Computerized 3-D reconstruction of two "double teeth"

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Abstract - “Double teeth” is a root malformation in the dentition .

The purpose of this study was to reconstruct three-dimensionally the external and internal morphology of two “double teeth”. The first one was formed by the conjunction of a mandibular molar and a premolar, and the second one from a maxillary molar and a supernumerary tooth.

The steps followed towards 3-D reconstruction included serial cross sectioning, photographing of the sections, digitization of the photographs, extraction of the boundaries of interest for each section, surface representation using triangulation and, finally, surface rendering using photorealistic effects. The resulting three-dimensional representations of the two teeth helps us to efficiently visualize their external and internal anatomy. The results showed fusion of the radical and coronal dentine, as well as fusion of the pulp chambers for the first case, whereas fusion only of the radical dentine and of the pulp chambers for the second case.

Key words: Dental anatomy; 3-D reconstruction; double teeth.

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There is a great variety of tooth malformations, or of dental anomalies in general, in number, size and form of the teeth(1). “Double teeth” is a term recommended by Brook and Winter(2) for teeth resulting from fusion, gemination or concrescence. “Double teeth” is an uncommon but by no means rare condition(3).

The existing literature presents reviews and case reports(2-11) and a structural and ultrastructural study of such teeth(12).

Knowledge of the root canal morphology of each group of teeth is necessary for the endodontist. Different methods have already been used for the study of the root canal anatomy of teeth(13-17).

The purpose of this study was to reconstruct three-dimensionally by means of a computer the external and internal morphology of two “double teeth”. This is a novel method for the study of the anatomy of teeth.

Materials and methods

Two “double teeth”, which were extracted because of crowding and caries were used in this study. The first tooth was formed from a mandibular molar and a premolar, and the second from a maxillary molar and a supernumerary tooth.

The teeth were inserted in a 5% sodium chloride solution for 24 hours for cleaning, washed under running water and air-dried . After that they were embedded in a two phase polyester resin. Serial cross sections were taken from each block, 48 hours later, by using a special microtome (Isomet, Buehler, Illinois, U.S.A.). The thickness of each section was 0.75 mm. Twenty-five sections were obtained from the first and twenty-three sections from the second tooth. Each section was photographed under a stereomicroscope (Stemy SV8, Zeiss, Wetzlar, Germany). Because of the high magnifications available from the specific stereomicroscope with respect to the size of the sections, no single photograph could cover an entire section. Therefore, 3-6

photographs were taken from each section, each one representing a partial view of it. These photographs were then collaged in order to obtain the entire microscopic image of each section. The collage can be easily observed in the images of the sections that appear in Figures 1-4, 7-8.

The first step towards 3D reconstruction was the digitization of the photographs (Fig. 1,2), using a scanner (Epson 6000, Seiko Epson Corporation, Nagano, Japan). The obtained grayscale images were further processed using contrast enhancement methods in order to make different objects more distinguishable and increase the visual image quality(18). The external boundaries of the teeth and the root canal tracks were extracted for each section (Fig. 1,2) and proper alignment of the sections was performed using heuristic techniques. The aligned object contours were finally represented as lists of points for easier contour manipulation(19). The resolution of the scanned photographs were arranged to such a level, in order to have discrimination in the needed boundaries, as these were what we needed for the three-dimensional representation.

The next step was the three-dimensional representation of the surface of the teeth, the pulp chambers and root canals, using the triangulation method. The relative algorithm requires the user's interaction in order to decide which contours to connect between successive sections in order to produce the 3D wireframe model(20).

All the above procedures, boundary extraction, alignment and three-dimensional representation, were implemented by using software developed in the Artificial Intelligence and Information Analysis Laboratory, Department of Informatics, Aristotle University of Thessaloniki. This software was developed for PC environment.

Finally, the visualization of the 3D reconstructed model of each tooth was performed by using surface rendering from different viewpoints around the 3D model, combined with photorealistic effects such as color and texture addition, lighting and shading. The materials used for the surface rendering were the transparent purple glass for the outer surface and the opaque yellow mate for the pulp chamber, so that the best possible visual result was achieved. The visualization was made using Autodesk 3D Studio Release 4 (Autodesk, Inc.).

Results

First case

The histologic examination under the stereomicroscope showed a fusion of the dentine of the two conjoined teeth, not only at the radical (Fig. 3), but also at the coronal level (Fig. 4). The configuration of the dentinal tubules of the two tissues arising from different tooth germs was characteristic and confirmed their origin.

By using the 3D reconstruction method the anatomical structure of the external and internal morphology of the tooth became clear. A conjunction of two root canals in the cervical third of the roots was observed (Fig. 5). At the middle third, two root canals were distinguished with two apical foramina (Fig. 6). The first root canal had a normal appearance, while the second canal was extremely broad and had a “double” entrance (Fig. 5,6).

Second case

The histological examination showed a fusion of the dentine of the two conjoined teeth at the radical level (Fig. 7). In the middle third of the roots the root canals were joined (Fig. 8).

By using the 3D reconstruction method, four root canals and four apical foramina were observed (Fig. 9,10). The conjunction of the root canals was also clearly seen.

Discussion

As “double teeth” can be formed from the conjunction of two teeth at an early stage of development, when the teeth are still tooth germs, a true confluence of the dentine can arise(1). This was confirmed by our histological investigation, where we could distinguish the conjunction of the dentine of both conjoined teeth.

The confluence appeared to occur either at the coronal or the root level, or even at both levels, depending on the developmental stage when the malformation was initiated.

The method used in this work for the study of the external and internal anatomy of “double teeth” has already been used for the reconstruction of the root canal configuration of C-shaped teeth(20). It is an interesting method for the study of teeth with different malformations, and especially of teeth that are to remain in their position in the mouth.

The method of sectioning in general on different levels of teeth of interest have been used from other investigators(13-17) for the study of the anatomical and histological features of these teeth.

These investigators had used sectioning of the teeth of interest for the study of their anatomical structure, but in no way serial sectioning of the whole tooth and furthermore digitization of the sections and 3D reconstruction of these teeth.

One of the advantages of the method is that one can observe the internal anatomy of the teeth from different angles. This makes the method an interesting educational tool.

It would be very interesting also in case we were able to apply animation on the teeth of this work, but unfortunately for a paper we have to give only two-dimensional imaging.

Nevertheless this is a new method, very interesting as an application of the new technologies in dentistry.

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Fig. 1. Digitized photograph of a section of the first case (left). External and internal boundaries of the tooth section (right).

Fig. 2. Digitized photograph of a section of the second case (left). External and internal boundaries of the tooth section (right).

Fig. 3. Section demonstrating conjunction of the dentine of the two teeth (arrow) at the radical level. Two distinct root canals are seen at this level.

Fig. 4. Section demonstrating conjunction of the dentine of the two teeth (arrow) at the coronal level.

Fig. 5. 3D reconstruction of the first "double" tooth. Root canals are yellow, while the rest of the reconstructed tooth is purple glass. A conjunction of the root canals at the cervical third is seen.

Fig. 6. 3D reconstruction of the same "double" tooth seen from another angle.

Fig. 7. Section demonstrating conjunction of the dentine (arrow) of the two conjoined teeth at the cervical third of the roots.

Fig. 8. Section demonstrating conjunction of the root canals (arrow) at the middle third of the roots.

Fig. 9. 3D reconstruction of the second “double” tooth.

Fig. 10. 3D reconstruction of the second “double” tooth seen from another point of view. Four root canals are seen, three are very tiny while the fourth is wider, as a result of conjunction.