Comparison of Generated Forces and Apical Microleakage Using Nickel-Titanium and Stainless Steel Finger Spreaders in Curved Canals

Saman R. Gharai, DDS, MS, Jeffrey R. Thorpe, DDS, James M. Strother, DDS, MS, and Scott B. McClanahan, DDS, MS

Abstract

The purpose of this study was to compare (a) forces generated during lateral compaction and (b) apical microleakage for nickel-titanium (NiTi) and stainless steel (SS) finger spreaders. Twenty-eight extracted human teeth were instrumented using a standardized rotary instrumentation technique. NiTi and SS #30 spreaders were used to obturate molar roots while the forces generated during obturation were measured on a Universal testing machine. Apical microleakage was determined using a fluid filtration method. There was no significant difference in microleakage between spreaders. NiTi spreaders produced significantly less force than SS spreaders in all specimens ($p < 0.001$).

From the Department of Endodontics and Research Department, Naval Postgraduate Dental School, Bethesda, MD.

Address request for reprints to Dr. Scott B. McClanahan, 5419 Flint Tavern Place, Burke, VA 22015-2109; E-mail address: mcclanahansb@nnd10.med.navy.mil.

In recent years, nickel-titanium (NiTi) rotary techniques have been developed to improve root canal preparation. Because of the unique properties of the alloy such as super-elasticity, shape memory, and superior resistance to torsional fracture, NiTi files have been able to improve the morphological characteristics and safety of root canal preparation (1). However, obturation of the root canal system is still a critical factor in successful endodontic therapy along with thorough debridement and sterilization. According to a survey of dental schools in the United States, 90% teach lateral compaction of gutta-percha as their primary obturation technique (2). It has been recommended that endodontic spreader placement should be within 1.0 mm of the working length and therefore, approximately 2.0 mm from the working length with the master cone in place to obtain the most favorable apical seal during lateral compaction (3, 4). Stainless steel (SS) spreaders may fail to achieve this deep penetration in curved canal systems because of resistance occurring as a result of binding against canal walls (5, 6). This inflexibility could lead to an insufficient apical seal or possibly a vertical root fracture (VRF). Meister et al. suggested that excessive force during lateral compaction of the gutta-percha caused 84% of VRF (7). Although many practitioners are using NiTi rotary files to clean and shape curved root canals, SS spreaders are still used during obturation.

It has been shown that NiTi spreaders penetrate to a significantly greater depth than SS spreaders in curved canals (6). Schmidt et al. demonstrated that NiTi spreaders penetrated deeper with a standardized force and required less force to penetrate to a standardized distance than do SS spreaders. Therefore, using NiTi spreaders may minimize the potential for VRF in curved canals during lateral compaction (8). However, this study was performed on standardized plastic blocks that do not have the anatomical variability encountered in natural teeth. Also, no study to this date has evaluated the quality of the apical seal obtained by these two different types of spreaders in regards to microleakage. The purpose of this study was to compare (a) forces generated during lateral compaction and (b) apical microleakage for NiTi and SS finger spreaders.

Materials and Methods

Twenty-eight extracted human molars were used in this study. After removal of calculus and soft-tissue debris, the teeth were stored at room temperature in 0.2% sodium azide. The palatal roots of maxillary molars and the distal roots of mandibular molars were resected at the cementoenamel junction. Each root was examined for cracks and fractures with a transilluminator (Kinetic Instruments Inc., Bethel, CT). Patency of each root was verified by introducing a #10 Flex-O file (Dentsply Maillefer, Tulsa, OK) until the tip was visible at the apical foramen under a dental operating microscope (Global Surgical Corporation, St. Louis, MI). Individual working lengths were calculated as being 1.0 mm short of these measured positions. File lengths were measured with a digital caliper (Mitutoyo Corp., Tokyo, Japan) accurate to 0.03 mm. Canal curvature was determined with the Schneider's method using digital radiographs (Schick Technologies Inc., Long Island City, NY) (9). All canals were prepared using rotary instruments in an ATR Tecnika motor (Advanced Technology Research, Pistoia, Italy) with a 16:1 reduction angle at 300 rpm and 35 torque.

The canals were prepared using GT and Profile 0.04 taper (Dentsply Tulsa Dental, Tulsa, OK) NiTi rotary instruments following the technique described by Hata et al. (10)

During preparation 6.0% sodium hypochlorite (Ultra Clorox Company, Oakland, CA) was used as the irrigant and Prolube with EDTA (Dentsply Tulsa Dental) as a lubricant. Canal patency was reverified after instrumentation with a #10 file. Canals were then dried with paper points. Both NiTi and SS size #30 finger spreaders (JS Dental Manufacturing Inc., Ridgefield, CT) were used on the same root during obturation in an alternating fashion. A new spreader was used for each root. Each spreader was measured at D_0 and D_9 using the digital caliper to insure that NiTi and SS spreaders had similar diameters and tapers. Each spreader was mounted on a Universal testing machine (MTS Bionix 200, MTS Systems, Irvy sur Seine Cedex, France) and the root was set in a metal ring holder. The spreader tip was centered at the orifice of the access cavity. A size 35 master gutta-percha cone (Dentsply Maillefer) was placed into the root to the working length. The Universal testing machine was set to penetrate into the canal 2.0 mm from the working length. Subsequently, size 25 accessory cones were placed into the canal as the machine was set to penetrate five times at 1.0 mm decreasing intervals. At each depth, the force was recorded. The apical 3.0 mm of the gutta-percha cones were coated with Roth 801 root canal sealer (Roth International Ltd., Chicago, IL), mixed in accordance with the manufacturer's instructions. To control rebound of gutta-percha, no more than 5 s was allowed to elapse between removal of the spreader and insertion of the accessory cone. After the initial five-step obturation was completed using one type of spreader, the gutta-percha cones were grasped with a cotton forceps and removed from the canal. The root was then radiographed to ensure that all the filling material had been removed before using the alternative spreader on the Universal testing machine to obturate the same root. After the second obturation, excess gutta-percha was seared off at the canal orifice using the System B heat source (Sybron Endodontics, Orange, CA) set at 250°C and then vertically compacted. Each root was reexamined for cracks and fractures with a transilluminator. The roots were stored for 30 days in a humidifier at 37°C to allow the sealer to set.

Based on decreasing canal curvature, roots were assigned so that sample curvatures were matched between groups. In group one, 10 root canals were finally obturated using the NiTi spreader. In group 2, 10 root canals were finally obturated using the SS spreader. Group three contained four root canals (negative controls), which were obturated and the entire root coated with nail polish for the microleakage portion of the study. Group four contained four root canals (positive controls), which were not obturated and not coated with nail polish. Individual roots in groups 1 and 2 were coated with nail polish except for the apical 3 mm of the root. Each root was mounted on an acrylic block using an 18 gauge monoject needle and quickset epoxy resin (Henkel Loctite Corp., Rocky Hill, CT). A 10 ml plastic needle syringe (Exelint International Co., Los Angeles, CA) was placed over the root and sealed with an epoxy paste (Protective Coating Co., Allentown, PA). The apical microleakage was determined using a fluid filtration method at 10 lbs per square inch (psi) and measuring in millimeters the air bubble movement in a glass capillary tube over a set time period as illustrated in Fig. 1. The pressure of 10 psi chosen for this study was extrapolated from studies by Wu et al., which used the fluid flow model to test root fillings (11, 12). A single operator (S.R.G.) performed all the procedures.

An independent samples *t* test compared the root curvatures in the NiTi and SS groups. Two-sided comparisons were done to check the mean difference in diameter for D_0 and D_9 between NiTi and SS spreaders, to determine whether the two spreaders were equivalent (alpha = 0.05). Because the accuracy of the digital calipers was within 0.03 mm, a difference in mean spreader diameter between NiTi and SS of less than or equal to 10% was considered to be of no clinical significance. The forces generated at each length for each type of spreader were compared by a paired *t* test. An independent samples *t* test was used to evaluate the apical microleakage measurements. To verify results, the ratio of the number of samples that leaked compared with the number of samples that did not leak for the NiTi and SS spreader groups were evaluated with the Exact test (StatXact, Cytel Software Corp., Cambridge, MA).

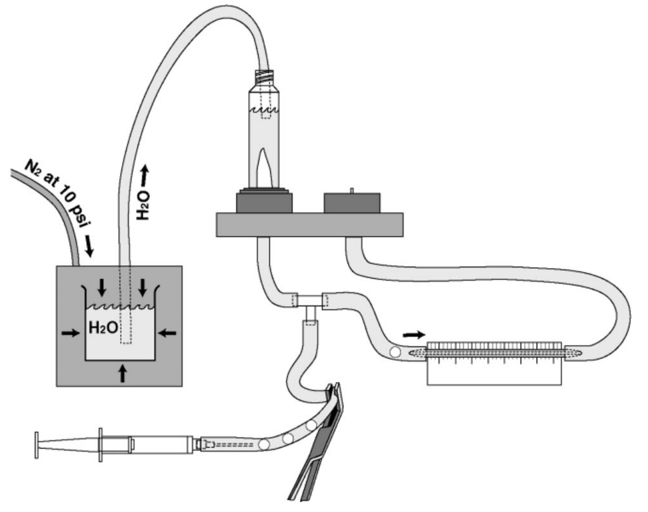

Figure 1. Fluid filtration apparatus measuring apical microleakage.

TABLE 1. Spreader forces generated ($p < 0.001$).

Spreader Type (n = 20)	Mean Force (kg)	Standard Deviation (kg)	Minimum Force (kg)	Maximum Force (kg)
NiTi	0.81	+/−0.62	0.01	2.71
SS	1.57	+/−1.50	0.01	7.02

Results

The differences in root curvature of the NiTi (mean 19.54° ± 10.87) and SS (mean 25.04° ± 23.49) groups were not statistically different. The differences in mean spreader diameters for D_0 and D_9 fell within the 90% clinical confidence intervals and equivalence was concluded. For every length, the NiTi spreaders (0.81 kg ± 0.62) placed significantly less force than SS spreaders (1.57 kg ± 1.50) on all specimens ($p < 0.001$) as shown in Table 1. After obturation none of the roots showed evidence of cracks or fractures.

No leakage was observed in the negative control group. Positive control specimens (2747.3 mm/min ± 17.0) leaked significantly more than all other groups. There was no significant difference in apical microleakage between NiTi (36.0 mm/min ± 35.8) and SS (11.0 mm/min ± 28.1) spreaders. Fluid filtration results were verified with the Exact test and there was no significant difference in leakage.

Discussion

Lateral compaction technique has demonstrated less favorable apical leakage results in curved canals compared with straight canals (13). This microleakage may be a result of insufficient compaction of gutta-percha secondary to the inability of the SS spreaders to penetrate within 1.0 mm of the working length in curved canals. Clinicians may exert excessive forces on SS spreaders to achieve the depth of penetration required for an adequate apical seal.

An important cause of endodontic failure is VRF, which occurs most often in a buccolingual direction (14). Excessive forces during lateral compaction have been implicated as a major cause of VRF, which ultimately results in extraction (15). A photoelastic study demonstrated that SS spreaders created areas of concentrated stress. The NiTi spreaders induced stress patterns, which spread out along the surface of the canals. Thus, the concentration of stress and the potential for VRF was reduced (16).

In this study, there was no significant difference in microleakage between the two types of spreaders. This may be a result of the fact that both spreaders were initially forced to within 2.0 mm of the working length, which reinforces the critical factor of spreader depth penetration (4). However, to penetrate to this standardized distance, SS spreaders consistently exerted significantly more force when compared to NiTi spreaders. During obturation of roots with greater curvatures, it was necessary to use multiple SS spreaders, since the forces generated caused them to bend and rendered them inoperable. Yet for NiTi specimens, only one spreader was required to complete each obturation procedure. The average force generated by SS spreaders was 1.57 kg and for NiTi spreaders was 0.81 kg. The maximum force generated by a SS spreader was 7.02 kg and the NiTi spreader was 2.71 kg. The range of forces reported in vitro as most commonly used by endodontists to laterally compact gutta-percha has been 1.0 to 3.0 kg and those of higher magnitude up to 4.9 kg are safe and will not result in VRF (17). Yet, a spreader load as small as 1.5 kg has been shown to produce a fracture (18). Therefore, to minimize the risk of VRF in curved canals, NiTi spreaders should be the spreader of choice for lateral compaction.

Under the parameters of this study, there was no significant difference in apical microleakage between NiTi and SS finger spreaders. However, NiTi spreaders generated significantly less force than SS spreaders ($p < 0.001$).

Acknowledgment

The views expressed in this article are those of the author(s) and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense or the U.S. Government.

Dr. Gharai is a former endodontic resident at the Naval Postgraduate Dental School, Bethesda, MD. Dr. Thorpe is a former staff member of the Endodontics Department, Naval Postgraduate Dental School, Bethesda, MD. Dr. Strother is a former staff member of the Research Department, Naval Postgraduate Dental School, Bethesda, MD. Dr. McClanahan is the Chairman, Endodontics Department, Naval Postgraduate Dental School, Bethesda, MD.

References

1. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;14:346–51.
2. Cailleteau JG, Mullaney TP. Prevalence of teaching apical patency and various instrumentation and obturation techniques in United States dental schools. J Endod 1997; 23:394–6.
3. Allison DA, Weber CR, Walton RE. The influence of the method of canal preparation on the quality of apical and coronal obturation. J Endod 1979;5:298–304.
4. Allison DA, Michelich RJ, Walton RE. The influence of master cone adaptation on the quality of the apical seal. J Endod 1981;7:61–5.
5. Dang DA, Walton RE. Vertical root fracture and root distortion: effect of spreader design. J Endod 1989;15:294–301.
6. Berry KA, Loushine RJ, Primack PD, Runyan DA. Nickel-titanium versus stainless-steel finger spreaders in curved canals. J Endod 1998;24:752–4.
7. Meister FJ, Lommel TJ, Gerstein H. Diagnosis and possible causes of vertical root fractures. Oral Surg Oral Med Oral Pathol 1980;49:243–53.
8. Schmidt KJ, Walker TL, Johnson JD, Nicoll BK. Comparison of nickel-titanium and stainless-steel spreader penetration and accessory cone fit in curved canals. J Endod 2000;26:42–4.
9. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271–5.
10. Hata G, Uemura M, Kato AS, Imura N, Novo NF, Toda T. A comparison of shaping ability using ProFile, GT file, and Flex-R endodontic instruments in simulated canals. J Endod 2002;28:316–21.
11. Wu MK, De Gee AJ, Wesselink PR. Leakage of four root canal sealers at different thickness. Int Endod J 1994;27:304–8.
12. Wu MK, De Gee AJ, Wesselink PR, Moorer WR. Fluid transport and bacterial penetration along root canal fillings. Int Endod J 1993;26:203–8.
13. Mann SR, McWalter GM. Evaluation of apical seal and placement control in straight and curved canals obturated by laterally condensed and thermoplasticized gutta-percha. J Endod 1987;13:10–7.
14. Lertchirakarn V, Palamara JE, Messer HH. Load and strain during lateral condensation and vertical root fracture. J Endod 1999;25:99–104.
15. Tamse A. Iatrogenic vertical root fractures in endodontically treated teeth. Endod Dent Traumatol 1988;4:190–6.
16. Joyce AP, Loushine RJ, West LA, Runyan DA, Cameron SM. Photoelastic comparison of stress induced by using stainless-steel versus nickel-titanium spreaders in vitro. J Endod 1998;24:714–5.
17. Lindauer PA, Campbell AD, Hicks ML, Pelleu GB. Vertical root fractures in curved roots under simulated clinical conditions. J Endod 1989;15:345–9.
18. Holcomb JQ, Pitts DL, Nicholls JI. Further investigation of spreader loads required to cause vertical root fracture during lateral condensation. J Endod 1987;13:277–84.