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Computerized Analysis of the Instrumentation of the Root Canal System

E. Berutti, MD, DDS

A method is proposed for a three-dimensional visualization of the root canal system before and after the cleaning and shaping procedure to analyze the relationships of the root canal walls. The first part of the study provided cross-sections of the root perpendicular to the root canal. A system for remounting the sections of the root before and after instrumentation was set up. Micrographs of the sections were transferred to a graphics computer which rebuilt and elaborated the sections, providing a three-dimensional model of the root with the image of the root canal system before and after instrumentation. This experimental computerized model enables sections of all kinds to be produced, with great possibilities for measurement and analysis.

One of the most debated arguments in endodontics is how to evaluate the effectiveness of instrumentation techniques. Various investigation methods have been proposed, including serial sections and evaluation under the stereomicroscope (1) and histological sections and evaluation under the optical microscope (2). Both of these techniques only provide images of the canal after instrumentation and only in two dimensions. The scanning electron microscope enables us to evaluate the cleaning of the canal walls but not the shaping (3).

Weine has proposed the use of simulators to evaluate instrumentation (4); in this case we do have a three-dimensional view, but the canal is not oriented as it is in the anatomical context of the root. Furthermore, the plastic material of which the simulator is made has neither the consistency nor the characteristics of dentin.

Abou-Rass and Jastrab (5) have evaluated various instrumentation techniques using silicon impressions of the canal; as with the simulators, the canal is shown after instrumentation and is not in the context of the root. Radiological analysis can only provide a two-dimensional image (6).

The method of Bramante et al. (7) is very interesting, enabling us to observe transverse sections of extracted teeth before and after instrumentation through a reassembly system.

MATERIALS AND METHODS

Mesial roots of first permanent mandibular molars were conserved in a 10% solution of formalin; residues of calculus and alveolar bone were removed by ultrasound. The coronal and median thirds of the roots were analyzed, since it is in these roots and in these areas of the canal that instrumentation must be extremely accurate and careful to avoid stripping.

In order to obtain sections perpendicular to the root canal in the coronal and median thirds, the roots were embedded in resin blocks using a positioning device, so as to have that part of the canal parallel to the long axis of the block (8). To enable the sections to be repositioned correctly in space, two aluminum rods were contained in the embedding system; these were perfectly parallel to the long axis of the block (centering system). Following Bramante's method (7), a plaster stone removable muffle was constructed which enclosed the resin block. Sections were cut using the Tronconeuse P100 (Pressi, Grenoble) equipped with a diamond disc of 101-mm diameter and 0.31-mm thickness. The resin block containing the root was fixed to a special arm of the saw, keeping the long axis (and so the canal in the coronal and median thirds) parallel to the cutting disc; five cuts were made (Fig. 1). The first was just below bifurcation, and successive cuts were made at intervals of 1 mm. The lower face of each section was used; the five lower faces were photographed under the stereomicroscope (Stereomicroscope SR with photographic system MC63A; Carl Zeiss, Oberkochen, Germany) with a magnification of ×16. The sections were then reassembled inside the plaster muffle and the canals were instrumented. Files up to #25 were used for the apex, and reamers from #25 to #60, decreasing in length by 1 mm each time, to prepare the body of the canal. Gates Glidden #2 burs were used to increase the taper of the coronal third. Irrigating solution was 3% sodium hypochlorite.

The sections were then removed from the plaster muffle, and the five lower faces, now instrumented, were photographed again under the stereomicroscope with ×16 magnification. Using an IBM 5080 graphic work-station (19-inch screen, resolution of 1024 × 1024 pixel) connected to an IBM 4341 computer, with the software product CATIA (Computer-Aided Three-Dimensional Interactive Application), the outlines of the five sections before instrumentation were transferred into the computer by the graphic tablet.

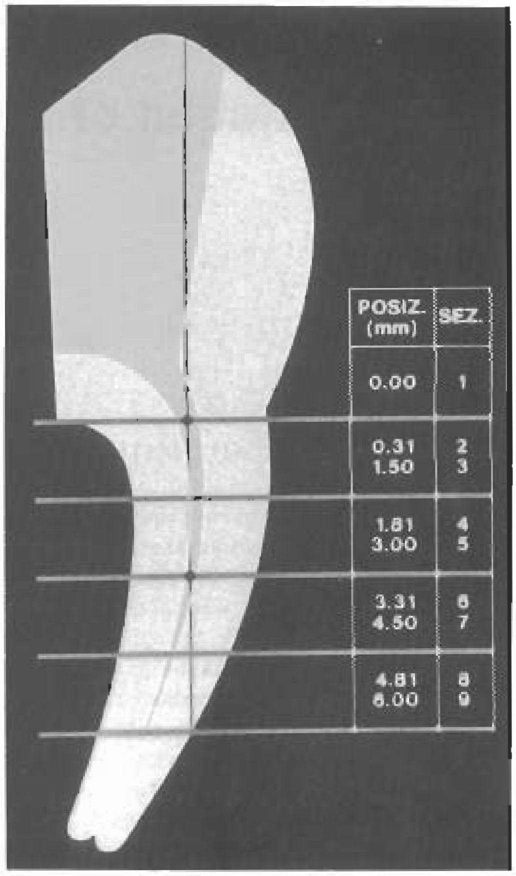

FIG 1. Diagram of the cuts made through the root embedded in the resin block.

The microphotographs were enlarged and were very clear, with distinct and well-defined outlines. On these enlarged images, a sufficient number of points on the outline were digitalized to give an extremely accurate approximation of a closed curve. The curves were digitalized manually rather than automatically; the process was interactive, and those parts of the outline with sharper or more complex curves were defined with a higher number of points than the other, less complex parts. Comparison of the microphotographs with the images of the curves obtained showed that this technique was correct and reliable: correspondence between the two was more than sufficient for the purpose of this research. Subsequently, it was quick and simple by a process of rototranslation to superimpose the various planes containing the curves (sections) in the correct position, so as to have a single reference system in the centering system (transverse sections of the aluminum rods embedded in the block and correctly oriented in space). Through operations proper to the software product CATIA, the surfaces lying on the curves were then constructed and visualized through isoparametric curves (wire frame model) (Fig. 2). The same operation was carried out for the five lower faces of the sections after instrumentation of the canals (Fig. 3). The two experimental models, that is the root and canal before and after instrumentation, were then superimposed. In this way the external surface of the root was visualized with the instrumented canal containing the original canal correctly positioned inside it (Fig. 4).

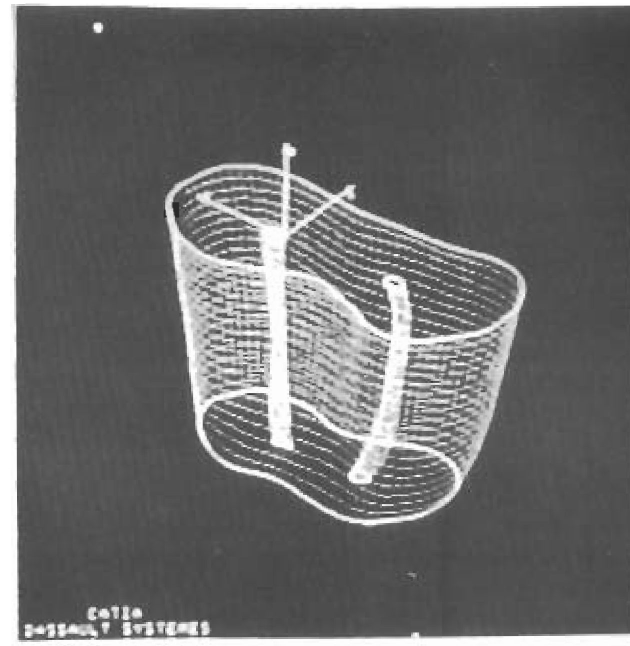

FIG 2. Median and coronal thirds of mesial root of first lower molar reconstructed in three-dimension through isoparametric curves before instrumentation of root canals.

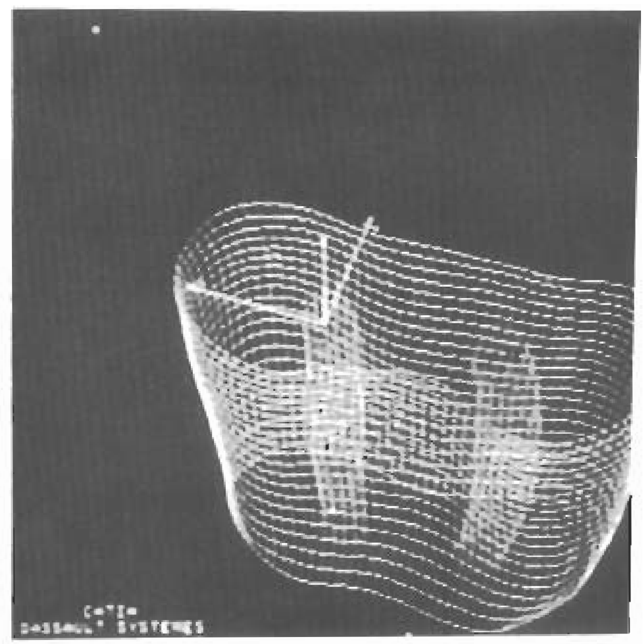

FIG 3. Same view as in Fig. 2 after instrumentation of root canals.

The outer surface of the root was then eliminated and the canals visualized (Fig. 5). The relationship between the original canal and the instrumented canal was analyzed. In order to ensure better correspondence to reality, a solid model was obtained from the wire frame. Transverse cuts were made through the canals, and color and shading were added. As can be seen in Fig. 6, this provides a considerable amount of information concerning the relationship between the external root surface and the instrumented canal and between the instrumented canal and the original canal.

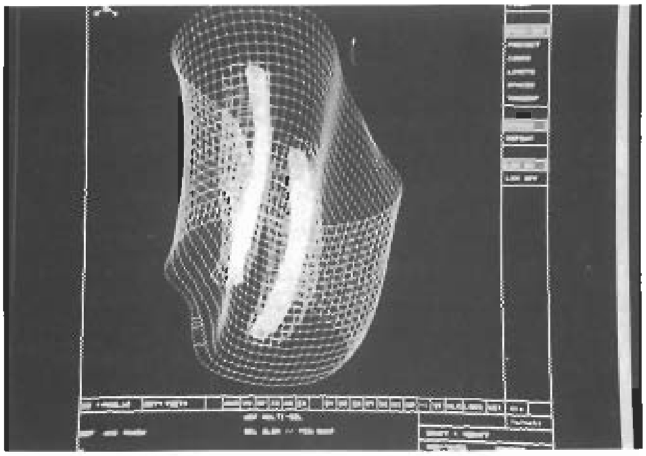

FIG 4. Superimposition of models in Figs 2 and 3. External surface of root and canals before and after instrumentation are visualized in three-dimension simultaneously.

FIG 5. After the elimination of the external surface of the root, the instrumented canal is evidenced with the original canal inside it.

DISCUSSION

The computer can provide animated images of the experimental model; the figures are stills taken from such a film. The models can be rotated in any plane in space and enlarged; all types of section can be made. On the experimental models we can obtain metric measurements, volumes, and surfaces. If we know the density of dentin, we can calculate the weights. The digitalization operations were found to be rapid and

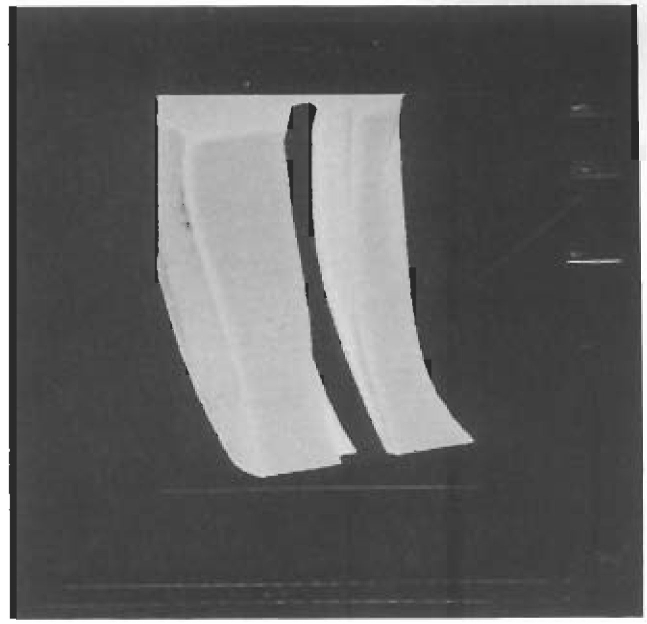

FIG 6. Solid model. Mesiodistal transverse sections passing through the mesiolingual canal.

reliable, thanks to the centering system incorporated. The use of the experimental models was extremely simple, thanks to the versatility of the software product CATIA used. The precision of the experimental model was found to be more than sufficient, thanks to the digitalization system, and to the very high resolution offered by the screen used (1024 × 1024 pixel).

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Dr. Berutti is assistant professor, Department of Endodontics, University of Turin, Italy. Address requests for reprints to Dr. E. Berutti, Via Paolini 12, 10138, Torino, Italy.

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