A dozen ways to prevent nickel-titanium rotary instrument fracture

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During the past 15 years, nickel-titanium (NiTi) rotary instruments have become a part of the standard armamentarium in endodontics. They are used extensively by generalists and specialists to facilitate the cleaning and shaping of root canals,[1] and it appears that with the increased application of these instruments in contemporary endodontic practice, fractures have become more prevalent.[2,3]

Fractured instruments are a definite hindrance to the goals of cleaning, shaping and filling root canals,[4,5] and they may adversely affect the outcome of endodontic treatment.[2,6-8] Techniques for removing fractured instrument fragments from root canals have been described in the dental literature.[9,10] However, removal of fragments may be impossible or impractical, especially when they are small and located in the apical portion of narrow curved root canals or when repeated attempts at removal could result in excessive enlargement of

ABSTRACT

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Background and Overview. With the increased use of nickel-titanium (NiTi) rotary instruments for root canal preparation in endodontics, instrument fracture has become more prevalent. Extensive research has been conducted on the physical properties and mechanical characteristics of NiTi rotary instruments, as well as the factors that can contribute to instrument failure. NiTi rotary instruments are subjected to torque and are susceptible to cyclic fatigue, which are the main causes of instrument fracture. However, with an understanding of how these instruments function in preparing root canals and by applying ways to reduce torque-generated metal fatigue, clinicians can use the instruments safely in clinical practice.
Results. The author presents 12 measures that clinicians can take to prevent NiTi rotary instrument fracture and discusses them in detail.
Clinical Implications. NiTi rotary instrument fracture complicates the progress, and compromises the prognosis of endodontic treatment. However, when clinicians take appropriate measures, rotary instrument fractures can be prevented.

Key Words. Nickel-titanium; rotary; instrument; fracture; prevention.
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the canal or perforation of the root.[7,8]

Since instrument fracture complicates and compromises endodontic treatment and prognosis,[2,6-8] clinicians must be constantly aware of the possibility of rotary instrument fracture and take every precaution to avert this mishap. The purpose of this article is to present measures that clinical operators can take to reduce the risk of NiTi rotary instrument failure and prevent fracture during root canal preparation.

ROTARY INSTRUMENT ASSESSMENT

NiTi. NiTi is a superelastic shape-memory metallic alloy that, when flexed, undergoes a martensitic transformation from its original austenitic structure and, if stressed beyond its elastic limit, will rupture. During root canal preparation, NiTi rotary instruments are subjected to cyclic fatigue, which can lead to distortion and fracture, especially when the instruments are flexed severely.[11] Extensive investigations of the physical properties of NiTi rotary files under dynamic testing procedures have shown that torsional stress and cyclic fatigue are the main causes of instrument fracture.[11-14] Observations of the fractured surfaces of NiTi rotary instruments under scanning electron microscopic (SEM) examination have revealed the presence of peripheral serrations, dimples and craters that are characteristic of ductile-type fractures.[13-15] Therefore, NiTi rotary instruments should not be subjected to excessive torsional and bending stress during operation.

Size, taper and cutting flute depths are important factors that affect the torsional and bending properties of rotary instruments.

Instrument design. NiTi rotary instruments are available in a variety of types, with different functional features that affect the manner in which they engage and cut dentin. The structural characteristics and mechanical designs of these instruments have a definite influence on their susceptibility to fracture.[15-19] In particular, the size, taper and cutting flute depths are important factors that affect the torsional and bending properties of rotary instruments.[15-19]

Size. A comparative study of the fatigue resistance of NiTi rotary instruments of different sizes and flute designs revealed that large instruments were highly susceptible to fatigue failure.[15] Research has demonstrated that as an instrument's cross-sectional diameter increases, it becomes less resistant to cyclic fatigue.[18] After performing dynamic stress tests on various NiTi rotary instruments, investigators found that as an instrument's size and taper increase, the torque generated during rotation increases and the fracture time decreases.[12,13]

Taper. In cyclic fatigue-to-fracture tests of different NiTi rotary instruments, researchers found that 0.06 taper instruments had less resistance to fracture than did 0.04 taper instruments.[19] Shen and colleagues[20] compared the types of failures that occurred with NiTi rotary instruments of various geometric designs and reported that a very high percentage (21 percent) of the instruments that fractured had progressively larger tapers and a much lower percentage (7 percent) had consistently even tapers. They also noted that failures for progressively tapered instruments tended to be fractures, whereas for evenly tapered instruments, failures tended to be unwinding deformations.[20] In this regard, instruments that show unwinding as a failure characteristic may be safer for use than those that fracture spontaneously. Additionally, Guilford and colleagues,[21] in comparing the torque required to fracture different types of rotary instruments, found that progressively tapered instruments failed rapidly with little rotation.

Cutting flute depth. Instruments with deep cutting flutes and progressively larger variable tapers have rapidly changing cross-sectional diameters along the entire length of their shafts. These instruments develop high torque levels that make them more prone to metal fatigue and fracture. However, instruments that have shallow cutting flutes, evenly tapered shafts and consistently shaped cross-sectional areas are more resistant to fracture. This is because the torsional and bending stresses that develop during use are distributed uniformly along these instruments' entire length.[19-21] Therefore, practitioners should be completely familiar with the mechanical features and working limitations of rotary instruments and select those that are less prone to fracture.

ABBREVIATION KEY. NiTi: Nickel-titanium. **SEM:** Scanning electron microscopic.

Instrument use. Microstructure and surface analysis of unused NiTi rotary instruments revealed that there were distortions in the lattice structure of the alloy, variations in the microhardness of the metal, and machining and milling marks as well as metal strips and microcracks on their surfaces.[16,22,23] It is important for clinicians to realize that these pre-existing conditions associated with the manufacturing process may contribute to the propagation of instrument fractures during use.[24,25] Cyclic fatigue and torsional testing procedures that measured rotation time and torque level at fracture have demonstrated that used rotary instruments are significantly more susceptible to fracture than are new ones.[26,27] These findings are further supported by SEM observations of used instruments that revealed signs of deterioration, including surface cracks that can progress to fractures with further use.[22-25,28] Sotokawa[29] found that by applying a systematic schedule for the disposal of endodontic instruments, the incidence of fracture can be reduced.

Therefore, it is advisable and prudent to dispose of all instruments after they have been used for a specific number of clinical cases, rather than wait for deformations and distortions to appear. Manufacturers recommend that rotary instruments be discarded after they have been used for one clinical case.

CANAL CURVATURE ASSESSMENT

The fracture potential of an instrument rotating in a curved canal becomes greater as the angle of curvature increases and the radius of curvature decreases.[11,13,14] Zelada and colleagues[30] and Martin and colleagues[31] reported that during the preparation of root canals in extracted molar teeth, all instrument fractures occurred in severely curved canals with angles of curvature greater than 30 degrees. A careful preoperative radiographic examination with fine hand instruments in the canals will reveal the presence and acuity of root canal curvatures. Therefore, when curvatures are present, the operator should be wary of the possibility of a fracture and proceed cautiously during root canal preparation.

ACCESS PREPARATION

In the internal configuration of an adequate endodontic access preparation, the entrances to the root canal orifices are not obstructed by the presence of excessive dentinal bulk or restorative material, and there is an unimpeded direction from which instruments can approach the apical portion of the root canal or the point of initial root canal curvature.[32] When instruments can negotiate root canals easily, bending and flexing stresses are lessened and the potential for fracture is reduced. Endodontic access becomes even more crucial for avoiding an instrument fracture when teeth are difficult to reach because of limited mouth opening.[33] Therefore, practitioners should make adequate access preparation a priority, as an important first step in avoiding rotary instrument fracture.

CANAL ORIFICE ENLARGEMENT

The enlargement of root canal orifices facilitates the negotiation and instrumentation of the apical part of root canals, especially in curved canals of multirooted teeth.[34,35] Leeb[34] used maxillary and mandibular extracted molars with curved roots to demonstrate that after the canal orifices were enlarged, instruments more easily penetrated the canals. The canal orifice can be enlarged effectively by the sequential use of nos. 4 and 2 low-speed, long-shank round burs followed by nos. 4 and 3 Gates Glidden drills.[34,35] These instruments, used carefully, can efficiently create a 2- to 4-millimeter oval-shaped funnel that serves as an accessible unobstructed entrance and guides rotary instruments into the root canal without causing excessive bending or binding, which could lead to metal fatigue. Therefore, practitioners should enlarge orifices before introducing NiTi rotary instruments into the root canal.

Practitioners should enlarge root canal orifices before introducing nickel-titanium rotary instruments into the canal.

MANUAL INSTRUMENTATION

Hand instruments can create a smooth, open passageway for rotary instruments to follow as they progress to the apical terminus. Three studies have demonstrated that manual root canal instrumentation with fine stainless steel hand instruments, used in a step-back manner before rotary instruments were used, significantly reduced the incidence of rotary instrument fracture during the preparation of curved canals.[36-38] Roland and colleagues[36] and Patino and colleagues[37] used fine hand instruments to enlarge curved root canals in extracted molars manually, and Berutti and colleagues[38] manually enlarged standardized curved canals in resin blocks to a size 20 hand instrument, creating a glide path for rotary instruments. All of these studies showed that manual enlargement of root canals with fine hand instruments significantly reduced the failure rate of rotary instruments.[36-38] Therefore, practitioners should use rotary instruments only after root canals have been negotiated and enlarged with fine hand instruments.

ROTATIONAL SPEED AND TORQUE CONTROL

Electric motors have been developed to control both rotational speed and torque during root canal instrumentation so that when the torque on an instrument, rotating at a constant speed, reaches a preset level, the motor automatically reverses its rotational direction and allows the file to be withdrawn before it locks and fractures in the root canal.[39] Gabel and colleagues[40] investigated the influence of rotational speed on the failure of NiTi rotary instruments for the preparation of root canals in extracted molar teeth and found that instrument distortion and fracture were four times more likely to occur at higher rotational speeds (333 rotations per minute) than at lower rotational speeds (167 rpm). Gambarini[41] found that instruments used in low-torque motors (< 1 Newton per centimeter) were more resistant to fracture than those used in high-torque motors (> 3 N/cm). Therefore, practitioners should use electric motors set at low rotational speeds and low torque levels during root canal preparation.

CROWN-DOWN TECHNIQUE

In the crown-down technique, larger instruments are used first in the coronal aspect of the canal, followed sequentially by smaller instruments in the apical aspect of the canal. The advantages of this technique are that it removes infected coronal dentin and obstructions before apical preparation and enlarges canals incrementally. In a study by Blum and colleagues[42] in which the root canals of mandibular incisors were prepared with NiTi rotary instruments using either a step-back or crown-down technique, the researchers found that less vertical force and torque were created with the crown-down technique and that instrument tips had less contact with dentin and less stress during the early phases of instrumentation. This is important, since test fractures performed on NiTi rotary instruments have demonstrated that fractures tend to occur close to the tip.[43] Studies of the failure of NiTi rotary instruments used to prepare root canals in extracted molar teeth found that a greater number of fractures and distortions occurred with sizes 20 and 25, and that most instruments fractured within 1 to 3 mm from the tip.[30,40,44] Additionally, in two separate investigations of failure of rotary instruments that were used with the crown-down technique to prepare a total of 210 curved root canals in extracted teeth, researchers found that no fractures occurred and only two instruments became deformed.[45,46] Therefore, practitioners should apply the crown-down technique as a standard operational procedure with rotary instruments.

IRRIGATION AND LUBRICATION

Irrigation and lubrication are essential for accomplishing adequate débridement of root canals. SEM studies of the efficacy of root canal cleaning have demonstrated that dentinal debris generated during instrumentation becomes packed in root canals and that irrigation is necessary for its removal.[47-49] A preparation of urea peroxide and ethylenediamine tetraacetic acid as a lubricant[50] is a combination commonly used for root canal preparation.[1] Irrigants and lubricants reduce root canal clogging, frictional resistance and mechanical overloading, thereby decreasing the torsional stresses placed on rotating instruments. Therefore, during root canal preparation, practitioners should lubricate instruments generously and irrigate canals copiously.

ROTARY INSTRUMENT MANIPULATION

The manner in which NiTi rotary files are manipulated for preparing root canals is extremely important. It has been shown that a cyclic axial motion applied to rotary instruments during operation was significant in preventing premature fracture.[51] Also, a pecking or pumping motion, which lowers apical forces during root canal preparation, has been advocated by researchers as an important way to prevent instrument binding and torque-generated cyclic fatigue.[12-14]

Li and colleagues[14] tested the cyclic fatigue of NiTi rotary instruments under static and dynamic pecking motion conditions and found that as the pecking distance increased, the fracture time increased, suggesting that this type of instrument manipulation is critical for preventing rotary instrument fracture. Yared and colleagues[45] found that when a slight apical pumping motion was used to reduce the development of excessive torque during the root canal preparation of extracted molar teeth, no instruments fractured. Therefore, one may conclude that practitioners should use a pecking or pumping movement when manipulating rotary instruments.

OPERATOR PROFICIENCY

Studies have demonstrated that higher rates of NiTi rotary instrument fracture occur with inexperienced operators than with experienced ones.[52,53] Rotary instruments tend to thread and screw into root canals, which subjects them to high levels of torque as they bind and lock in the canal.[39,52,53] In addition, instrument locking may be enhanced when the root canal preparation begins to acquire the shape and taper of larger instruments as they extend deeper into the canal, creating a taper-lock effect.[39,52,53] This is a valid concern; Schrader and Peters[54] found that using NiTi rotary instruments with different tapers reduced canal contact areas and instrument fatigue–related failures during root canal preparation in extracted teeth. The operator's ability to sense and resist these binding and locking tendencies is a skill that can be obtained only with experience. Yared and colleagues,[39,52,53] in several extensive investigations, showed that preclinical training in the use of NiTi rotary instruments for the preparation of root canals in extracted molar teeth was crucial for avoiding instrument fracture. Therefore, inexperienced operators should engage in preclinical training exercises as learning experiences before using these instruments on patients, then proceed carefully in clinical practice as they gain experience.

SUMMARY AND CONCLUSION

There are several measures that practitioners can take to prevent NiTi rotary instrument fracture during root canal preparation:

- avoid subjecting NiTi rotary instruments to excessive stress;
- use instruments that are less prone to fracture;
- follow an instrument use protocol;
- assess root canal curvatures radiographically and instrument them carefully;
- ensure that the endodontic access preparation is adequate;
- open orifices before negotiating canals;
- enlarge root canals with fine hand instruments;
- set rotational speed and torque at low levels;
- use the crown-down technique;
- irrigate and lubricate root canals during preparation;
- manipulate rotary instruments with a pecking or pumping motion;
- if inexperienced, engage in preclinical training in the use of rotary instruments.

Instrument fracture is a serious iatrogenic mishap that can complicate and compromise endodontic treatment. It therefore is imperative that clinicians using these instruments in practice apply all appropriate measures to reduce the risk of fracture. Recently published laboratory and clinical assessment studies have shown that when operators are aware of the possibility of instrument fractures and take measures to avoid them, the incidence of fracture can be as low as four per 1,000.[55,56] ■

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