Root Canal Wall Dentin Structure in Uninstrumented but Cleaned Human Premolars: A Scanning Electron Microscopic Study

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Abstract

Introduction: Conventional endodontic treatment includes instrumentation of the canals in most cases to size #25/.06 or larger, which changes the original canal wall anatomy. In recent years, energy-driven equipment, such as photon-induced photoacoustic streaming (Fotona LLC, Dallas, TX) and a multisonic GentleWave system (Sonendo Inc, Laguna Hills, CA), have been introduced to facilitate cleaning of minimally instrumented canals or even uninstrumented canals. The purpose of this study was to examine root canal wall anatomy in premolar teeth cleaned by a noninstrumentation method after #10 K-file patency examination. **Methods:** Twenty-four freshly extracted human premolars were accessed, and patency was established by a #10 K-file. Seventeen teeth were treated by the GentleWave system using 3% sodium hypochlorite, and 7 untreated teeth served as negative controls. The dentin surface in the coronal, middle, and apical thirds of the root canal was examined by scanning electron microscopy after tooth splitting. The canal wall structures were assessed using a predefined scale of 4 parameters: calcospherites, surface irregularities, dentinal tubule openings, and tissue debris. **Results:** A clean surface of mineralized dentin was exposed with no organic tissue remnants or debris left in the root canal system, including the isthmus areas between the 2 canals. The uninstrumented root canals showed an irregular dentin structure in many areas, including previously unreported finger-like projections. The isthmus areas had no or only a few dentinal tubule openings. The dentin structures were well preserved in the test group, whereas in the untreated control teeth tissue debris covered most of the dentin surface. **Conclusions:** Root canal wall dentin in premolars cleaned with a noninstrumentation method showed a wide structural variety, especially in the middle and apical region. No organic tissue remnants or dentin debris were detected. *(J Endod 2018;■:1–7)*

Key Words

Calcospherites, debris, dentin, GentleWave, microstructure, noninstrumentation, tissue remnants

Significance

Human premolars can be completely cleaned free of organic matter with a specific noninstrumentation method. This can greatly contribute to saving the root structure. The absence of dentin debris because of noninstrumentation cleaning may facilitate a better antimicrobial effect of the treatment.

The root canals of human teeth are inherently complex systems with many irregular structures (1, 2). The anatomic complexity of the root canal system enables bacteria to hide and multiply (3), and despite instrumentation of high quality and the use of different irrigating solutions, debris often remains in specific areas of the canal (4). When adequate cleaning cannot be achieved, the sealing of portals of communication with periapical tissues is more difficult, and the persisting intracanal bacteria in the root canal system may eventually cause failure of the endodontic treatment (5). Conventional endodontic treatment includes instrumentation of the canals in most cases to a minimum size of #25/.06 or #30/.04 and often larger than these. This has been necessary for 2 main reasons: to optimize cleaning by irrigation, especially of the apical root canal, and to support the making of a high-quality root filling. As a result of canal preparation, much of the root canal wall area is flattened by the instruments, and original wall structures remain only in areas that are beyond the reach of the files.

In recent years, energy-driven equipment, such as photon-induced photoacoustic streaming (Fotona LLC, Dallas, TX) and the multisonic GentleWave (GW) system (Sonendo Inc, Laguna Hills, CA), have been introduced to facilitate cleaning of minimally instrumented canals or even uninstrumented canals (6). A noninstrumentation cleaning method has the advantage of saving the tooth structure, but by leaving canal wall structures untouched, it might also create a greater challenge for the removal of tissue remnants and biofilm by irrigation in the complex microanatomic landscape. The details of dentin morphology have been investigated by several previous studies (7–12). Some of these studies examined the microscopic structure of tubular dentin using coronal dentin (7, 8, 10); others focused on root canal dentin morphology and the root dentin structure after instrumentation (9, 11, 12), when much of the original root canal structure has already been changed. There are no reports of the shapes and structures of the root canal dentin wall after the use of the newly introduced, energy-driven noninstrumentation cleaning methods.

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Recent histologic and scanning electron microscopic (SEM) studies in extracted human molars have indicated that the GW system, using the GW molar instrument, creates a clean root canal space and no erosion of dentin could be detected (13, 14). There are no studies so far using the GW instrument for premolar and anterior teeth or the anatomy of the root canal dentin surface after the cleaning procedure.

The goal of the present study was to evaluate the surface morphology of the root canal wall dentin after GW cleaning without instrumentation in human premolars using scanning electron microscopy. The shape and the amount of calcospherites, surface irregularities, dentinal tubule openings, and tissue debris were examined.

Materials and Methods

Tooth Collection

Twenty-four single-rooted permanent premolar teeth extracted for orthodontic reasons were collected and visually and radiographically examined. All samples were intact teeth with no previous root canal treatment, extensive coronal restoration, root caries, root resorption, or open apices. The protocol of this study was approved by the ethics committee of the university (certificate H12-02430). All samples were accessed according to standard endodontic procedures. A #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was inserted into the canals to confirm patency, but no filing was performed. Radiographs and examination under a stereomicroscope showed that root development was completed, and none of the teeth had an open apex. Eight of the 24 teeth had 2 joining canals in 1 root.

To maintain the original root canal microstructure, no instrumentation was performed in this study. Samples were randomly divided into 2 different groups with 7 and 17 samples in each group, respectively. Seven untreated premolars were used as a negative control with 2 samples having 2 joining canals. The remaining 17 teeth were cleaned by the GW premolar instrument with 6 samples having 2 joining canals.

Cleaning Protocol

The GW system consists of a console and a treatment instrument whose mechanism has been previously described (6, 15). According to the manufacturer, a degassed stream of fluid generates a broad spectrum of sound waves that travel through the fluid into the root canal system (15). After the access cavity was created, the tip of the treatment instrument was placed in the space of the access opening and the pulp chamber of the teeth and sealed with a block-out resin material (Kool-Dam; Pulpdent, Watertown, MA). The treatment consisted of 3% sodium hypochlorite for 5 minutes followed by distilled water for 15 seconds. The sodium hypochlorite solution was dispensed by the treatment instrument at a flow rate of 45 mL/min. Irrigation using EDTA was not done because the canals were not instrumented.

SEM Analysis

After cleaning, external grooves were made on the buccal-lingual surface of the roots with a 0.17-mm-thick diamond disc (Brasseler Inc, Savannah, GA), and the roots were split into 2 halves by a single-edge razor blade and a hammer. Thus, the sample size was 14 and 34 for the negative control and test groups, respectively.

The dentin halves were subjected to increasing concentrations of ethanol (50%, 70%, 80%, and 100%) for serial dehydration. The dehydrated specimens were sputter coated with iridium using a Leica EM MED020 Coating System (Leica Microsystems Inc, Concord, Canada) for SEM analysis. The surface of the root canal wall after treatment was imaged by scanning electron microscopy (Helios Nanolab 650; FEI, Eindhoven, Netherlands).

Image Evaluation

An SEM image at 50× magnification was taken at each of the coronal, middle, and apical thirds of the root to obtain an overall view. The presence and absence of calcospherites, surface irregularities, dentinal tubule openings, and tissue debris were rated and scored using a modified predefined scale system (16). The scoring system used in the present study is described in Table 1. SEM images at the magnifications of 200× and 1000× were used for scoring. Specific areas of dentin were observed for qualitative analysis at greater magnification ranging from 4000× to 20,000× whenever there was a need to determine the type of tissue (ie, organic or inorganic).

The scoring of surface irregularities and tissue debris was performed using SEM images at 200× magnification, and the scoring of calcospherites and dentinal tubule openings were performed using 1000× magnification. A total of 288 images (48 samples × 3 canal thirds × 2 magnifications) were analyzed by 2 examiners who were blinded to the group distribution to examine and score the images. The percentage of the count of each score level among the total sample size in each group (34 in the noninstrumentation group and 14 in the negative control group) was calculated to show the distribution of each score. Extra SEM images (in addition to the 288 images) with magnification higher than 4000× were taken when necessary to identify specific dentin microstructures and to separate mineralized irregular structures from organic tissue remnants and inorganic debris.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows, Version 16.0 (SPSS Inc, Chicago, IL). The weighted coefficient kappa was used to measure interobserver reproducibility. The differences in the scores between groups were analyzed by the Kruskal-Wallis test and the Mann-Whitney test at a significance level of $P < .05$.

Results

Score distribution attributed to each parameter on the three thirds of the canals is summarized in Figure 1. The kappa value for the

TABLE 1. Scale of Values Assigned to Different Parameters Evaluated

Scale	1	2	3	4
Calcospherites	Absent	Covering less than 50% of the root canal surface	Covering 50%–75% of the root canal surface	Covering over 75% of the root canal surface
Surface irregularities	Absent	Covering less than 25% of the root canal surface	Covering 25%–75% of the root canal surface	Covering over 75% of the root canal surface
Dentinal tubule openings	0%–25% open	25%–50% open	50%–75% open	75%–100% open
Tissue debris	Absent	Covering less than 25% of the canal surface	Covering 25%–75% of the canal surface	Covering over 75% of the canal surface