandibular right first bicuspid (x 16).

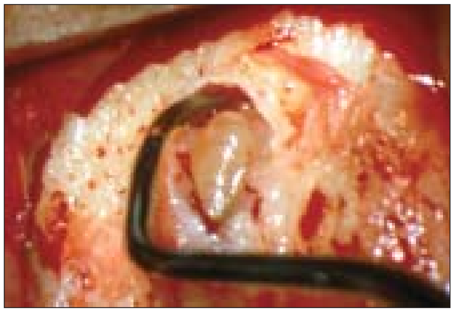

Figure 9. Periapical curettage of a maxillary right first bicuspid (x 8).

Figure 10. 170L tapered fissure bur in an Impact Air 45 handpiece.

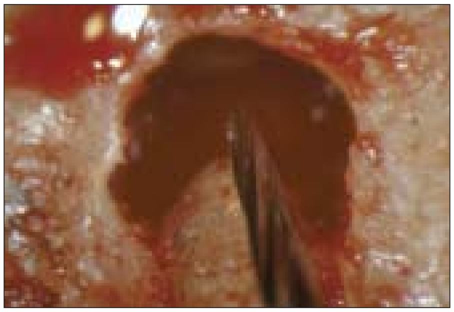

Figure 11. 170L tapered fissure bur in an Impact Air 45 handpiece placed against the apex of a maxillary left lateral incisor just before activation (x 16).

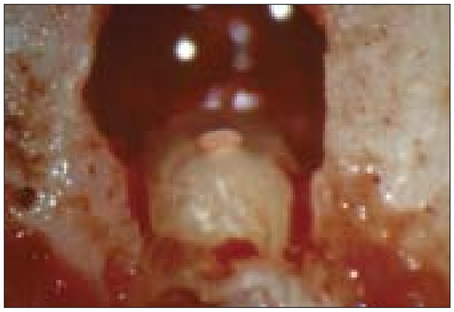

Figure 12. The beveled surface of the root of a maxillary left lateral incisor (x 16).

apices of maxillary and mandibular molars. When used in conjunction with the SOM, a long-shanked surgical bur can be placed with a high level of accuracy in the posterior regions of the mouth. When using the handpiece, the water spray is aimed directly into the surgical field but the air stream is ejected out through the back of the handpiece, thus eliminating much of the splatter that occurs with conventional high-speed handpieces. Because there is no pressurized air or water, the chances of producing pyemia and embolism are significantly reduced. The handpiece can be autoclaved, and a fiber optic system is available as an option.

After the root-end resection has been completed, the beveled surface can be easily examined for the presence of an isthmus, a very common finding. Recent studies[16,17] have revealed presence of a complete or partial isthmus at the 4 mm level of the mesiobuccal root of the maxillary first molar 100 percent of the time, and a complete isthmus in 90 percent of the time at the 3 mm level of the mesial root of the mandibular first molar (**Figure 13**).

Ultrasonic Tips

Apical preparations are now made with ultrasonic tips. Next to the SOM, the most exciting advancement in endodontic surgical technology has been in piezoelectric ultrasonic. Dentists are familiar with ultrasonic root scaling and ultrasonic cleaning and shaping of root canal systems. Piezoelectric ultrasonic units contain mechanisms that create ultrasonic vibrations in the range of 25 kHz to 40 kHz by exciting piezoelectric crystals in the handpiece. The units are self-tuning regardless of changes in scaler tip, file, or load, for maximum stability during operation. Water for cavitation and air pressure for activation are regulated by foot control. Continuous irrigation along the scaler or file cools the cutting surface while maximizing debridement and cleaning.

Various types of stainless-steel and diamond coated ultrasonic tips are available for apical preparation. The tips are 0.25 mm in diameter and about 3 mm in length. By comparison they are about one-tenth the size of a conventional micro-head handpiece (**Figure 14**).

A variety of tips are available to accommodate virtually all access situations. When used, they are placed in the long axis of the root so that the walls of the preparation will be parallel and encompass about 3 mm of the apical morphology. As the piezoelectric crystal in the handpiece is activated, the ener-

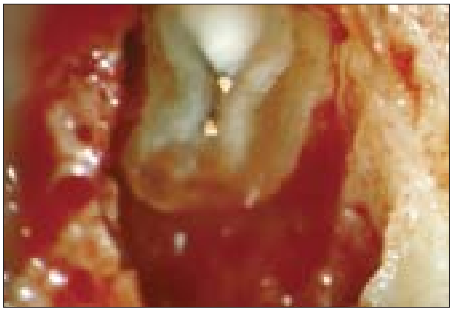

Figure 13. Isthmus on the beveled surface of the mesial root of a mandibular left first molar (x 16).

Figure 14. Ultrasonic tip and microhead handpiece with a No. 1 round bur.

Figure 15. Ultrasonic tip after activation, approximately 3 mm into the apical preparation (x 16).

Figure 16. Apical preparation of the root of a maxillary left lateral incisor using a 3 mm microsurgical mirror. Note the gutta-percha at the base of the preparation.

Figure 17. One-half millimeter blunt Blue Micro Tip (Vista Specialty Products, Racine, Wisc.) mounted in a Stropko Irrigator on a tri-flow syringe.

gy is transferred to the ultrasonic tip, which then moves forward and backward in a single plane. Typically, a 3 mm preparation takes about one to two minutes. The advantages of the ultrasonic tips over burs are:

- Smaller apical preparations[18]
- Cleaner apical preparations[18]
- Easier isthmus preparations between the exits of apical canals
- Easier access to the root tips
- Lesser strain and fatigue for the operator
- Better apical preparations (parallel walls in the long axis of the root)[18]

The combination of the SOM and ultrasonic tips make previously challenging cases much easier. Apical preparation can be visualized and executed with a level of confidence that was previously unattainable. By combining magnification and ultrasonics, preparation of the apex can be conservative and can actually be viewed in the axial plane of the root (**Figure 15**).

Instrument Miniaturization

Magnification in endodontic surgery has led to miniaturization of endodontic surgical instruments. The entire armamentarium of the endodontic surgery has improved to facilitate precise treatment on tooth structures at magnifications of 15 to 30 times. Many standard operative and surgical dental instruments are no longer useful or appropriate for surgery when using the SOM.

Micro-Mirrors

Another development in endodontic microsurgery is the introduction of the surgical micro-mirror. These mirrors come in a variety of shapes and sizes and have diameters ranging from 1 mm to 5 mm. By using the SOM, it is now possible to look up into the apical preparation to check for completeness of tissue removal (**Figure 16**). Before using these mirrors, it was impossible to assess the thoroughness of apical preparation. Failure to completely remove old root canal filling material and debris from the facial wall of the apical preparation before placement of an apical seal may be the cause of surgical failures in the past.

Microsurgical Irrigation

Traditionally, practitioners dried apical preparations with paper points prior to placing root-end filling materials. A recently developed microsurgical irrigator now fits over the tri-flow syringe and allows for the directional micro-control of air and water (**Figure 17**). This instrument allows the apical preparation to be completely rinsed, dried and inspected with microsurgical mirrors before placement of a root-end filling material.

Today, practitioners can make apical preparations with a high level of confidence and accuracy with the combination of microscopic visualization, micro-mirrors, ultrasonic tips and microsurgical irrigators. Together with miniature carriers, condensers and pluggers, endodontists can now predictably identify and treat complex root canal anatomy, often overlooked in the past.

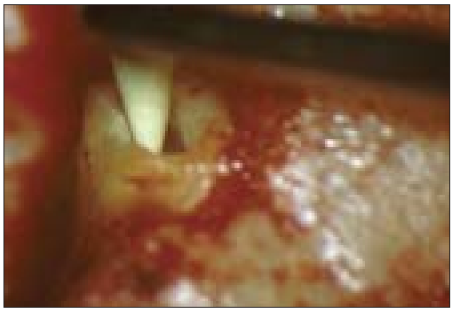

Figure 18. Placing retrofill material in the apical preparation of the root of a maxillary right lateral incisor with a No. 12 spoon excavator (x 16).

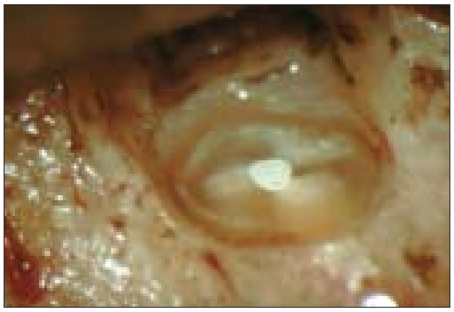

Figure 19. Finished retrofill of the root of a maxillary left cuspid (x 16).

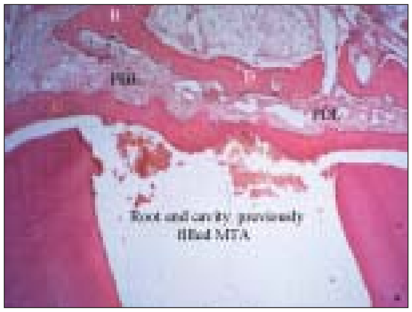

Figure 20. Histological section of a monkey tooth filled with MTA as a root-end filling material demonstrates the regeneration of cementum over the resected root and MTA root-end filling material.

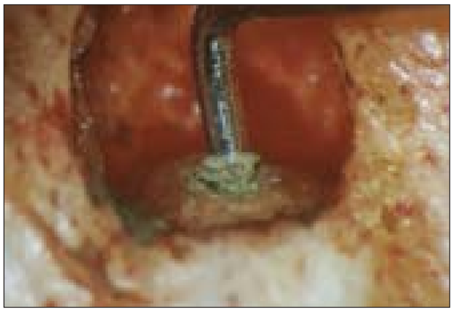

Figure 21. Condensing MTA with a P-1 plugger (x 16).

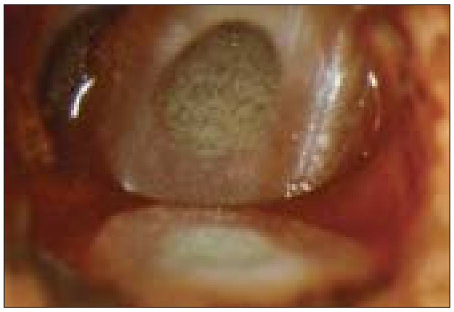

Figure 22. Micro-mirror view of finished MTA (x 16).

Figure 23. (Clockwise from top) Working ends of a P-1 plugger, the ball burnishing end of a B-3 plugger, opposite ends of a Stropko double-ended condenser, and working end of a P-2 (which is a "cowhorn" version of the P-1).

Root-End Filling Materials

After the apical preparation is thoroughly dried and examined, it is ready to be filled with a root-end filling material. The ideal root-end filling material should be biocompatible with periradicular tissues, resistant to absorption or breakdown by tissue fluids, and hermetically seal the canal.[19]

Cement consistency root-end filling materials such as SuperEBA and ProRoot MTA (Dentsply; Tulsa, Okla.) are currently the materials of choice. SuperEBA is mixed to a putty consistency and carried to the apical preparation in small, truncated cones 1 mm to 2 mm in size on a No. 12 spoon excavator (**Figure 18**). The cross-sectional diameter of this instrument is 1 mm; therefore, it does not block visual access to the apical preparation. The tip of the cone reaches the base of the preparation as the sides of the cone contact the walls. Between each aliquot of material, a P-1 plugger is used to condense the SuperEBA. The P-1 plugger is a double-ended instrument with right-angled condensing surfaces of 0.25 mm and 0.50 mm on opposite ends. Additional aliquots of SuperEBA are added and condensed until there is a slight excess mound of material on the beveled surface of the root. Final compaction is accomplished with the ball burnishing end of a B-3 plugger (SybronEndo; Orange, Calif.). When the cement has set, an ET UF9 30-fluted finishing bur (Brasseler; Savannah, Ga.) or a smooth diamond is used to finish the procedure (**Figure 19**).

After the SuperEBA has been finished, a CX-1 microsurgical explorer is used to check for marginal adaptation and integrity. This is an extremely sharp instrument and caution must be exercised during its use. Final examination of the root-end filling is performed after the surface has been dried with a Stropko Irrigator, because it is more accurate to check the margins of the preparation when the beveled surface of the root is dry.

A new root-end filling material, mineral trioxide aggregate (MTA) is proving to be an impressive material for various endodontic uses including root-end filling and perforation repairs.[20] A tri-calcium compound, it provides excellent sealing properties and is extremely biocompatible with periradicular tissues. MTA provides a superior apical seal compared to other root-end filling materials and is not adversely affected by blood contamination. In

several studies, histological sections demonstrate the regeneration of new cementum over the MTA root-end filling,[20] a phenomenon that is not seen with other commonly used root-end filling materials (**Figure 20**).

ProRoot MTA is mixed with the supplied liquid to a very thick and dry consistency and carried to the apical preparation in a 0.90 mm diameter MAP System carrier (Roydent Dental Products; Johnson City, Tenn.). This carrier fits inside the apical preparation and allows for accurate placement of ProRoot MTA. The material is condensed with a P-1 plugger (**Figure 21**), and additional increments are added until the material is flush with the beveled surface. The ProRoot MTA is then finished with moist gauze and inspected with a micro-mirror (**Figure 22**).

The Effect Of New Advances On The Other Aspects Of Periradicular Surgery

As our surgical technique is re-evaluated, one of the natural consequences will involve modifying some of our surgical instruments. Many of the instruments now available will have to be redesigned with the endodontic micro-surgeon in mind. Conventional pluggers, curettes, and microamalgam carriers are just too big to work in small places. Several instrument companies have designed instruments for the various stages of endodontic microsurgery from flap design to flap closure (**Figure 23**).

The radiograph has been an essential tool for the endodontist. Although the SOM will not replace the radiograph in surgery, we can use fewer radiographs per procedure because we can see well by direct visualization. The bony crypt can be scrutinized for small particles of root-end filling material, lessening the need to stop the surgery and take a check radiograph. This decreases the patient's exposure to radiation.

Patient education can be a valuable result of videotaping through a video camera, which can be mounted on the surgical microscope. After surgery, the procedure can be viewed on a high-resolution monitor with the patient. The videotape can be viewed in its entirety or highlighted by using the fast-forward on the VCR. Most patients are quite receptive to reviewing the procedure post-surgically. This results in a better appreciation of the technology by the patient.

Most endodontists send their referring dentists a final radiograph of the completed case as part of the surgical report. An exciting addition to the final radiograph can be a video print of the completed case. Video printers have been available on the consumer market for some time and can easily be connected to a VCR or the video camera mounted on the microscope. A micro-computer inside the video printer automatically analyzes the image, and prints are created in 70 seconds by a high-density sublimation dye process. The video prints are 4 inches by 6 inches. Many different images can be digitized during the surgery and later recorded on a single print. Digital cameras can also be mounted to the microscope and images can be exported for use in computer presentations.

Most insurance companies require a radiograph of a completed surgical case before claim settlement. Often, the inclusion of a video print or a portion of videotape can help an insurance consultant get a better understanding of what occurred during the periradicular surgery. This can clarify and expedite claim processing.

Risk management is a familiar term to all of us. In addition to providing our patients with drawings and written surgical consents, videotaping certain high-risk procedures may provide the documentation necessary to prevail in a lawsuit. Videotaping has become a common practice in many medical specialties.

Does it Really Make a Difference?

A frequently asked question is, "Does it really make a difference?" A recent prospective study[17] showed that the one-year healing rates of endodontic surgery performed under the SOM in conjunction with microsurgical technique was 96.8 percent. A long-term follow up of these cases showed that 91.5 percent of these cases remained healed after five to seven years.[21] Although it is impossible to tell whether the unusually high success rate resulted from the technique or the material, the clinical impression is that it is both the technique and the material with the emphasis on technique. Similar results are expected with ProRoot MTA.

Summary

Endodontic surgery is not "oral surgery" in the traditional sense. Rather, this procedure is actually "endodontic treatment-through a surgical flap." Simply cutting off the apex of a root and placing a filling in the vicinity of the canal does not accomplish the goals of surgical endodontic treatment. Endodontic surgery should result in sealing of all portals of exits to the root canal system and the isthmuses, eliminate bacteria and their byproducts from contaminating the periradicular tissues, and provide an environment that allows for regeneration of periradicular tissues. To accomplish these goals, endodontists have developed new techniques, materials and instruments. Enhanced illumination and magnification have greatly improved what practitioners can perform. Developments in root-end filling materials have increased both quality and biocompatibility of apical seals. Together, these advances have significantly improved the state of the art and science of endodontic surgery, giving a second chance to a tooth that was considered for extraction. **CDA**

References / 1. Bergenholtz G, Lekholm U, et al, Retreatment of endodontic fillings. *Scand J Dent Res* 87:217-24,1979.

2. Allen R, Newton C, Brown C, A statistical analysis of surgical and nonsurgical endodontic retreatment cases. *J Endodon* 15(6):261-6, 1989.

3. Sjogren U, Hagglund B, et al, Factors affecting the long-term results of endodontic treatment. *J Endodon* 16(10):498-504, 1990.

4. Van Nieuwenhuysen J, Aouar M, D'Hoore W, Retreatment or radiographic monitoring in endodontics. *Int Endod J* 27:75-1, 1994.

5. Sundqvist G, Figdor D, et al, Microbiologic analysis of teeth with failed endodontic treatment and outcome of conservative retreatment. *Oral Surg* 85:86-3, 1998.

6. Gutmann JL, Harrison JW, Surgical Endodontics. Boston, Blackwell Scientific, 1991

7. Arens DE, Torabinejad M, Chivian N, Rubinstein R, Practical lessons in endodontic surgery. Chicago, IL, 1998, Quintessence Publishing Co., Inc.

8. McDonald NJ, Torabinejad M, Endodontic surgery In: Principles and practice of endodontics by: Walton RE and Torabinejad M. W. B. SAUNDERS COMPANY, Philadelphia Penn., 2002.

9. Rubinstein RA, New horizons in endodontic surgery, Part I: The operating microscope. *Oak County (MI) Dent Review* 30(12):7, 1991.

10. Rubinstein RA, New horizons in endodontic surgery, part II: Periapical ultrasonics and more. *Oak County (MI) Dent Review* 30(13):9,1991.

11. Carr G,Microscopes in endodontics. *Calif Dent Assoc J* (11):55-1, 1992.

12. Pecora G, Andreana S, Use of dental operating microscope in endodontic surgery. *Oral Surg Oral Med Oral Pathol* 75:751-8, 1993.

13. Pecora G, Covani U, Giardino L, Rubinstein R,Valutazioni clinico-statistiche sull'uso dello stereomicroscopio in odontoiatria. *Riv Ital D Stoma* 8:425-1, 1993.

14. Izawa T, Kim S, Suda H, Pecora G, Rubinstein R: Microscopic endodontic surgery. *Quintessence Int* (Japan) 13:54-5, 1994.

15. Shelton M, Working in a Very Small Place: The Making of a Neurosurgeon. Ed 1, New York, Vintage, 1989.

16. Weller N, Niemczyk S, Kim, S, The incidence and position of the canal isthmus: part 1. The mesiobuccal root of the maxillary first molar. *J Endodon* 21:380-3, 1995.

17. Rubinstein R, Kim S, Short-term observation of the results of endodontic surgery with the use of a surgical operation microscope and SuperEBA as root-end filling material. *J Endodon* 25:43-8, 1999.

18. Wuchenich G, Meadows D, Torabinejad M, A comparison between two root-end preparation techniques in human cadavers and burs. *J Endodon* 20: 279-2, 1994.

19. Torabinejad M, Watson TF, Pitt Ford TR, The sealing ability of a Mineral Trioxide Aggregate as a retrograde root filling material. *J Endodon* 19:591-5, 1993.

20. Torabinejad M, Chivian N, Clinical applications of Mineral Trioxide Aggregate. *J Endodon* 1999; 25:197-205.

21. Rubinstein R, Kim S, Long-term follow-up of cases considered healed one year after apical microsurgery. *J Endodon* 28:378-3, 2002.

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