Three-Dimensional Reconstruction: A New Method for the Evaluation of Apical Microleakage

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The purpose of this study was the evaluation of a new method for studying apical microleakage by using a three-dimensional (3-D) reconstruction method. Fourteen human single-rooted mandibular teeth were used for this work. The canals were prepared with hand instruments by using the step-back technique. To supply a focus to the study of the method, the teeth were divided into two groups that were obturated using two different sealers. India ink was used for passive stain. Serial cross-sections 0.75 mm thick were taken from each specimen by using a special microtome. Each section was photographed under a stereoscopic microscope. Each section was photographed under a stereoscopic microscope. Each photograph was digitized and processed to obtain a 3-D reconstruction of the external surface of the teeth, their corresponding prepared root canals, and their apical microleakage. Sample size and experimental methods were not designed to make valid groups; however, apical microleakage was observed in both groups ranging between 2.25 to 8.25 mm height. The 3-D reconstruction method has proved to be a useful tool in the study of apical microleakage.

MATERIALS AND METHODS

Fourteen human single-rooted mandibular anterior teeth were used. The teeth were cleaned in a 3% sodium hypochlorite solution for 48 h to remove any organic debridement. An initial radiograph was taken of each tooth; after that their working lengths were determined with a #10 K-file and an intermediate radiograph was taken. One millimeter was subtracted to gain the working length for each case. Canals were then prepared by the step-back technique using a #35 Hedstrom file, such as a master apical file. Sodium hypochlorite (2.5%) was used as an irrigation solution during instrumentation. After final irrigation the canals were dried with paper points. Subsequently, the teeth were divided into two groups that were obturated using two different endodontic sealers and cold lateral condensation of gutta-percha. The teeth were stored at room temperature in 100% humidity. Two days later the crowns were removed and the roots were coated with three layers of nail polish, except for the 3 mm apically, and were put in India ink for 5 days (Royal Talens, Apeldoorn, Holland) for passive staining. The roots were rinsed under running water and the nail polish was removed. The teeth were incubated in a two-phase polyester resin and 48 h later serial cross-sections were taken from each specimen (0.75 mm thick) by using a special microtome (Isomet, Buehler, IL).

Each section was photographed under a stereoscopic microscope (Stemy SV8, Zeiss, Germany). Because of the high magnifications used in the stereomicroscope with respect to the size of the sections, no single photograph could cover an entire section. Therefore, in most cases, we had to take more than one microphotograph from each section, each one representing a partial view.
FIG 1. (a) Cross-section of the apical third of a tooth. Little microleakage is observed. (b) No microleakage is seen on the cross-section of the coronal third. (c) 3-D reconstruction of the endodontic-treated tooth. The external surface of the tooth is shown as purple, the root canal as yellow, and apical microleakage as cherry red.

These photographs were then collaged to obtain the entire microscopic image of the section and were digitized with a resolution of 72 dots per inch, by using an image scanner (Epson 6000, Seiko Epson Corporation, Nagano, Japan). The gray scale used was 0 to 255. To make different dental tissues more distinguishable and to increase the visual image quality, the contrast was enhanced by using EIKONA3D, a digital image processing package for 3-D image processing developed for Microsoft Windows 95 (15).

Then, the contours of the external surface of the roots, the root canal tracks, and the apical microleakage were followed for each section. Subsequently, semiautomatic alignment of the sections of each specimen was performed using image processing techniques. A heuristic contour after an algorithm was incorporated to store object contours as a list of points to make contour manipulation easier.

Surface representation (3-D) was used in this work to reconstruct the outer surface of the root, the inner surface of the root canal, and apical microleakage. The triangulation method was used in this stage to produce the 3-D wireframe model.

All of the above procedures—contour extraction, alignment, and 3-D surface representation—were implemented by using EIKONA3D (15).

Finally, visualization of the 3-D reconstructed model of each root was performed by using surface rendering from different viewpoints around the 3-D model, combined with photorealistic effects, such as color and texture addition, lighting, and shading. The materials used for surface rendering were the transparent purple glass for the outer surface of the root, yellow glass for the root canal, and cherry red for apical microleakage, so that the best possible visual result was achieved. This final stage was achieved using Autodesk 3D Studio Release 4 (Kinetix, Autodesk, Inc., San Rafael, CA.)

RESULTS

Usage of the serial cross-sectioning and 3-D reconstruction allows for studying the apical penetration of India ink on each section and the entire microleakage through its 3-D reconstruction.

The linear penetration of India ink was measured and found to be between 2.25 to 8.25 mm. There were cases where penetration was very small (Figs. 1a and 1b), although there were other cases in which a more widespread penetration of India ink was observed (Figs. 2a and 2b) during microscopic study of serial cross-sections.

Through the 3-D reconstruction that followed we were able to study the apical microleakage in space by observing the penetration from different view angles (Figs. 1c and 2c). Finally it must be mentioned that the 3-D reconstruction can be used not only for the study of the linear apical length but also for volume measurements of microleakage.

DISCUSSION

Wu and Wesselink (14) observed that data obtained from the linear measurements of dye penetration after longitudinal splitting or decalcification and clearing of roots varied much more (range: 0.5 to 9.25 mm and 0.12 to 5.96 mm, respectively) than data obtained after cross-sectioning of the samples (range: 1.07 to 3.9 mm). They (14) also emphasized that the most popular method—linear measurement of tracer penetration along the root filling—did not produce relevant and reliable semiquantitative data, because these techniques did not provide any information about the volume of the tracer that penetrated along the root canal obturation. They have judged that quantitative, volumetric studies should be
Fig 2. (a) Cross-section of the apical third of the treated tooth. Microleakage is obvious in almost half of the perimeter of the root canal. (b) Cross-section of the coronal third of the treated root. (c) Three-dimensional reconstruction of the case. The external surface of the tooth is shown as purple, the root canal as yellow, and apical microleakage as cherry red.

more reliable and valid because it might be more relevant to know the volume of fluid that can penetrate through an obturated root canal than to obtain information about the length of a gap in a filled root canal.

Use of computer-aided 3-D reconstruction for the evaluation of the apical microleakage is a new method which, by using proper colors, texture, lighting, and shading, enables us to study the three structures (the external surface of the teeth, the inner surface of the root canal track, and apical microleakage) in 3-D space from different view angles. Furthermore this method enables the accurate evaluation of the total volume of microleakage from different viewpoints.

This method uses high-magnification microscopic images of the cross-sections, thus allowing histological study of microleakage.

In conclusion, the computer-aided 3-D reconstruction of dye microleakage method proved to be an interesting and useful tool for qualitative and quantitative studies of apical microleakage of different types of endodontic sealers.

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References