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RESEARCH

Root canal system in the mesiobuccal root of the maxillary first molar: an *in vitro* comparison study of computed tomography and histology

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Objectives: The purpose of this study was to investigate a new diagnostic approach to the examination of the canal configuration of the mesiobuccal root of the maxillary first molar.
Materials and methods: High-resolution computed tomography (CT) was compared with histology *in vitro*. There were 152 teeth investigated and classified according to Weine and Vertucci.
Results: CT describes the exact canal configuration, verifying information identical to histology, and thus serving as the "gold standard" *in vitro*. With regard to canal position, 9 (5.92%) of the teeth examined were Vertucci type 1, 48 (31.58%) were Vertucci type 2, 91 (59.87%) were Vertucci type 4, 1 (0.66%) was Vertucci type 5, 1 (0.66%) was Vertucci type 6. Of the 152 teeth examined, 3 (1.97%) could not be classified using Weine, 2 (1.31%) could not be classified according to either Weine or Vertucci, and no Vertucci types 3, 7 or 8 were identified.
Conclusions: CT offers complete information on the number and configuration of root canals. As the root canal configuration of the adult does not change rapidly, CT investigations can be used for multiple subsequent treatments.
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Burns described the maxillary first molar as "…possibly the most treated, least understood, posterior tooth".[1] Peak et al described a success rate for the maxillary first molar of only 77% after a period of 3 years.[2] A better knowledge of the root canal system is an absolute necessity for a successful root canal treatment.

Studies have shown that the root of a tooth has not only one or two canals, it can also branch out on numerous side and lateral ramifications. Weine divided the position of one or two canals within one root into four categories (Weine I–IV).[3,4]

Vertucci also analysed the root canal anatomy in his studies and described a classification encompassing eight different types.[5–7]

With the help of conventional radiology, it is possible to get an overview of the position of the root canals, yet problems with the diagnostic result arise due to, for instance, the superimposition effects of the zygomatic bone.[8] In addition, the canals often overlap due to the anatomy and X-ray viewpoint, so that the complexity of the canal system cannot be characterized.[9–11] "Radiography is often of limited assistance to the clinician in assessing variations in root canal anatomy of the mesiobuccal root canal. In all studies the mesiobuccal root canal of the maxillary permanent first molar has been shown to be most complex".[12]

The aim of this study was to assess the precision of a medical CT scanner with high resolution imaging protocol and dental reconstruction software for evaluation of the canal configuration of maxillary first molars in comparison with histological investigation.

Materials and methods

In this study, the root canals of the mesiobuccal root of the maxillary first molars were examined. In the first examination stage, 152 (80 left and 72 right) maxillary molars were embedded in Optosil® (Haereus Kulzer) and transverse CT

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images were obtained with Tomoscan SR-6000 (Philips Medical Systems, Best, The Netherlands) as described by Gahleitner et al.[13] The "field of view" of choice was as small as possible (50 mm) to guarantee sufficient detail recognizability. The slice thickness was 1 mm with a table feed of 1 mm. Scanning time per layer was 2 s. The tube current was 75 mA, and the tube voltage was 120 kV.

Subsequently, the same teeth were cleaned and decalcified for 6 days using an electrolytic decalcification device (42 ml 100% formic acid + 48 ml 25% hydrochloric acid, filled with aqua destillata to 500 ml), which operates with 1.2 A at 12 V (EG-33, Medax, Nagel GmbH, Kiel). Afterwards, the teeth were stored in small embedding cassettes (Sanova Diagnostic, Vienna) and placed overnight in the embedding machine (Tissue Tek VIP, Sakura), where they were incubated for 1 h each in formaldehyde, using increasing concentrations of alcohol, xylol, and paraffin. Then the molars were embedded in 52°C paraffin in special cups (Shandon, UK; Tissue Tek, Sakura). Histological sections, 10 μm thick, were cut by a rotation microtome (Leica RM 2155, Leica). The sections were mounted and dried overnight on previously specially coated (silanicised with 3-Aminopropyltriethoxysilane, Sigma Inc.) slides (Menzel-glasses). Afterwards, they were stained with haematoxylin-eosin.

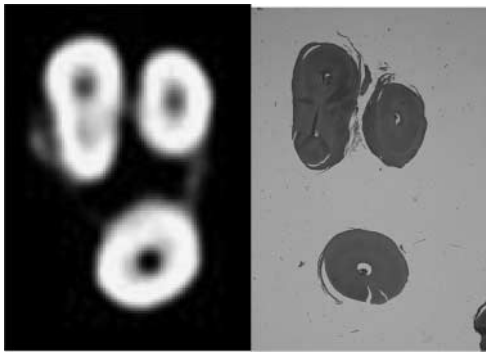

Figure 1 Comparison of the radiological CT images with the histological cut slide (110×) preparations. Enlargement is not equal. The lumina in the CT appear larger because of the "edge enhancement artefact" during image reconstruction

The histological sections and CT layers were coded. Data analysis was conducted based on an *a priori* planned design. The slide preparations were viewed under the microscope (Alphaphot YS2, Nikon) by 110-fold enlargement. Then, they were examined systematically and, because of the CT layer thickness of 1 mm, only every 100th histological section was photographed. Later, the histological and radiographic data were compared. Statistical calculation was performed with Excel.

The following criteria were evaluated in the present study with CT:

(1) Number of canals
(2) Classification based on Weine (I–IV)[4]
(3) Classification based on Vertucci (I–VIII)[5]

The use of both classification groups is based on the fact that Weine is the more frequently used classic classification, but Vertucci is more detailed.

Results

A comparison of CT images with histological findings showed that the position of the canals pictured on CT matched the anatomic realities (Figure 1).

With regard to canal position, 9 teeth (5.9%) were Vertucci type 1 (= Weine classification 1), 48 (31.6%) were Vertucci type 2 (= Weine classification 2), 91 (59.9%) were Vertucci type 4 (= Weine classification 3), 1 (0.66%) was Vertucci type 5 (= Weine classification 4), and 1 (0.66%) was Vertucci type 6. Three molars (1.97%) could not be classified using Weine, and 2 molars (1.31%) could not be classified using either Weine or Vertucci. Vertucci types 3, 7, and 8 were not found in our group. A comparison of our results using Weine and Vertucci classifications also showed that not all the examined teeth could be classified using Weine or Vertucci categories (Figure 2).

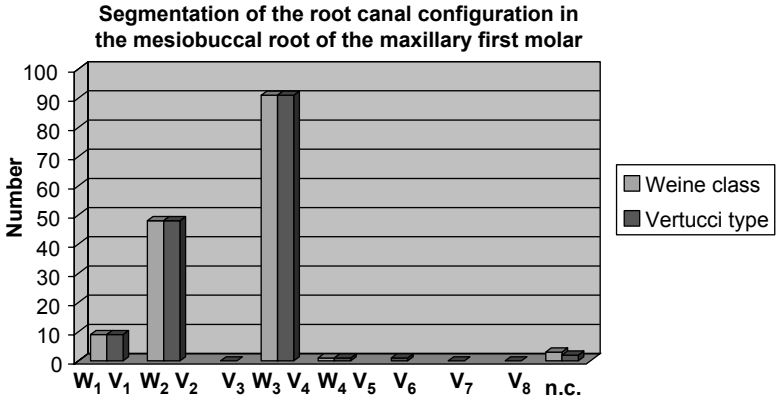

Figure 2 A comparison of our results using Weine and Vertucci classifications, as well as the non-classifiable root canal configurations. n.c., non-classifiable

Discussion

For many years, the number of roots in the maxillary first molars have been examined as well as X-rayed.[9,14–16] However, more recent studies have shown discrepancies between anatomical reality and the actual clinical discovery of the second mesiobuccal canal.[17]

In this study, we found that the canals can be followed and demonstrated accurately to the apex of the molars in the mesiobuccal root using CT. When histological findings were compared with CT results, canal configurations were always identical. To date, it has been possible only to verify the canal positions precisely using histology after extraction. CT, on the contrary, offers a reliable, non-invasive diagnostic approach to study the canal positions *in vivo* in advance and, consequently, perform an exact root canal treatment. On the one hand, this makes it significantly easier for the treating physician to search for the canals and to perform an apical root canal treatment, in the case of a Weine category 4, or to consider to take immediately a "standard" root resection with a retrograde apex sealing. On the other hand, the patient also benefits by avoiding premature extraction due to poor root canal treatment. CT allows the exact evaluation of neighbouring anatomic structures *in vivo*.

In conclusion, the knowledge provided by CT will assist the dentist in reaching the proper diagnosis and treatment of endodontic cases. CT data can be used for a long period of time, since the root canal configuration of the adult barely changes over many years (the root canal configuration of a vital tooth can change through secondary dentine building). CT has the disadvantage of providing a relatively high radiation exposure, but recent studies have shown that the application of low dose protocols gives encouraging results concerning image quality and measurement accuracy in relation to radiation exposure.[13,18,19] The disadvantages of a CT scan include the costs and the higher ionizing radiation exposure. However, the problems with past studies, with regard to the precise imaging of a CT scan, have been resolved.[20–22]

In conclusion our *in vitro* study indicates that CT is a viable tool for evaluation of unclear root canal configurations of the maxillary first molar.

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