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Histological Evaluation of the Effectiveness of Five Instrumentation Techniques for Cleaning the Apical Third of Root Canals

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The efficacy of five instrumentation techniques for cleaning the apical third of curved root canals was assessed by histological examination. Mesial root canals of freshly extracted human mandibular molars were prepared by the following instrumentation methods: step-back technique using stainless steel files; step-back technique using nickel-titanium files; ultrasonic technique; balanced force technique; and Canal Master U technique and instruments.

The apical portion of the root was histologically processed, and cross-sections were examined for remaining soft tissue, predentin, and debris. The results showed no significant differences among the techniques. Although the five instrumentation methods were effective in removal of major amounts of tissue from the canals, none totally debrided the entire root canal system, especially when variations in the internal anatomy were present.

One of the major goals of chemomechanical preparation is to clean the root canal system as completely as possible (1). Cleaning involves the removal of bacteria, their products, and degenerated tissues and can be carried out by means of the mechanical action of both the endodontic instruments and the flow and backflow of irrigant solution. In addition, because some irrigant solutions, e.g. sodium hypochlorite, have the ability to dissolve organic material, they may exert a cleaning effect by chemically removing soft tissue remnants and bacterial cells from the root canal system.

It has been demonstrated that cleaning of the root canal is not always easily accomplished, especially during the preparation of narrow and curved canals (2). To deal with the complex problem of preparing curved root canals, several instrumentation techniques and modified instrument designs have been proposed and popularized. These include the step-back (3), balanced force (4), ultrasonic (5), and Canal Master (Brasseler, Savannah, GA) (6) techniques. Moreover, recent advances in technology allowed the introduction of endodontic files manufactured from a nickel-titanium (Ni-Ti) alloy, with more elastic flexibility, as well as improved resistance to torsional fracture (7). Studies (8, 9) have reported that Ni-Ti instruments caused significantly less canal transportation than conventional files, providing preparations more centered and tapered.

Since it has been claimed that no current technology or instrument is effective in thoroughly cleaning the root canal system (10), the purpose of this study was to compare the cleaning of the apical third of the root canal by five instrumentation techniques, through histological evaluation.

MATERIALS AND METHODS

Fifty-three mesial canals of vital freshly extracted human mandibular molars, with curvatures varying between 25 and 40°, were selected for this study. After extraction, the teeth were stored in phosphated buffered saline until use. Conventional access preparations were made and a #10 K-type file was introduced into each canal until it appeared at the apical foramen. The working length (WL) was established by subtracting 1 mm from this measurement. Canals were further randomly divided into five groups of ten canals each. The control group included three uninstrumented root canals. Preparations were carried out as follows.

Group 1—Step-Back Technique—Stainless Steel Files

The root canals were prepared by the step-back technique using the Flexofile (Maillefer, Ballaigues, Switzerland) with circumferential filing motion. Apical preparation was done at the WL with #15 through #25 files. The coronal portion of the canal was flared with Gates-Glidden burs #2 and #3, and the preparation was completed using step-back of 0.5 mm increments. Recapitulation with a #25 file at the WL was done after each larger size file.

Group 2 —Step-Back Technique—Ni-Ti Files

Canals were prepared by the step-back technique using Ni-Ti files (NiTiFlex, Maillefer, Ballaigues, Switzerland) with watch-winding and pull motion. Apical preparation was done to a #35

NiTiFlex. The coronal portion of the root canal was then flared using Gates-Glidden burs #2 and #3, and progressively larger files were used to step-back the canal in 1-mm increments, joining the apical preparation with that performed by Gates-Glidden burs.

Group 3—Ultrasonic Technique

The root canals were initially prepared by hand instrumentation with a #15 K-type file at the WL. A #15 ultrasonic file, used in the Enac unit (Enac-Osada, Tokyo, Japan), was placed in the canal penetrating the full WL. The unit was activated for 10 s with the file stopped. Afterward, the #15 ultrasonic file was worked with a push-pull circumferential motion for approximately 1 min. The apical patency was checked using a hand #15 file, and the coronal portion of the root canal was flared using #2 and #3 Gates-Glidden burs. Hand #15 K-files and ultrasonic #15 files were used alternately until a hand #30 K-file could penetrate the full WL without binding the canal walls.

Group 4—Balanced Force Technique

Canals were prepared based on Roane et al. (4). A #15 Flex-R file (Union Broach, New York, NY) was inserted in the canal with a clockwise rotation of no more than 180°. Each placement motion was followed by a counterclockwise rotation of 120° or greater with slight apical pressure to produce the cutting of the dentin. These alternated rotary motions were repeated until the WL was reached and the canal diameter enlarged by counterclockwise rotation of 360°. The canal was enlarged at the WL to a #25 Flex-R file. Gates-Glidden burs #2 and #3 were used to flare the canal portion coronal to curvature. Apical preparation was then completed by enlargement through #40 Flex-R file.

Group 5—Canal Master U (CMU) Technique

The root canals were prepared based on Wildey and Senia (6). After the initial preparation using a #15 K-type file at the WL, the coronal two-thirds of the canal were flared by means of CM rotary instruments #50 and #60. CMU hand instruments sizes 20 through 35, including the intermediate sizes 22.5, 27.5, and 32.5, were used in continuous clockwise rotation to prepare the root canal at the WL. The preparation was stepped-back in 1-mm increments using progressively larger CMU files through #50, including the intermediate sizes.

During all procedures the teeth remained wrapped by wet gauze. Copious irrigation with a 5% sodium hypochlorite solution was always done following each file size.

The apical 5 mm of each root was sectioned and removed for histological processing. Canals were flooded with 10% neutral buffered formalin and stored in this same solution until histological processing. Specimens were then washed, decalcified in 5% HNO_3 and embedded in paraffin wax. Serial cross-sections were cut at 6 μm and alternately stained with hematoxylin and eosin or Gomori Trichrome. Sections from apex to WL were excluded from the examination.

The cross-sections were examined in a light microscope, and the cleansing of the root canals was evaluated using a scale ranging from 0 to 3, slightly modified from the criteria adopted by Langeland et al. (11): 0—canal containing tissue remnants, predentin, or debris in all of the sections; 1—canal containing some tissue, predentin, or debris in most of the sections; 2—canal relatively clean, containing tissue remnants, predentin, or debris in some of the sections; 3—canal thoroughly cleaned in all sections examined, free of tissue, predentin, or debris.

The scores were analyzed for differences by means of the Kruskal-Wallis test, with the significance level established at $p < 0.05$.

TABLE 1. Scores achieved by the instrumentation techniques

Technique	Scores for each specimen	Means of the scores
Step-back (FF)	1112222223	1.8
Step-back (Ni-Ti)	0122223333	2.1
Ultrasonic	1111222223	1.7
Balanced Force	1112222333	2.0
Canal Master U	0112223333	2.0

FF, Flexofile; Ni-Ti, nickel-titanium.

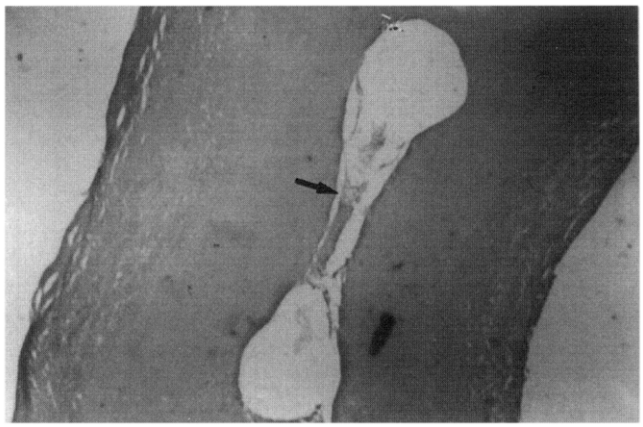

FIG 1. Canals prepared by the step-back technique, using stainless steel files. Notice tissue remnants (arrow) in isthmus between canals (hematoxylin and eosin, original magnification × 40).

RESULTS

The scores provided by the five techniques are shown in Table 1. The analysis of data failed to show any statistically significant difference among the groups ($p > 0.05$). The means of the scores revealed that the instrumentation techniques were, on the whole, relatively effective in debriding the main canal. However, total cleansing of the root canal system was not frequently observed, since tissue remnants were present in isthmuses and branches of the main canal (Figs. 1, 2, and 3). All canals classified as score 3 showed no significant anatomic variation (Fig. 4).

The control group contained normal or inflamed pulp tissue and an intact predentin layer.

DISCUSSION

Although the five techniques tested in this study have been effective in removing major amounts of tissue and debris from most of the root canals, on the whole none was able to totally clean the entire root canal system. The results indicated that the reason for this ineffectiveness is related to the variations in the root canal internal anatomy. Isthmuses and ramifications, observed in most specimens in this study, contained tissue remnants not contacted by instruments during canal preparation by the different techniques

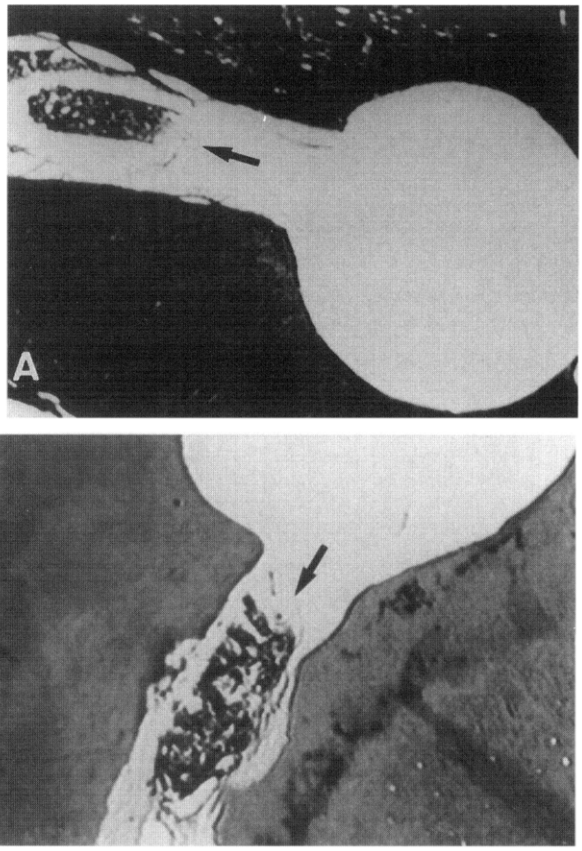

FIG 2. Tissue remnants in root canal branches (arrows) unaffected by instruments and irrigants. *A*. Canal prepared by the balanced force technique (Gomori Trichrome, original magnification × 400). *B*. Canal prepared by the step-back technique with stainless steel files (hematoxylin and eosin, original magnification × 400).

tested. In pulpal infectious processes these inaccessible areas may harbor bacteria and their products that might not be affected by the cleaning action of the chemomechanical preparation, thereby creating a potential for the long-term failure of the endodontic therapy.

Endodontic instruments are manufactured from a relatively inflexible wire, with a standard design. Despite the modifications introduced, the design and the physical limitations make the endodontic instrument inadequate to effectively clean the root canal system, regardless of the instrumentation technique used (12).

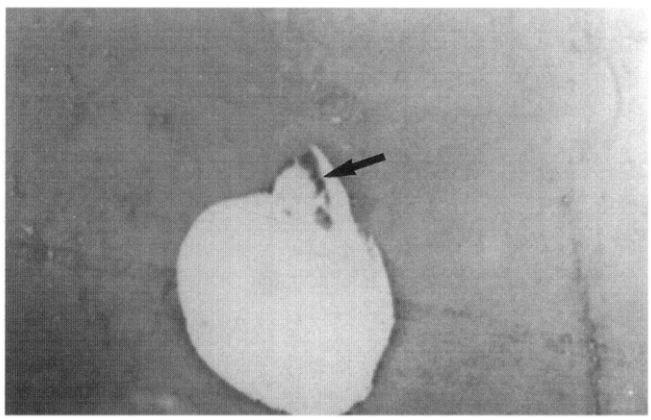

FIG 3. Canal prepared by the ultrasonic technique. Some tissue was not touched by the files (arrow) (hematoxylin and eosin, original magnification × 100).

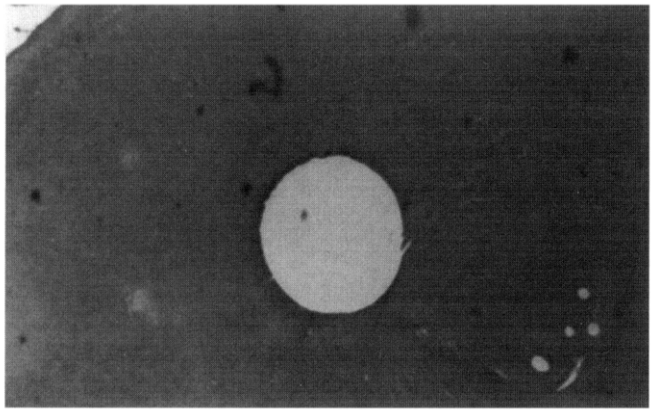

FIG 4. Canal enlarged by the Canal Master U technique and instruments. Notice that the preparation was rounded and centered (hematoxylin and eosin, original magnification × 100).

It has been said that the cleaning effectiveness of the ultrasonic technique is linked to the phenomena of cavitation and acoustic streaming (5, 13). However, the results of the present study are in agreement with others (14, 15) that have not found significant differences between ultrasonic and hand techniques in cleaning root canals. The reason for this may be that cavitation is unlikely to occur in a confined area such as root canal, where the contact of the file with the canal walls may dampen the oscillatory motion and the displacement amplitude of the file. To ensure cavitation, the file must vibrate at a displacement amplitude of at least 135 μm (16), which is difficult to achieve in the clinical situation. On the other hand, acoustic streaming possibly occurs in the root canals provided that severe file-dentin wall contact is avoided (17). In our study, a #15 ultrasonic file was allowed to freely vibrate during some stages of the canal preparation. Nevertheless, if acoustic streaming occurred, it seemed not to have relevance in enhancing the cleaning of the root canals.

The results of this study showed that none of the five instrumentation techniques tested were effective in completely debriding the root canal system.

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