ARTICLE 4

# 21ST-CENTURY ENDODONTICS

GERALD N. GLICKMAN, D.D.S., M.S., M.B.A.; KENNETH A. KOCH, D.M.D.

A B S T R A C T

**Background.** Endodontics as a discipline has offered patients the opportunity to maintain their natural teeth. As the population expands and ages, the demand for endodontic therapy can be expected to increase as patients seek dental options to keep their teeth for a lifetime.

**Clinical Implications.** New materials, techniques and instruments are entering the marketplace to assist dentists in providing patients with more predictable and reliable endodontic treatment. In addition, these new systems make the delivery of endodontic services more efficient. This article describes these advances in endodontic treatment for dentists interested in incorporating these advances into their clinical practice.

Over the past decade, nickel titanium rotary instrumentation, microscopic endodontics, digital radiography, a plethora of obturation systems, and biocompatible sealing materials have helped practitioners perform endodontic procedures more effectively and efficiently than ever before. This is not implying that endodontic treatment has become easier; however, better tools and technology have made it more predictable and challenge us to take on a wider variety of complex cases.

Diagnosis, in fact, has become more challenging. Overall, case management is more complex as geriatric patients and those who are medically compromised are more inclined to seek treatment to save their teeth.

In the 21st century, as long as basic principles of endodontic therapy are followed, the equipment and tools that clinicians now have available to them increase the chances for predictable outcomes when performing endodontic therapy.

This article focuses on the new technology of the "endodontic revolution" underway. Research and development in key endodontic areas needing major improvement are also addressed.

## NICKEL TITANIUM ROTARY INSTRUMENTATION

The introduction of nickel titanium, or NiTi, rotary instrumentation has made endodontics easier and faster than hand instrumentation, resulting in consistent and predictable root canal shaping. The rotary technique is less fatiguing for the practitioner and NiTi decreases postoperative pain for the patient, most likely due to a combination of file design and a crown-down modality. Rotary instrumentation, however, is not a panacea for every case. By incorporating a hybrid technique that combines variable tapers, different systems (including hand filing) and modification of individual techniques, many of the endodontic problems that had arisen during the early years of rotary instrumentation have become noticeably reduced.

NiTi is extremely flexible; it is five times more flexible than stainless steel and appears to be 10 times more resistant to stress.[1] The metal is superelastic[2] and has the additional property of shape memory. Research investigations have proven that NiTi is biocompatible and anticorrosive and does not weaken following sterilization.[3,4] However, it is not easy to manufacture. What is interesting about this alloy is that it can exist in either one of two crystalline phases. When NiTi file is at rest, it is in the austenite stage. When this alloy is torqued and placed under stress, it transforms into martensite; this is known as a martensitic deformation and is typical of alloys that are superelastic. When the file is fluctuating between transformations (for example, while rotating and being torqued within a canal), the instrument is more susceptible to permanent deformation and fracture or separation. This problem can be alleviated by understanding respective system usage and limitations, using consistent and constant revolutions per minute, using unstressed files and passively using files to resistance rather than forcing them.

While air turbine motors can achieve the goal of using NiTi files at a consistent and constant RPM, there has been a noticeable shift to electric engines. Electric engines generally offer a more consistent RPM, are smoother than air turbines and are noticeably quieter. As electric engines have become more popular, they have continued to evolve. Practitioners can now operate files with torque-control electric engines. The advantage of a torque-control engine is that when a file is stressed beyond a certain preset limit, the file will automatically reverse and, in certain cases, back itself out of the canal. This is a decided safety factor and obviously beneficial for the practitioner. Torque-control engines will continue to evolve to the point where the engines will be able to recognize the various files when placed in the contra-angle handpiece. This is where technology is heading in modern endodontics. Most companies that manufacture rotary files have electric engines that are associated with their systems. There are also battery-charged portable engines that have torque control capabilities. Certainly, an advantage of these engines is their portability, but a primary disadvantage is their need for recharging.

Historically, there have been two major techniques to clean and shape root canals: step-back and crown-down. The step-back preparation[5] results in a conservative apical preparation with coronal flaring. Research has shown that step-back can give predictable results, but it can be time-consuming as well as frustrating since a number of procedural errors can readily occur with this technique. In turn, the crown-down method[6] is increasing in popularity among general practitioners and specialists. The method initiates shaping from the coronal third first; the apical preparation is completed last. The crown-down preparation is beneficial because it allows for early removal of coronal dentin, often the major restrictor to achieving and maintaining working length throughout any cleaning and shaping procedure. In turn, the crown-down method allows for a more efficient mechanism to shape canals, irrespective of whether stainless steel or NiTi files are used, hand or rotary. However, due to the absolute necessity to limit stress on NiTi files and due to the availability of increased tapers, crown-down is an essential principle of all NiTi rotary techniques.[7] With step-back, the clinician would instrument a small canal with a hand file and feel a no. 25 or no. 30 file binding. The thought was that the file was binding in the apical few millimeters. In actuality, the file was not binding in the apical third but rather in the coronal half of the canal. By using a crown-down technique, the cervical constricture is eliminated and the coronal dentin is passively removed with larger files or reamers; in turn, a smaller file proceeds unhindered into the apical third of the canal, resulting in increased tactile awareness in the apical third of the canal. Hence, a file that does not bind in the coronal half, only in the apical one-third, possesses exquisite proprioceptive properties.

In addition, the crown-down technique enhances the efficacy of the endodontic irrigant sodium hypochlorite, or NaOCl (2.5 percent or 5.25 percent); early funneling of the canal permits a quicker and deeper penetration of the apical portion of the canal with the irrigant. The sooner and the more readily available NaOCl is to the apical third, the longer the antimicrobial and tissue-dissolving properties of NaOCl can be effective.

When the increased irrigation efficacy is combined with a design of a rotary file that helps pull debris coronally, there appears to be less postoperative discomfort. With a significant amount of hand filing in the apical third of a canal, especially with a traditional step-back, a piston effect is created that often pushes debris periapically. However, with rotary instrumentation and a crown-down technique, tissue and debris are pulled more coronally rather

***When increased irrigation efficacy is combined with a rotary file that helps pull debris coronally, there appears to be less postoperative discomfort.***

Figure 1. Four canals on mandibular molar were prepared using nickel titanium, or NiTi, rotary files.

Figure 2. Three canals on mandibular molar were prepared using nickel titanium, or NiTi, rotary files. Note abrupt curvatures in the mesial canals.

than being pushed apically.

Traditionally, Gates-Glidden drills, Peeso reamers and even large files have been used to enlarge the coronal portion of the root canal. Hand instruments such as K-type files, reamers and Hedströms as well as sonics have been used to instrument the body of the canal; apical preparation historically has been performed with either K-type files or reamers.

New technology, however, has resulted in the use of NiTi rotary files throughout the entire body of the root canal. This ability to use NiTi rotaries in such a manner is a result of both the material and design of the instruments. Currently, there are tip designs in both cutting and noncutting modes, the noncutting tip being the safer. The practitioner can also select cutting edges that can be neutral in design or slightly more positive. Additionally, some files have incorporated radial lands into their design. The radial lands, particularly in combination with noncutting tips, help maintain file centering in the root canal, significantly reducing canal transportation.

Irrespective of the system chosen, rotary instrumentation results in a consistent and smooth preparation. For the practitioner, NiTi rotary instrumentation helps reduce hand fatigue and enhances practice efficiency.

Currently, there are a number of rotary systems available. The major systems include the Profile Rotary System (Dentsply Tulsa), the Profile GT Rotary System (Dentsply Tulsa), the Quantec Series 2000 (Analytic Endodontics), the Lightspeed System (Lightspeed), and the Power-R System (Moyco/Union Broach). The majority of these systems use tapered files with a combination of tip designs to create their preparations and shapes. The only exception to this is the Lightspeed system, which uses a Gates-Glidden (U-blade)–type design to create a circular apical preparation.

Obviously, NiTi rotary instrumentation has been the driving force in changing how root canals are shaped (Figures 1 and 2), but it is also important to realize that there are some limiting factors associated with NiTi. For example, NiTi rotaries cannot be used to bypass or remove ledges; a curved stainless steel hand file is still required to "get around" and smooth out the ledge.

A learning curve exists for all rotary instrumentation systems, as well. It cannot be stressed enough that one needs to take hands-on courses and practice before incorporating any system into clinical practice.

NiTi is more expensive than stainless steel, but the benefits of rotary instrumentation make the increased costs much more acceptable.

Lastly is the universal concern for file separation. Concerning longevity, NiTi rotary files are no more susceptible to breakage than stainless steel files so long as all principles of rotary instrumentation are strictly adhered to, clinicians understand and master the respective systems prior to clinical use, and proper usage and disposal schedules are developed for NiTi. In addition, it is important to understand what causes breakage. Aberrant canal anatomy, instrument fatigue and improper usage patterns can contribute to file separation. It is much more critical in a rotary technique to fully comprehend the canal anatomy of each canal. For example, NiTi files should be avoided in canal systems where two canals come together, when a canal bifurcates or where there is an "S" curve. During use, clinicians should continually observe for instrument fatigue, as any overuse or abuse of files will predispose them to failure. How a NiTi file is used and the type of canal form it is used in are probably just as critical as how many times a respective file is used; for example, calcified and severely curved canals will logically stress NiTi files more than patent straighter canals. Usage and constant monitoring is additionally important because these files need to operate at the proper RPM and in a consistent manner.

Although rotary instrumentation with NiTi has proven to be a valid and science-based modality, with many dental schools already incorporating the concept into their predoctoral curricula, there will likely be change in the years ahead. For example, there could be new shape memory alloys developed with superior properties over NiTi. Nevertheless, there is no question that NiTi rotary instrumentation has solidly established its presence in the clinical domains of some of dentistry's harshest skeptics, but most likely, this is just the beginning of a period of dramatic change in how root canal systems are cleaned and shaped.

## OBTURATION SYSTEMS

During the past 15 years, great efforts have been made to enhance the manipulative properties of gutta-percha by thermoplasticizing the rubberlike material before its insertion or thermosoftening the gutta-percha once it has been cemented in the canal "cold." As a result, obturation systems have evolved that use heat-softened gutta-percha delivered via injection or via a carrier, and that deliver heat to cold gutta-percha cones cemented in place. Much of the research on such systems has focused on their sealing properties in vitro; few long-term clinical studies are currently available. A significant component of the scientific literature, however, has focused on these techniques and has found them to be comparable to the traditional techniques of cold lateral compaction and warm vertical compaction.[7,8]

***This is just the beginning of a period of dramatic change in how root canal systems are cleaned and shaped.***

Two important principles must be conveyed to all practitioners about obturation techniques. First, no filling method will be effective without proper cleaning and shaping of the root canal system. Second, although some of the systems may appear rather simple to use, they do in fact require a thorough understanding of the respective principles and a rather long learning curve in order to achieve predictable outcomes.

Core-carrier systems such as Thermafil Plus (Dentsply Tulsa), Densfil (Dentsply), and Soft-Core (Soft-Core) have the unique characteristic of using a carrier to "carry" or deliver a warmed or thermoplasticized layer of gutta-percha to a sealer-lined canal; in turn, the entire carrier remains in the canal along with the compacted gutta-percha unless a portion of the carrier is removed to allow for post space. Various types of ovens/heaters are used to quickly heat-soften the obturator prior to its insertion. These carriers are made of solid or hollow plastic or metal, either stainless steel or titanium. The plastic carriers are more tapered than the metal carriers and act to compact the gutta-percha apically as well as laterally.

SimpliFill (Lightspeed) is designed to be used as a filling technique for canals prepared using the Lightspeed instrumentation technique. Apical GP plug carriers, corresponding to the same size as the master apical rotary size achieved with Lightspeed, are used to deliver a cone of gutta-percha to the apical one-third of the canal. A specially-designed rotary condenser (Microseal, Analytical Endodontics) carrying warm gutta-percha is inserted along the laterally compacted master core of gutta-percha. The handpiece is run to deposit and amalgamate the two forms of gutta-percha.

The Obtura (Obtura), affectionately known as the "gutta-gun," delivers thermoplasticized gutta-percha into a canal through special needles attached to the heating gun. The Obtura can now be used for backfilling and within a matter of seconds, the remainder of the canal is sealed.[9] The Obtura is especially beneficial for large canals, resorptive defects and complex anatomy.

The System B (Analytic Endodontics) was developed as an alternative to the traditional method of warm vertical condensation, which many firmly believe is a very time-consuming and tedious procedure. The System B uses one plugger in one continuous sweeping motion—thus the name "continuous wave technique"—to thermoplasticize and compact a cemented gutta-percha cone in the apical one-third of the canal. The remaining coronal two-thirds of the canal can be backfilled with the Obtura or with another method.

Although the clinician has a variety of obturation techniques to choose from today, he or she should keep in mind that as of the year 2000, there is no method that produces a leakproof seal. In light of this, perhaps one of the biggest challenges that faces endodontics in this millennium is to find a gutta-percha replacement: a material that can form a leakproof seal that is bioinductive and promotes regeneration, or a "smart" material that can adapt to the ever-changing microenvironment of the canal system. These descriptions serve as potential directives for research and development efforts in endodontics.

## MICROSCOPY AND ENDOSCOPY

Enhanced magnification and illumination systems have raised the "awareness level" of what practitioners can visualize and perform. Conditions that were once almost impossible to manage and had unpredictable results can now be predictably managed simply because one has the ability to see better. The advent of endodontic microscopy[10] and endoscopy has opened up a whole new world of exploration. A few years ago, only a few clinicians believed in its utility; now graduates of advanced education programs in endodontics are required to be competent in microscopy. With magnifications of ×10 and beyond, the clinician can look for fractures or cracks and can even evaluate the quality of a restorative procedure.

With respect to nonsurgical endodontic therapy, the microscope can facilitate the location of a hidden or calcified canal. Subsequent to the rise of microscopy came microsurgical armamentaria. Instruments such as microforceps and microextractor tubes for removing obstructions, micropluggers and micropaddles for repairing stripping perforations, and ultrasonic tips for preparing root-end cavity preparations or removing restorative materials are now in the marketplace.

The introduction of endoscopy[11] at the turn of the millennium involves using a fiberoptic probe to explore internal and external components of the root canal. Images taken via the probe are projected on a video monitor for evaluation purposes. Besides aiding the clinician in diagnosis and technique, the ability to communicate to a patient what is being viewed educates the patient and thereby enhances the doctor-patient interrelationship. One day, clinicians should be able to perform basic endodontic procedures in real time using endoscopy.

At this time, the microscope is a tool and its use is not a part of the standard of care for endodontic therapy. Only until scientific studies are available to prove that a higher degree of success is obtained in endodontic therapy via microscopy can one speculate as to whether or not microscopy is becoming the standard. However, most individuals would generally agree that if clinicians see something better, they should be able to evaluate and manage it better. Much of the research in microscopy is currently evaluating whether this concept is indeed true.[12]

## MINERAL TRIOXIDE AGGREGATE

Mineral trioxide aggregate, or MTA (ProRoot MTA, Dentsply Tulsa), is one of the newest and most promising materials to enter the realm of endodontics in many years. This root canal repair material is a grayish powder consisting of fine, hydrophilic particles that set in the presence of moisture. The hydration of the powder—composed of tricalcium silicate, tricalcium phosphate, tricalcium oxide and others—creates a colloidal gel that solidifies to form a strong impermeable barrier. The material sets within three to four hours and has a working time of five minutes. MTA has been shown to be biocompatible[13] and has compressive strength equal to that of intermediate restorative material, or IRM.

Dye studies[14] have indicated the sealability of MTA to be superior to amalgam and equal or better than other contemporary root end filling materials. Histologically, cementogenesis has been induced when MTA was used as a surgical root-end filling material. Although the material is somewhat costly and difficult to work with, primarily due to its naturally sandy consistency when hydrated, the indications for its usage include clinical scenarios when there are often no other viable options, especially perforation repair. Clinical case reports have been published to validate its potential value in such instances. Indications for MTA include pulp capping, internal repair of perforations (noncommunicative), apexification and root-end filling.[15] In the near future, a white powder form of MTA will be on the market so that any potential staining of tooth structure is eliminated when used in an area where esthetics is an issue.

### DIGITAL RADIOGRAPHY

Digital radiography has revolutionized clinical dentistry probably more than any of the aforementioned advances.[16] A filmless and paperless office is no longer a vision on the horizon. Historically, digital radiography was developed commercially to reduce radiation exposure. A special sensor was developed to replace the traditional film. When radiation is detected, the sensor transmits the information to the computer, displaying the image on a screen. This instantaneous "digitized" image can be analyzed, manipulated, measured, stored and transmitted electronically. No chemical developing is necessary.

The benefits of digitization are overwhelming. For patients, there is a 60 to 90 percent reduction in radiation exposure, thus alleviating most of their concerns about radiation exposure. Patients also have the advantage of viewing an image of their tooth on a large screen. As the doctor explains the nature of the problem, while showing it to the patients, patients become more involved in the clinical decision-making and treatment.

Currently, there are two basic mechanisms of digital radiography. Direct digital imaging involves the use of a sensor that is directly wired to the computer. Systems such as DenOptix (Dentsply/Gendex), RVGui (Trex Trophy), CDR (Schick Technologies) and Dexis Digital X-Ray (Provision Dental Systems) use this approach.

Indirect imaging or cordless systems such as Digora (Soredex) and DenOptix Digital Imaging System (Dentsply/Gendex) involve the use of a reusable filmlike pack without wires. This essentially records an image that must be scanned to digitize the image before it can be viewed on the computer. Although indirect imaging still incorporates reduced radiation exposure and image manipulation, it usually takes a few minutes before the image can be viewed. Since digital radiography is undergoing rapid change, the prospective buyer is faced with numerous concerns: costs, changing hardware, variable sensor type and size, resolution, storage and image manipulation software, computer interfacing, and so on.

The future of digital imaging looks promising as the technology continues to advance and more imaginative and universal systems are engineered.

***Ultrasonic instrumentation has enabled the clinician to overcome many of the problems that have been associated with conventional forms of endodontic root-end preparation.***

### ULTRASONICS

For periradicular surgical procedures involving root-end restoration preparation, ultrasonic instrumentation has enabled the clinician to overcome many of the problems that have been associated with conventional forms of endodontic root-end preparation. The miniature-sized tips allow for precise designing of the preparation within the long axis of the root canal, including safe removal of isthmus tissue. Over the years, conventional burs used on microcontra-angled handpieces have been difficult to control, often resulting in overpreparation or perforation, preparations not within the long axis of the canal, and rough and irregular outline forms. In addition, in order to permit positioning of the head of the microcontra-angled handpiece in close proximity to the root-end, additional amounts of osseous structure had to be removed to align the bur parallel with the long axis of the root. Further compromising the biological status of the tooth is the additional beveling of the root-end that was needed simply to obtain access. With ultrasonics, beveling can be minimized, thereby exposing fewer tubules and preserving more root structure.

Ultrasonic systems usually feature a miniature handpiece attached to an ultrasonic unit. A variety of stainless steel and titanium tips are available with different features depending on the requirements of the case. Some tips are now being manufactured with a diamond or zirconium nitride coating and are purported to cut dentin faster. For nonsurgical cases, conventional tips with increased lengths and restricted diameters are available for finely controlled removal of canal calcifications, obstructions and posts. Retroprep tips, most with 3 millimeter lengths, .25-mm tip diameters and variable angulations, can be selected for virtually any root form and position.

It is important to note that any form of enhanced magnification such as loupes or microscopy with illumination facilitates the use of ultrasonics for both orthograde and surgical endodontics.

### THIRD-GENERATION APEX LOCATORS

Many of the problems with previous generations of apex locators occurred when the root canal contained moisture-rich substances such as exudate, electrolytes like sodium hypochlorite and the products of hemorrhage. The new third-generation apex locators have overcome most of these problems, are more user-friendly and require minimal calibration. More importantly is the revelation that modern-day apex locators may even be more reliable than radiographic interpretation. Studies evaluating apex locators have demonstrated accuracies of working length determination to within 0.5 mm from the apical constriction, ranging from 75 percent to 93.4 percent.[17,18] Nonetheless, using today's apex locator in conjunction with a radiograph is still an extremely effective adjunct for determining working length and detecting perforations or root fractures.

Current apex locators utilize an alternating current within the canal and monitor the impedance between periapical tissue and oral mucosa via a lip clip. The circuitry within the machine calculates the impedance between the file tip and lip mucosa; the apex is detected using the calculated impedance via needle pointers, sounds, lights, digital reads or various combinations thereof depending on the machine used.

New technology in this area has resulted in microprocessors that measure frequency shifts and apical capacitances. As a result, accuracy of these locators has improved, especially in the presence of anatomical aberrations and canal moisture. Examples of these include the Root ZX (J. Morita USA), the Justwo (Medidenta International) and the Endex (Osada Inc.). Some of these use an alternating current of at least two frequencies, and measure and compare the two electrical impedances.

This millennium is certain to deliver even more accurate apex locators, perhaps even totally eliminating working length images. However, even if that goal is never attained, there are obvious advantages with the third-generation apex locators available today. These include an accurate working length determination, thereby reducing overall radiation exposure, as only a minimal number of images would be required. With accurate readings, there may be less chance for over- or underinstrumentation. Also, patient treatment time would be reduced as the result of the speed at which a length can be determined or verified.

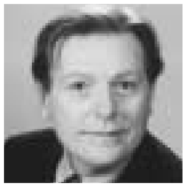
### 21ST CENTURY TECHNOLOGY AND PREDICTIONS

The explosive development of new technology in endodontic therapy, as well as innovative solutions to previously unanswered questions, will continue at an exponential rate well into this millennium. Although the latest tools for performing endodontics, such as rotary instrumentation and thermoplastic obturation techniques, have elevated the specialty to a level of sophistication never before attained, a number of areas remain that require significant advancement. First and foremost is the area of diagnostics. While medicine has catapulted itself in the areas of prevention and diagnosis, endodontics is lagging behind in these areas. For example, a chairside "litmus paper test" of the dentinal fluid of a vital tooth could be a valuable tool to instantaneously analyze the biological status of the pulp. A heavy infiltrate of inflammatory mediators could suggest an irreversibly inflamed pulp prior to any development of symptoms. As a result, diagnosis becomes more prevention-oriented than treatment-oriented. Pulpal diagnosis may no longer be strictly based upon ice application or tapping a tooth with the end of a mirror handle. Scenarios such as these are not too far off in the distant future.

Priority areas in endodontics that necessitate further research and product development include creative and biological methods for

- eliminating pulpal tissue in toto with "sterilization" of the root canal system;
- predictably repairing cracked and vertically fractured teeth

Dr. Glickman is an associate professor and the chair of the Department of Stomatology and director of Graduate Endodontics at the University of Texas-Houston Dental Branch. He maintains a part-time private practice limited to endodontics in Houston. Address reprint requests to Dr. Glickman at Department of Stomatology, University of Texas-Houston Dental Branch, Suite 375, 6516 John Freeman Ave., Houston, Texas 77030.



Dr. Koch is an endodontist and director, Professional Services, Dentsply Endodontics, Tulsa, Okla.

using bioinductive regenerative materials;
- creating the ideal endodontic file;
- replacing gutta-percha with a biological polymer or "smart material" that would greatly respond with property changes to minute physical or chemical stimuli within the microenvironment of the canal.

To imagine an endodontic obturating material that would completely seal a system and alter its structure or release a chemical in response to a pH change or bacterial influx is another possibility. The future of endodontics has never looked so bright, promising and exciting. ■

1. Walia H, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;4:346-51.
2. Stoeckel D, Yu W. Superelastic Ni-Ti wire. Wire J Int March 1991;45-50.
3. Serene TP. Nickel-titanium instruments in endodontics. In: Clark's clinical dentistry. Vol. 4. St. Louis: Mosby; 1997:1-7.
4. Serene TP, Adams JD, Saxena A. Nickel titanium instruments: Applications in endodontics. St. Louis: Ishiyaku EuroAmerica; 1994:1-5, 15-33.
5. Mullaney TP. Instrumentation of finely curved canals. Dent Clin North Am 1979;23:575-92.
6. Morgan LF, Montgomery S. An evaluation of the crown-down pressureless technique. J Endod 1984;10:491-8.
7. Gutmann JL, Saunders WP, Saunders EM, Nguyen L. An assessment of the plastic Thermafil obturation technique. Part 2. Material adaptation and sealability. Int Endod J 1993;26:179-83.
8. Budd CS, Weller RN, Kulild JC. A comparison of thermoplasticized injectable gutta-percha obturation techniques. J Endod 1991;17:260-4.
9. Johnson BT, Bond MS. Leakage associated with single or multiple increment backfill with the Obtura II gutta-percha system. J Endod 1999;25:613-4.
10. Mines P, Loushine RJ, West LA, Liewehr FR, Zadinsky JR. Use of the microscope in endodontics: a report based on a questionnaire. J Endod 1999;25:755-8.
11. Bahcall JK, DiFiore PM, Poulakidas TK. An endoscopic technique for endodontic surgery. J Endod 1999;25:132-5.
12. Baldassari-Cruz LA, Wilcox LR. Effectiveness of gutta-percha removal with and without the microscope. J Endod 1999;25:627-8.
13. Torabinejad M, Hong CU, Pitt Ford TR, Kettering JD. Cytotoxicity of four root end filling materials. J Endod 1995;21:489-92.
14. Torabinejad M, Higa RK, McKendry DJ, Pitt Ford TR. Dye leakage of four root end filling materials: effects of blood contamination. J Endod 1994;20:159-63.
15. Torabinejad M, Chivian N. Clinical applications of mineral trioxide aggregate. J Endod 1999;25:197-205.
16. Mouyen M, Benz C, Sonnabend E, Lodter J. Presentation and physical evaluation of RadioVisioGraphy. Oral Surg Oral Med Oral Pathol 1989;68:238-42.
17. Dunlap CA, Remeikis NA, BeGole EA, Rauschenberger CR. An in vivo evaluation of an electronic apex locator that uses the ratio method in vital and necrotic canals. J Endod 1998;24:48-50.
18. Pratten DH, McDonald NJ. Comparison of radiographic and electronic working lengths. J Endod 1996;22:173-6.