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Nonsurgical ultrasonic endodontic instruments

Mian K. Iqbal, BDS, DMD, MS

Department of Endodontics, The Robert Schattner Center, University of Pennsylvania, School of Dental Medicine, 240 South 40th Street, Philadelphia, PA 19104-6030, USA

One of the most important advancements in endodontics has been the use of the surgical operating microscope, which in turn necessitated the evolution of a number of microendodontic instruments. Among these, ultrasonic instruments have improved the most. Ultrasonic technology has been available for a long time [1]; the only thing needed to make a modern-day ultrasonic instrument was incorporation of a contra-angle bend and parallel working ends. The contra-angle design allowed for dramatic improvement in procedural access for both anterior and posterior teeth, in addition to an unobtrusive view under the microscope.

Ultrasonic instruments play an ever-increasing role in several aspects of endodontic treatment. Teeth with root canal obstructions are no longer automatically treatment planned for surgical endodontics; endodontic retreatment has become the procedure of choice. In addition, root canal obstructions are being removed in a more conservative manner that does not unnecessarily destroy the root structure. The identification of missed and hidden canals has become a predictable outcome rather than a serendipitous discovery. Access cavities are being cut and refined with greater precision, opening up gateways to better endodontics. Above all, these procedures are no longer being performed blindly; instead the clinician is now able to maintain visual contact with the operating field at all times during ultrasonic procedures.

The ultrasonic technique is essentially a nonrotary method of cutting dental hard tissue and restorative materials using piezo-electric oscillations. Cutting dentine structure with ultrasonic tips is analogous to cutting dentine with the thinnest bur imaginable. Because the operating field is so restricted, the use of high magnification and proper illumination is essential during the use of these instruments. The combination of ultrasonic instruments with the

E-mail address: miqbal@pobox.upenn.edu

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magnification and illumination provided by surgical operating microscope has been termed microultrasonics.

A variety of ultrasonic tip designs are available, varying in complexity from simple curves to multiangled bends. These tips can be long and slender or short and sturdy; they also can be end cutting or side cutting, and made of different materials such as stainless steel or titanium alloys. Stainless steel tips may be coated with zirconium nitride or diamond grit to increase efficiency and durability. Some tips are designed to function dry, whereas others come with water ports to increase the cooling and washing effect. A thorough understanding of these and other variables is critical for the proper selection and usage of ultrasonic tips.

Almost all of the currently available systems provide the option for using ultrasonic instruments in a wet or dry field. The advantages of a wet field include easier washing of the field and the cooling effect. However, the area must be dried to provide the clinician with a clearer view of the operating field. A Stropko surgical irrigator (EIE/Analytic Technology, Orange, California) may be used to work continuously in a dry field. The device attaches to a standard quick-change air–water syringe and can be used to blow air on the field to maintain visibility. This allows the clinician to maintain visual contact with the operating field at all times during the procedure. The irrigator not only delivers a controlled stream of water and air to precisely irrigate and dry the operative field, but also prevents the development of localized emphysema.

Today, ultrasonic tips are being made and coated with different materials. The Enac ultrasonic endodontic system (Osada Electric Co., Tokyo, Japan) uses stainless steel tips that are effective and very economical (Fig. 1). To improve efficiency, ultrasonic instruments also have been manufactured with a coating of zirconium nitride (ProUltra ultrasonic instruments; Dentsply, Tulsa, Oklahoma). These tips are designed to function dry. CPR ultrasonic instruments (Spartan CPR instruments, Fenton, Missouri) are similar in design to the ProUltra instruments, except that they are diamond coated and have built-in water ports (Fig. 2). These instruments are designed primarily to function on Spartan Piezo-Electric units (Obtura/Spartan, Fenton, Missouri). Diamond-coated tips purportedly last longer and are associated with greater efficiency when compared to uncoated or zirconium nitride-coated tips. Both the CPR and ProUltra systems also are accompanied by a set of slender and long tips made from titanium alloys (Fig. 3). Titanium alloy provides flexibility and greater vibratory motion to the tips. These tips are end cutting and are employed for cutting deep inside the root canals. Recently, a set of BUC (Fig. 4) access refinement tips (Spartan instruments) have been introduced to the market. The BUC tips also are diamond coated and have built-in waters ports that constantly bath the activated tips. The "4" series (Sybron Endo, West Collins Orange, California) is another popular system that is geared for troughing around posts and opening calcified canals (Fig. 5).

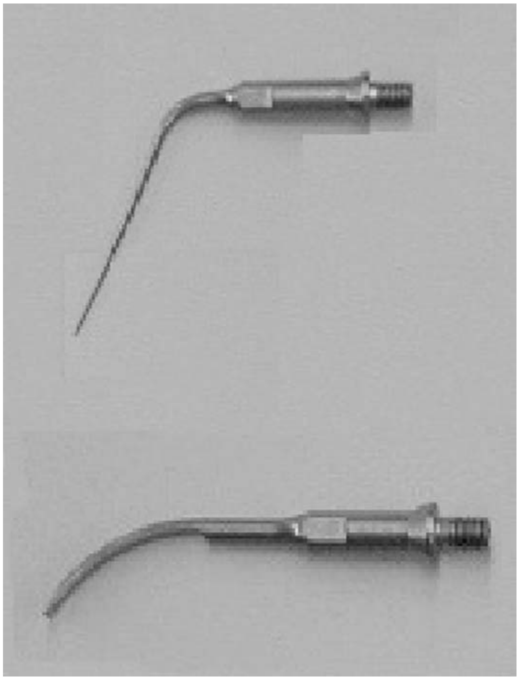

Fig. 1. Two tips from the Osada Enac ultrasonic endodontic system. The ST21, shown at the top, is used for removing solids from root canals. The bottom picture shows the vibratory tip ST09.

Breakage of ultrasonic tips is a common phenomenon. Once broken, these tips usually jump out of the canal or can be retrieved easily. However, some of these tips are quite expensive and must be used properly to avoid unnecessary breakage. The most common reason that tips break is because

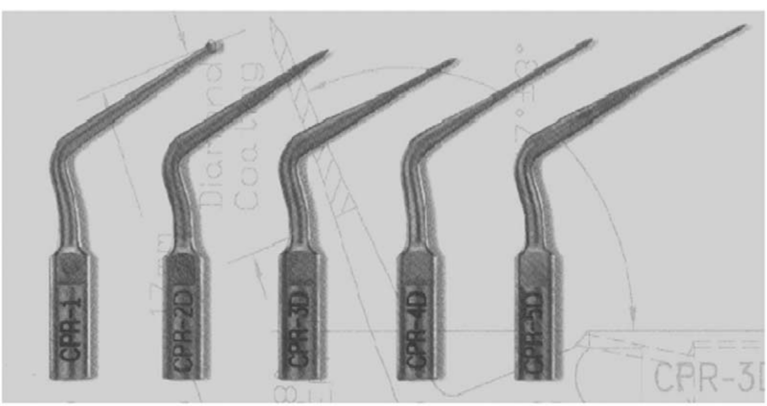

Fig. 2. Retreatment CPR tips 2D through 5D are diamond coated with built-in water ports that allow for wet or dry cutting.

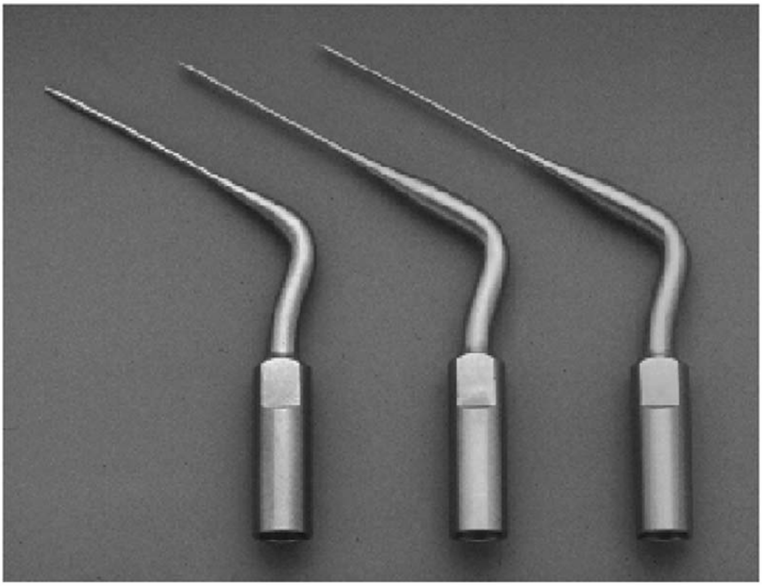

Fig. 3. Titanium CPR ultrasonic tips 6 through 8.

they are not operated at their recommended frequencies. Therefore, it is important to follow the manufacturer's recommendations with regard to the ultrasonic intensity at which a particular tip must be used. The results of a recent study [2] revealed a significant increase in displacement amplitude

Fig. 4. BUC access refinement tips 1 through 3.

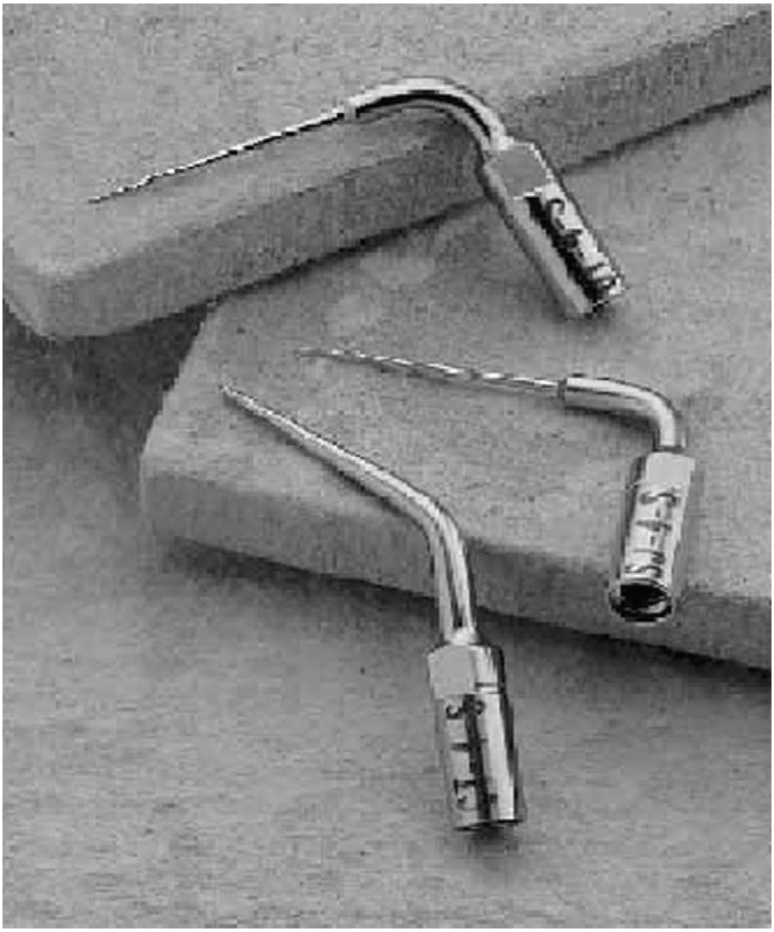

Fig. 5. The "4" series is specially geared toward post removal.

and depth of dentine cut with an increase in power setting. However, the slender and longer tips with small cross-sectional diameters (ie, CPR 6–8) will fracture easily when used at high intensity. On the other hand, short and sturdy tips used for vibrating posts out of root canals are operated at medium-high intensity. Similarly, tips that are used for bulk removal of dentine or restorative materials (eg, CPR 2) also need to be used at moderate to high intensities. The troughing tips (eg, CPR 3D–5D, BUC 3, and CPR 6–8) should be used at low intensity. In general, thick and short tips are operated at higher intensities, whereas long and slender tips are operated at lower intensities.

Tips with bends increase access to different parts of the mouth; however, excessive angulations also make these tips more vulnerable to breakage [3]. In addition, tips that are designed primarily for cutting dentine can break easily if inadvertently brought into contact with metals. The shanks of ultrasonic instruments come in different lengths ranging from 15 mm to 27 mm. The instruments are selected according to the depth at which they will be required to operate inside the root canal. For greater control, the shortest tip possible to reach the desired depth should be used. Not doing so may cause breakage of the instruments.

Each instrument system usually comes with its own ultrasonic engine, which is capable of generating ultrasonic frequencies in the range 20 kHz to 30 kHz. These frequencies generate comparable patterns of oscillation at the tip of the instruments. However, oscillation of the ultrasonic tip may be stalled if it is introduced into narrow canals or forcefully applied against dentine or restorative material. To be effective, these instruments must be kept moving at all times. If the instrument begins to stall, contact with the cutting surface should be broken temporarily to allow the tip to regain its oscillations. Also, to experience the full range of power, a wrench should be used to tighten the instruments in place; otherwise, the instrument may loosen during use. At the present time, the use of these instruments in patients with cardiac pacemakers is not recommended.

Although a number of other systems are available, it is not possible to describe all of them in this article. However, a closer look at the different systems reveals a number of similarities. From a practical point of view, it becomes more beneficial to know the utility of each type of ultrasonic tip rather than the system as a whole. These instruments can be separated into two categories—area specific or use specific—and come with established guidelines; however, it is possible to use an ultrasonic tip in an area other than the one for which it is specifically designed if the general principles regarding ultrasonic tips are understood and applied. With this in mind, the components of the different ultrasonic systems have been broadly classified as follows: (1) access refinement tips, (2) vibratory tips, (3) bulk removal tips, and (4) troughing tips.

Access refinement tips

Access cavity preparation is the most important phase of endodontic therapy. A properly designed access cavity that provides direct line access to all the root canals is key to endodontic success. A properly designed access cavity should allow for placement of endodontic instruments in the root canals in the same manner as flowers are placed in a vase. Traditionally, access cavities have been refined with burs that were designed primarily for operative preparations. Recently, a combination of access refinement ultrasonic tips and magnification has revolutionized the basic concept of access cavity preparation.

There are many advantages to using ultrasonic tips rather than burs to refine the access cavity to locate the underlying anatomy. There is no handpiece head to obscure vision and, therefore, the progressive cutting action can be observed directly and continuously under the microscope. The size of ultrasonic tips is smaller than the smallest burs; therefore, the dentine can be brushed off in smaller increments and with greater control. The process allows for exposure of any missed or hidden canals or recesses containing necrotic pulp tissue without gutting down the tooth structure (Fig. 6). The process is similar to archeologists unearthing artifacts at excavation sites. The dentine must be brushed off in smaller increments until the road map on the floor of the pulp chamber is uncovered completely. The usual term used for this procedure is "unroofing" the pulp chamber; however, this term is valid only when dealing with young and large pulp chambers. For pulp chambers that have receded with calcification, the term "uncovering" the floor of the pulp chamber is more appropriate.

Another advantage of ultrasonic instruments over burs is the production of cavitation within the cooling water that flows over the tip of the ultrasonic instrument [4]. Cavitation may be described simply as bubble activity in a liquid, which is capable of generating enough shock waves to cause disruption of remnants of necrotic pulp tissue and any calcific deposits. Therefore, it is no wonder that access cavities prepared with ultrasonic instruments have a thoroughly washed out and clean appearance (see Fig. 6B).

A number of tips are available to refine the access cavity. The uncovering of the floor of the pulp chamber can be accomplished with the help of the CPR 2D or BUC 1 tips. If the dark, colored floor of the pulp chamber is not visible, it usually is obscured by pulp stones or tertiary dentine deposits (Fig. 7). The pulp stones sometimes can be vibrated or teased out by the CPR 2D or BUC 1 tips (see Fig. 7A); at other times, they can be planed with the help of a BUC 2 tip—a process similar to planing the root surface. The tip of this instrument is designed with a planed surface and it can grind the floor until the dark-colored dentine becomes visible. The unveiling of the dark-colored floor of the pulp chamber is of critical importance because it dictates and guides the extension of access cavity.

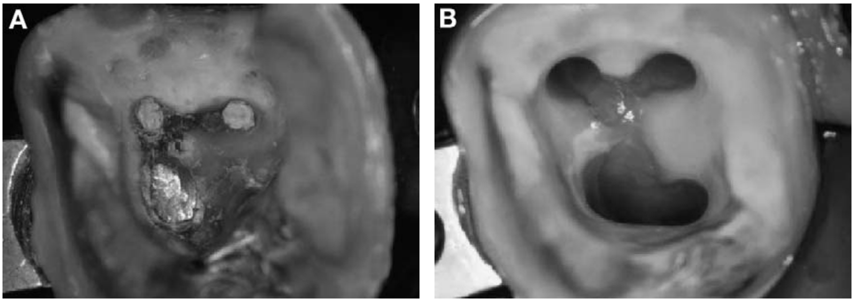

Fig. 6. (*A*) Mandibular molar requiring retreatment shows presence of gutta-percha in two mesial and one distal canal. The remaining chamber contained remnants of sealer cement and necrotic tissue. (*B*) Removal of gutta-percha filling and use of ultrasonic instruments exhibits debridement of the chamber and the presence of an untreated fourth distal canal.

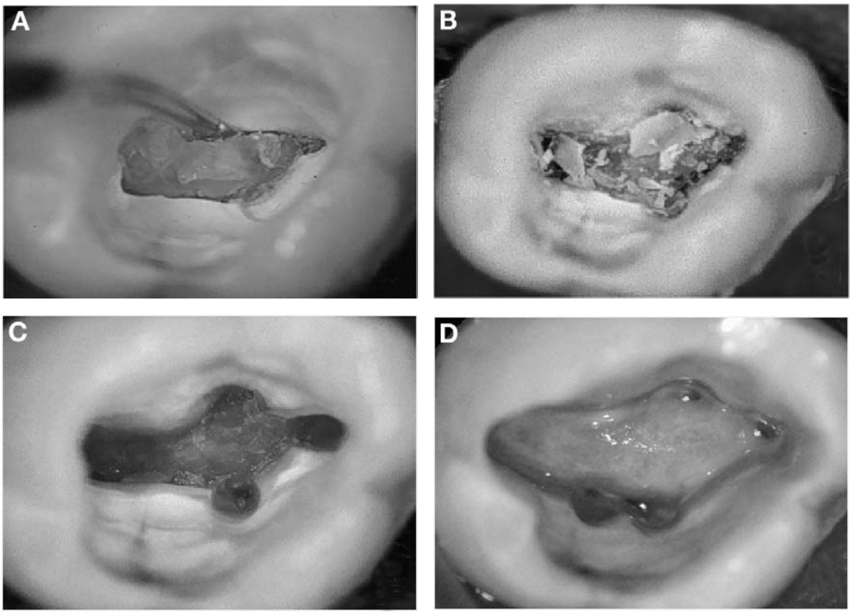

Fig. 7. (*A*) An ultrasonic tip is being used to remove heavy calcific deposits on the floor of a maxillary molar pulp chamber. (*B*) The use of ultrasonic energy led to shattering of pulp stone. (*C*) This picture reveals the presence of four root canal orifices, but the absence of any pulpal floor road map. (*D*) Continued removal of calcification and refinement of access cavity with ultrasonic instruments exposes the floor of the pulp chamber and the presence of an additional distobuccal canal. (Courtesy of Dr. Helmut Walsch, Munich, Germany.)

The second mesiobuccal canal (MB2) is reported to occur in more than 90% of maxillary molars [5]. On average, it is located 1.8 mm away from the mesiobuccal canal in a palatomesial direction. A protocol involving deepening of the bucco-lingual groove overlying the mesiobuccal root is essential for locating the MB2 [6]. The groove should not be extended toward the palatal canal but rather in a direction slightly mesial to it, so as to follow the bucco-lingual orientation of the mesiobuccal root. The refining tips can accomplish this task in a much-controlled manner by deepening the groove while at the same time restricting its mesiodistal dimension so as to not perforate the furcal or mesial aspect of the tooth.

The refining tips also are used for moving the mesial marginal ridges mesially to have a direct line access to the MB2 canal [7]. In addition, the tips also can be used for delineating the outlines of the root canal orifices so that the overhanging dentine deposits are removed and the orifices are exposed. This step sometimes can reveal the presence of two canals in a single orifice and helps to guide the instruments easily in and out of the canals. The ultrasonic tips can be used to dig and follow the sclerosed canals until patency is achieved. However, this procedure must be accomplished by a number of radiographic checks and restricted to the coronal aspect of the root trunk only. To check progress, an ultrasonic tip is used to dig a test hole at the most probable site of the sclerosed canal. The test site is filled with thermoplastisized gutta-percha and an orientation radiograph is exposed (Fig. 8). If the test site is found centered in the root and pointing correctly, then cutting is continued to enter the canal; otherwise, the direction of the cutting is modified according to information gathered from the radiograph. Radiographs are two dimensional in nature, however, and do not provide any information regarding the bucco-lingual depth of the tooth structure.

Vibratory tips

Removal of intraradicular posts has always been a challenge when performing endodontic retreatment. This procedure also has been fraught with unwanted consequences, such as root fracture or perforation. The implementation of ultrasonic energy has provided the clinician with an important adjunctive method for removal of posts. A number of studies [8–11] have shown conclusively that the use of ultrasonic vibration significantly reduces the amount of tensile force required to dislodge both the cast and prefabricated posts. The VT (Sybron Endo), Osada Enac ST09, and CPR 1 are examples of such instrument tips. The tips of these instruments are spherical or flat and are placed against the post to transmit vibration. They

Fig. 8. A check radiograph of a calcified central incisor showing an ultrasonically prepared test site filled with radiopaque gutta-percha. The ultrasonic tip was not aligned parallel to the long axis of the tooth and needed to be redirected to avoid root perforation.

are activated at the maximum intensity and moved circumferentially until the post loosens or dislodges. If this method does not loosen and free the post then alternate methods must be used. The manufacturer cautions against placing these tips directly on ceramics because it may cause severe damage to the prosthesis.

The inability to remove posts by vibration alone is dependent on many factors such as the type of luting agent, the length and type of the post, and the type of core buildup. The core buildup around the post should be removed before applying the vibratory tip. In some cases, the troughing tip should be used around the post and then vibratory tips should be reapplied to obtain the maximum benefit. Posts luted with zinc phosphate cement can be dislodged readily by ultrasonics because of microcrack formation in the cement [12]. However, posts luted with resin cements such as Panavia fail to dislodge by ultrasonic vibration, probably due to the lack of the microfracture propagation in these materials [12].

Bulk removal tips

Bulk removal tips are extremely sharp and sturdy tips that are operated at moderate or maximum intensity of the ultrasonic unit. BUC 1 and CPR 2D are examples of tips that fall into this category. Both of these tips are diamond coated and have an added advantage of a water port placed near the cutting surface of the tip for increased washing and cooling of the operative site.

These tips are designed primarily to remove dentine and core material quickly and expeditiously before subjecting the root canal obstruction to vibratory or troughing procedures. In retreating cast post and cores, the core portion is reduced and sculpted until it becomes an extension of the post itself [13]. This gives the clinician a purchase point to apply extraction devices when normal vibratory motions fail to dislodge the post completely. The controlled and incremental cutting with ultrasonic instruments under magnification provides a clear contrast between the core materials—for example, between composites and the underlying dentinal structure. Therefore, the chances of inadvertently perforating the crown of a tooth are reduced greatly.

Troughing tips

Troughing tips are used to create a sufficiently deep trough around posts to maximize the benefits of subsequently applied vibratory or extraction forces. In the past, troughing around the root canal obstruction was performed with trephine drills. This process was extremely destructive and frequently led to the gutting down and perforation of root trunks. Now with the help of ultrasonic tips, troughing around root canal obstructions can be performed in a predictable and controlled manner.

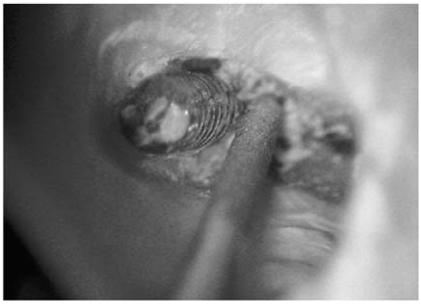

Fig. 9. The initial troughing around a post can be performed with shorter tips such as diamond-coated CPR 2D or 3D. (Courtesy of Dr. Samuel Kratchman, Exton, PA.)

Initially, the troughing is performed with instruments such as CPR 3D, 4D, and 5D, which are 15, 20, and 25 mm in length, respectively (Fig. 9). These instruments are used in the coronal, middle, and apical one third of root canals and their selection depends on the depth at which they need to be operated. These instruments are diamond coated and aggressively cut dentin along their lateral sides. The BUC 3 (Obtura/Spartan, Fenton, Ohio) or CT 4 tip (Sybron Endo), which also is available with a diamond coating, can be used for this purpose. The instruments not only remove cement that may be present around the post, but also remove a thin shelf of dentine around the perimeter of an obstruction.

If the obstruction is located in the deeper part of a straight canal, then titanium CPR tips 6 (red), 7 (blue), and 8 (green) are used, which are 20, 24, and 27 mm long, respectively. These instruments are quite slender, long, and parallel sided to cut deep into the root without taking away too much dentine, and at the same time provide maximum visibility under the microscope (Fig. 10). These instruments are especially useful when removing long and thick prefabricated post systems (Fig. 11). The fact that these

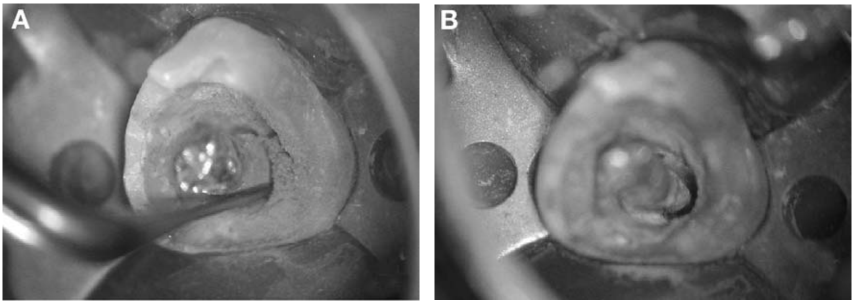

Fig. 10. (*A*) CPR 6 is being used to trough between the post and the lingual wall of the root canal. (*B*) View of the trough produced around the lingual aspect of the post with the help of ultrasonic files.

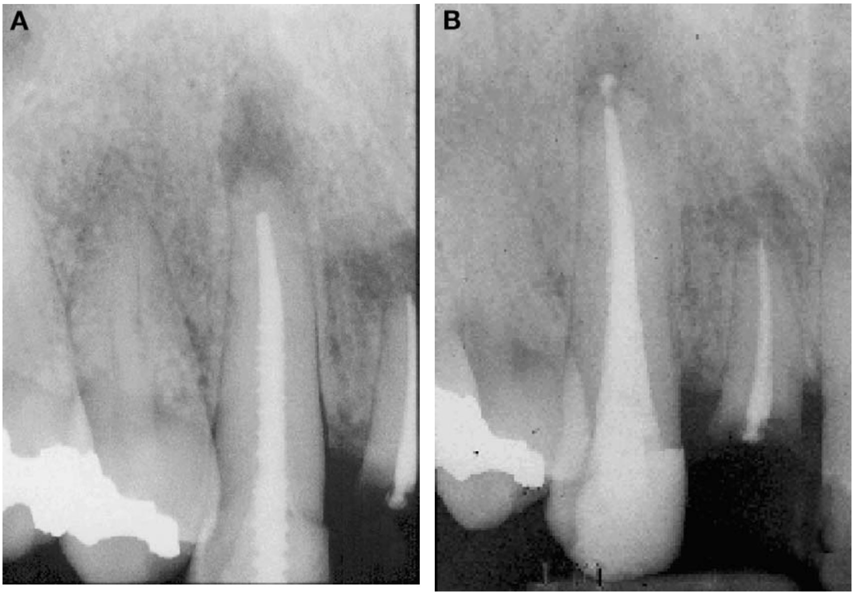

Fig. 11. (*A*) Radiograph showing the presence of a long, threaded post associated with a failing root canal treatment. (*B*) Radiograph showing completion of root canal treatment after removal of the threaded post.

instruments are made of titanium alloys and have thin cross-sectional diameters makes them extremely flexible and vibrant, but, at the same time, subject to breakage. The instruments should be used with a light touch; that is, with the same amount of pressure used to avoid breaking the lead tip of a pencil. These tips most commonly fracture when inadvertently brought into contact with metallic objects such as posts. Therefore, extreme caution needs to be taken when using these instruments. The instruments must be used at low intensities and always under the magnification provided by the microscope so as to not inadvertently contact any metallic obstruction.

Unlike CPR tips 3D, 4D, and 5D, which are diamond coated and active along the sides of their tips, CPR tips 6, 7, and 8 are end cutting and only active at their tips. Therefore, before troughing with these tips a collar of dentine must be exposed around obstructions that are embedded in root canals. The collar or shelf of dentine can be prepared around the obstructions with the help of LightSpeed instruments (LightSpeed, Inc., San Antonio, Texas). The tips of these instruments are flattened with the help of a grinding stone (Fig. 12), which allows them to cut dentine as close to the obstruction as possible. The instruments are used sequentially to the coronal extent of the obstruction until the canal is enlarged sufficiently, and a shelf of dentine is prepared around the obstruction (Fig. 13). Gates Glidden (GG) drills also can be used for this purpose; however, GG drills can be used only in the straight portions of the canal and are unable to

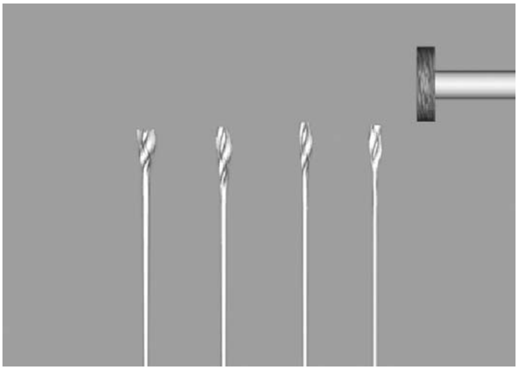

Fig. 12. Drawing showing LightSpeed instruments flattened at their tips with the help of a grinding stone.

negotiate any curvatures in the root canals [13]. Nevertheless, retreatment becomes difficult when the coronal end of the instrument lies apical to the elbow of the curvature and cannot be seen with the help of the surgical operating microscope. Once the shelf of dentine is prepared, CPR tips 6, 7, and 8 can be used to create a trough around the instrument (see Fig. 13D). The tips are moved counterclockwise around the fractured instrument to disengage it from the surrounding dentine [14]. Once loosened, the instrument usually moves coronally and ‘‘jumps out’’ from the root canal (Fig. 14). In other instances, the exposed part of the separated instrument can be grabbed and pulled out with one of the currently available extraction devices.

The use of NiTi rotary instruments has increased the incidence of file separation in endodontics. The NiTi files mainly break by either torsional fracture or flexural fatigue [15]. In the former case, the instrument usually gets forced into the root canal and, once jammed, fractures at its weakest point. This type of failure is associated most often with an unwinding of flutes that can be recognized under the operating microscope (Fig. 15A). The fractured instruments usually are engaged into dentine along their whole lengths and at times may be difficult to remove. On the other hand, fatigue failure causes the instrument to fracture at the point of its maximum flexure. These instruments do not exhibit any unwinding of flutes when observed under the operating microscope (see Fig. 15B). Even though these instruments are not tightly bound in dentine, they may be difficult to access because their coronal ends usually are located apical to the elbow of root curvature.

In addition to trephining around posts and removal of broken instruments and other intracanal obstructions, ultrasonic instrumentation also can be used for eliminating brick-hard paste-type materials [16]. The procedure can be accomplished with CPR 3D, 4D, and 5D; BUC 3; or ST21 Enac tips under the microscope so that the paste can be differentiated easily

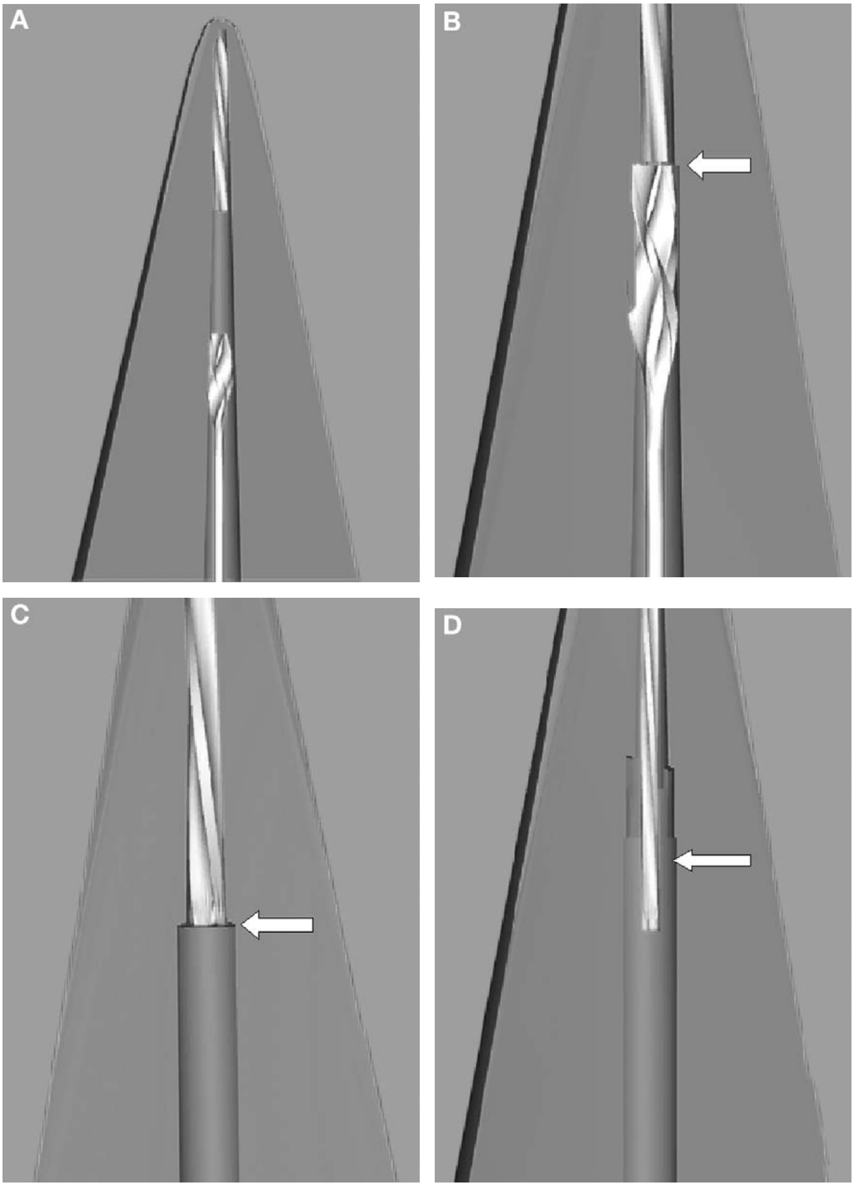

Fig. 13. (*A*) Initially, a small-sized instrument is selected and carried down to the obstruction. (*B*) Instruments are used sequentially to enlarge the root canal space. The arrow in the figure points toward the approximation of a modified LightSpeed instrument and the root canal obstruction. (*C*) The arrow in the figure points toward a shelf of dentine that has been created around the separated instrument. (*D*) The arrow indicates a trough created around the separated instrument with the help of ultrasonic tips.

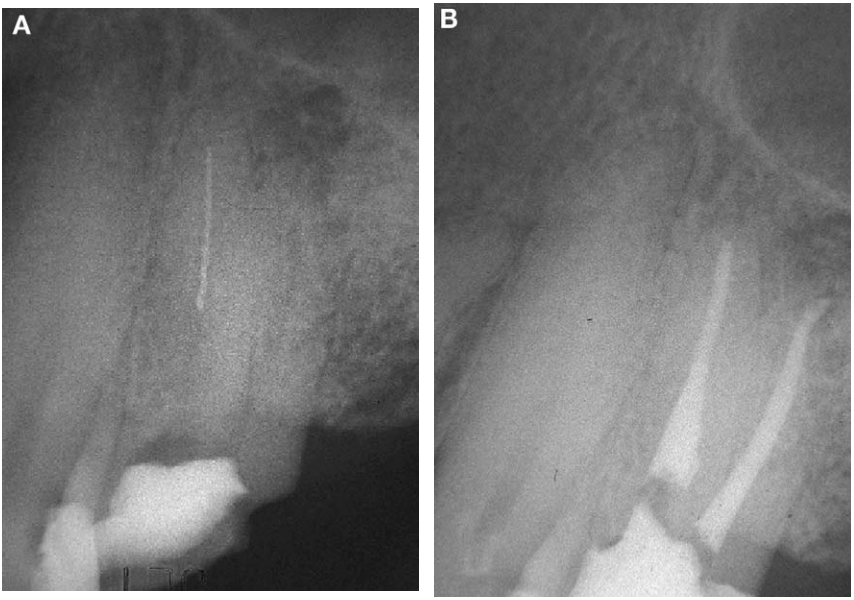

Fig. 14. (*A*) Preoperative radiograph of a maxillary left first premolar shows a separated instrument in the palatal canal. (*B*) Postobturation radiograph. The instrument was removed easily with ultrasonic vibration. (Courtesy of Dr. Bekir Karabucak, Philadelphia, PA.)

from the surrounding root canal dentine. Under the microscope, the paste—depending on its color—appears as a white or pinkish dot. The CPR tips are used to eliminate it by following the dot to its apical extent. However, no attempt should be made to remove paste materials around curves, because the ultrasonic files are unable to negotiate curvatures and may lead to perforation of the root surface. Ultrasonic tips also can be used to help MTA flow precisely into place. This is done by depositing mineral

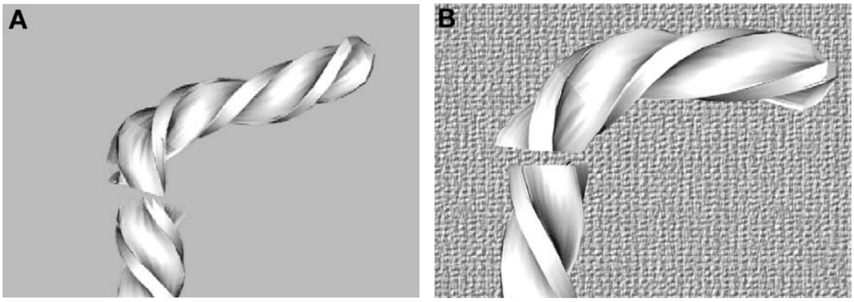

Fig. 15. (*A*) Drawing of a NiTi instrument depicting unwinding of the flutes associated with a torsional failure. (*B*) In case of flexure failure, no signs of unwinding of the flutes can be noticed.

trioxide aggregate (MTA) at a site (ie, perforation) and then vibrating it with an activated ultrasonic tip until it flows evenly into the defect.

Summary

The use of ultrasonic instruments has revolutionized the art of endodontic retreatment. These instruments have multiple uses and have become an integral part of the endodontic armamentarium. However, the use of ultrasonic instruments requires specialized knowledge and development of certain skills that may require training before use.

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