JOURNAL OF ENDODONTICS

Printed in U.S.A.
VOL. 27, NO. 12, DECEMBER 2001

Comparison of Laterally Condensed .06 and .02 Tapered Gutta-Percha and Sealer In Vitro

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The purpose of this in vitro study was to compare the quality of the seal in canals prepared in a standardized manner and obturated with a .06 or a .02 tapered gutta-percha master cone using lateral condensation. Forty-four extracted human anterior teeth with single, straight canals were divided into two experimental groups of 20 teeth each and two control groups of 2 teeth each. The teeth were instrumented with Series 29 Profile .06 tapered rotary nickel-titanium files to a master apical file of 0.46 mm. Teeth in group 1 were obturated with a .02 tapered master gutta-percha cone and Roth 801 sealer using lateral condensation. Teeth in group 2 were obturated similarly, except a .06 tapered master gutta-percha cone was used. The depth of spreader penetration was recorded in millimeters. Positive control teeth were instrumented but not filled. Negative control teeth were instrumented, obturated, and externally sealed. The teeth were placed into a coronal leakage apparatus that contained an upper and lower reservoir of trypticase soy broth separated by the tooth. A 24-h growth of *Proteus vulgaris* in 0.25 ml of trypticase soy broth was placed in the coronal reservoir every 7 days for 70 days and incubated at 37°C. Student's *t* test was used to determine whether there was a difference in spreader penetration between the groups, and a Fisher's exact test was used to determine whether there was a difference in bacterial leakage. The positive and negative controls validated the testing model. When a .02 tapered master cone was used, the spreader penetrated significantly closer to working length than when a .06 tapered master cone was used ($p < 0.05$). The difference between the groups in the number of samples that demonstrated complete bacterial penetration was not significant ($p > 0.05$).

Recent advances in instrument design and materials have resulted in the development of nickel-titanium rotary instrumentation for endodontic treatment of teeth. These new instruments have brought about innovations in blade designs, alternative sizing, and greater instrument tapers. Currently they are available in several configurations, including .02, .04, and .06 mm/mm tapers. Advantages of these instruments include ease and efficiency of use, fewer instrumentation errors, and better preparation of curved canals. In addition they can prepare canals in a manner that is both more centric and circular than is possible with stainless-steel instruments (1). This results in instruments that can efficiently machine canals to a more predictable and reproducible shape than previously possible with hand instrumentation.

Obturation of canals prepared with nickel-titanium instruments may be achieved using a variety of thermoplasticized or lateral condensation techniques. To take advantage of the more uniform canal preparation produced by rotary files, .02, .04, and .06 mm/mm tapered gutta-percha cones have been developed (Dia-Pro, Diadent Group, Burnaby, Canada). These master cones are manufactured to have matching master apical sizes and taper to correspond to .02, .04, and .06 taper rotary nickel-titanium file systems. Filling canals prepared with nickel-titanium instruments with a correspondingly tapered gutta-percha master cone and lateral condensation is advantageous because it is clinically efficient and seems to result in a radiographically acceptable outcome. The quality of the obturation or seal obtained using this technique, however, has not been investigated.

Because lateral condensation, unlike vertical condensation, does not create a homogeneous mass of gutta-percha, pools of sealer may be trapped in the filling mass as accessory cones are compacted against each other. Filling with a master cone with a larger taper may be advantageous in that a larger and more uniform mass of gutta-percha is introduced that potentially has less sealer entrapped in the filling mass. Because of the close approximation of the gutta-percha cone to the prepared canal walls, a potential disadvantage results from the inability of a spreader or plugger tip to predictably penetrate to within 1 to 2 mm of the working length. This could result in inadequate compaction of the master cone in the apical portion of the canal causing a potential deficiency in the seal of the canal (2). Using an in vitro apical leakage model, Allison et al. (2) found that teeth in which a spreader tip could be inserted within 1 mm of the working length with the master cone in place had considerably less apical leakage than did teeth in which the distance between the spreader tip and working length was greater.

The purpose of obturating the root canal system is to prevent leakage of bacteria and their products into the periradicular tissues and to seal within the root canal any irritants that cannot be fully removed. Many studies show that root canal fillings leak coronally in a relatively short time when exposed to the oral environment. Swanson and Madison (3) demonstrated extensive coronal leakage of dye along the canal wall and within the root canal filling material in coronally unsealed but obturated canals exposed to artificial saliva. This was later confirmed in vivo when Madison and Wilcox (4) demonstrated dye penetration along the entire length of obturated root canals exposed to the oral environment.

In 1990 Torabinejad et al. (5) demonstrated in vitro bacterial leakage of *Proteus vulgaris* and *Staphylococcus epidermidis* along the entire length of the root canal in an average of 48.6 and 24.1 days, respectively. More recently Trope et al. (6) reported the penetration of bacterial endotoxin through the obturated root canal in as few as 21 days.

Many methods for determining leakage have been used, including dyes, radioisotopes, microorganisms, and ion penetration using the electrochemical method (7). Studies demonstrate that dye penetration studies have inherent inadequacies, including false-positive readings if the particles are too small and false-negatives because trapped air bubbles prevent dye leakage (8). Another problem with these studies is their clinical relevance. The molecular weight of bacterial endotoxin is several times greater than methylene blue, the most commonly used dye (9). Bacterial leakage models avoid these types of inherent errors and additionally satisfy the need for clinical relevance (7, 8).

The purpose of this in vitro study was to compare the coronal bacterial leakage present after cleaning and shaping the root canal system with .06 rotary nickel-titanium files and then obturating the prepared canal with a .06 or a .02 master gutta-percha cone and sealer using lateral condensation.

MATERIALS AND METHODS

Forty-four extracted fully developed human maxillary and mandibular anterior teeth with single, straight canals were divided into two experimental groups of 20 teeth each and two control groups of 2 teeth each. All teeth were scaled with a periodontal scaler to remove soft tissue and calculus. The teeth were radiographed from facial and proximal orientations to confirm the presence of a single canal. After the teeth were decoronated to leave a root length of ∽15 mm, they were steam-autoclaved and then stored in a 0.2% thymol solution.

The teeth were accessed and instrumented using a crown-down technique with rotary .06 Profile Series 29 nickel-titanium files (Tulsa Dental Products, Tulsa, OK) to a master apical file size of 0.46 mm (#7 file). The working length was determined by inserting a #10 K-file into the canal until it was just visible at the apical foramen, then subtracting 1 mm. Apical patency was maintained throughout instrumentation using a #15 K-file. The canals were irrigated between files with 2 ml of 5.25% sodium hypochlorite. After the master apical file was reached, the canal was flushed with 5 ml REDTA (Roth International, Chicago, IL), followed by a final flush of 5 ml of sodium hypochlorite. After instrumentation was complete the canals were dried with paper points.

A thin layer of Roth 801 root canal sealer (Roth International) was applied to the preparation walls with a sterile paper point. Teeth in group 1 were obturated with a .02 tapered master cone (Diadent Group) and Roth 801 root canal sealer using lateral condensation of medium-fine accessory cones (Caulk, Milford, DE). Teeth in group 2 were filled using the same method as described above except a .06 tapered master cone (Diadent Group) was used. The distance of the spreader tip from the working length was measured by subtracting the depth of spreader penetration from the working length in each root.

The two teeth that were instrumented but not obturated were used as positive controls to demonstrate bacterial leakage through the entire length of the canal. The negative control teeth (two teeth) were instrumented, obturated, and sealed externally with two layers of clear nail polish. All experimental and control teeth were stored in a humidor at 98.6°F and 100% humidity.

The bacterial leakage model used was previously described and illustrated by Wolcott et al. (10). Briefly, the coronal 3 mm of each root was sealed in the lumen of an 18-mm segment of latex surgical tubing with cyanoacrylate cement and then sterilized in the steam autoclave. Under sterile conditions in a microbiology laboratory, the test apparatus was assembled and then placed into a presterilized test tube containing 1.5 ml of trypticase soy broth (TSB) creating an upper and lower reservoir. A 24-h growth of *Proteus vulgaris* in TSB 0.25 ml was placed in the 2-mm coronal reservoir produced by the tubing. Incubation was conducted for 70 days at 37°C and observed daily for turbidity of the TSB, which indicated leakage through the full length of the obturated canal. The coronal TSB was reinoculated every 7 days for 70 days. If the TSB became turbid, the TSB was plated and the microorganisms identified by their gross appearance. The number of samples exhibiting leakage after 70 days was determined for each group.

To determine whether there was a significant difference in bacterial leakage, a Fisher's exact test was used. To evaluate whether there was a significant difference in the depth of spreader penetration, the Student's *t* test was used. The confidence level was set at 95%.

RESULTS

The positive controls demonstrated leakage after 1 day, whereas the negative controls did not leak for the entire observation period, thus validating the testing model. The depth of spreader penetration, as measured by the distance of the spreader from the full working length, was 1.4 ± 0.9 mm and 2.9 ± 1.7 mm in groups 1 and 2, respectively. The difference in spreader penetration between the two groups was significant ($p = 0.001$). Over the 70-day experimental period, 9 (45%) of 20 teeth in group 1 and 7 (35%) of 20 teeth in group 2 demonstrated complete bacterial penetration. However the difference in complete bacterial penetration between the two groups was not significant ($p > 0.05$).

DISCUSSION

In this experimental model, it seems that filling canals prepared with .06 tapered nickel-titanium rotary instruments with matching .06 tapered gutta-percha master cones results in a seal of the root canal system that is equivalent to that produced by the lesser tapered cones. Although there was a significant difference in mean spreader penetration between the two groups, that difference did not produce a significant difference in the quality of the coronal seal. The distance the spreader penetrated into the canal did not affect the amount of bacterial leakage through the filled canals.

Although filling canals with greater tapered cones results in an acceptable coronal seal, the apical seal has not been investigated. Allison et al. (1) demonstrated an increase in apical leakage when the spreader penetration was greater than 1 mm from working length. However they measured the penetration of a radioactive tracer, which may not provide accurate information relative to the clinical situation, compared with a bacterial leakage model (7, 8). Radioisotopes and dyes are several magnitudes smaller in size than bacteria and their byproducts. They can give a false-negative result because of entrapped air or a false-positive result if their particles are small enough (9).

In addition the relevance of apical leakage has been questioned. Historically, it has been suggested that dissolution of sealer in the apical canal can lead to stasis and degradation of fluid in the apical part of the canal and can lead to and maintain periapical inflammation. Many studies, however, have failed to demonstrate that sterile tissue fluids in teeth or hollow tubes in vivo produce inflammation (11–13).

In this study the experimental period was 70 days. Torabinejad et al. (5) demonstrated an average penetration time for *Proteus vulgaris* of 48.6 days. Conversions occurred over a range of 3 to 63 days. Whether significant differences in bacterial penetration would occur over experimental periods greater than 70 days is unknown.

The type of bacteria used in this study was a motile aerobic species typically not seen in root canal infections. Root canal failure or infection mainly involves facultative or obligate anaerobes, including *Enterococcus faecalis*, *Prevotella* sp., *Porphyromonas* sp., *Veillonella* sp., and *Fusobacterium* sp. (12, 13). The penetrating ability of these bacteria, alone or in combination, may be different from the species used in our study.

The teeth used in this study were straight with single canals that could be prepared in a standardized manner with rotary instruments. Most posterior teeth, however, have complex anatomy with curves, isthmuses, cul-de-sacs, and fins. Further study is needed to determine whether filling these more complex teeth with matched gutta-percha cones will result in an acceptable seal.

In conclusion, obturating straight root canals in vitro with laterally condensed .06 tapered gutta-percha master cones that match the shape of .06 tapered nickel-titanium rotary instruments prevents complete bacterial penetration as effectively as laterally condensed .02 tapered master cones. In addition, the depth of spreader penetration does not seem to affect the amount of coronal microleakage. Therefore clinicians may use these new filling materials with confidence in teeth with relatively straight canals. Additional studies are warranted using teeth with more complex anatomy in a leakage model using anaerobic bacteria.

This study was supported by the I. B. Bender Research Fund.

The authors thank John Holderbach, General Clinical Supervisor of Microbiology, and his staff in the Department of Pathology and Laboratory Medicine (AEMC) for their assistance in the microbiological aspects of the study. We also thank Ms. Pat Seiple for assistance in sterilization of the apparatus.

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