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Maxillary Incisor Root Canal Diameter Assessments Using Cone-Beam Computed Tomography Imaging

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Abstract

Objective: This study aimed to measure the buccolingual direction and mesiodistal direction diameters in the apical third of the root canal maxillary incisor teeth using cone-beam computed tomography scans and to examine the effect of age, gender, and previous trauma.

Methods: Totally 58 maxillary incisors were studied. We collected data regarding sex, age, and previous dental trauma. OnDemand 3-dimensional software (Cybermed, Seoul, Korea) was used to measure the canal's diameter in buccolingual and mesiodistal directions at 1, 3, and 5 mm from the apex. The results were statistically analyzed using the *t*-test for the comparison of the axial diameter at each level, and Pearson chi-square test was used for the comparison of age or gender and canal diameter. The significance level was set at $P < .05$.

Results: The buccolingual diameter was larger than the mesiodistal diameter in all measurements. A constant decrease in diameter was observed toward the apex. The most common type of apical part of the canal is oval and tapered.

Conclusions: Given the results, adjustments to the chemo-mechanical preparation and obturation method to the canal morphology must be made.

Keywords: Age, canal diameter, CBCT, gender, maxillary incisors, root canal morphology

INTRODUCTION

Cone-beam computed tomography (CBCT) is widely used in endodontics.[1] It is recommended in a variety of conditions, among which are detection of apical periodontitis, pre-surgical evaluation of an affected tooth, assessment of dentoalveolar trauma and root resorptions, identification of obliterated or missed canals, and treatment planning.[1-3] However, the use of CBCT should be justified in any case and follow the European Society of Endodontology (ESE) position statement, indicating compliance with as low as reasonably achievable law (ALARA). Each case requires a preliminary evaluation as to the actual need for CBCT[3] and is weighed by the prudent clinician, considering the patient's exposure to additional radiation.

The pulp space keeps on changing after the tooth's eruption and even after the root has completed its development. This is attributed to the deposition of secondary or reparative dentin, as a result of carious and traumatic injury. The most substantial change in the size of the pulp space takes place within 5 years after the completion of apexogenesis.[4] Many attempts have been made to understand the morphology of the root canal, using light microscopy or CBCT scans.[5-8] An ex vivo study, which compared the accuracy of CBCT and tactile sensation via the "first file to bind" method by means of a micro-CT, demonstrated the superiority of CBCT for the evaluation of canal's diameter at the working length.[5] Taschieri et al[7] explored the morphology of the foramen after apicoectomy and found that 90% were ovoid to circular. Ponce and Vilar Fernández[8]

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examined histological sections from maxillary incisors and canines by optical microscopy. The widest diameter of the apical foramen (AF) was found in lateral incisors, followed by canines and central incisors.

Sound knowledge of the anatomy and shape of the apical part of the canal is essential for performing a successful root canal treatment. The aim of this study was to measure the diameter of the apical root canal in central and lateral maxillary incisors from CBCT scans, using OnDemand software (Cybermed, Seoul, Korea), to examine the shape of the apical part of the canal and the effect of age and gender and previous trauma on the size of the canal.

METHODS

The study population included patients who were admitted for endodontic treatment of their maxillary permanent incisors in the department of endodontics and were referred for CBCT prior to the treatment. Totally 58 teeth were included in this retrospective study. The study was approved by the Hadassah Medical Center ethical committee (Date: January 14, 2018, approval code 0322-17-HMO).

Data including the patient's age and gender and previous traumatic injury were collected. Only maxillary central and lateral incisors were included. The teeth were assigned to 2 groups according to patients' age: group A—patients under 18 years and group B—patients over 18 years old.

Exclusion criteria include teeth with irregular anatomy (Dens Invaginatus, c-shaped anatomy, etc.), teeth with a serious traumatic injury, in particular, teeth with internal or external resorption, and teeth that were already endodontically treated.

For each patient, CBCT- based Dicom files were examined. The CBCT scans were done using Morita 8170- Accuitomo (J. Morita, Corp. Japan) in a small field of view diameter (40 × 60 mm). These were analyzed with the OnDemand software. Only scans with a resolution of a voxel size of 85 μm were selected for this study.

Canal Width

For each tooth, the width of the canal in the axial slices was measured in a mesiodistal (MD) direction and buccolingual (BL) direction at 3 different locations: 1,3, and 5 mm from the radiographic apex. A total of 6 measurements were taken for each tooth.

Analysis of variance *t*-test was carried out to estimate the association between patient's age or gender and the diameter of the canal, at different distances from the apex. The data were statistically analyzed using Statistical Package for the Social Sciences version 22. The significance level was set at $P \leq .05$. The data were also analyzed using descriptive statistics.

RESULTS

Totally 58 teeth, 28 maxillary central incisors and 30 maxillary lateral incisors, were examined; 24 male and 34 female. The teeth were divided into 2 groups: group A—patients under 18, n=28 and group B—patients over 18, n=30. Previous dental trauma was reported in 19 cases (32.8%). Immature apex was observed in 7 teeth (12.1%)

Canal Diameter

The diameter of the canal was wider in the BL direction than in the MD direction in all the readings, with an average difference of 0.18 ± 0.164 mm(min: 0.01 mm, max: 0.83 mm).

The narrowest diameter measured was 0.1 mm (1 mm from the apex—MD direction), and the widest diameter measured was 1.49 mm (5 mm from the apex— BL direction). A decrease in diameter was observed in all teeth as we approached the apex. The difference between the MD and BL width decreased from a mean of 0.2377 at 5 mm from the apex to 0.1577 at 1 mm from the apex (Figure 1).

When the measurements were compared between the right and left side, the teeth on the left side usually had a wider diameter. The most prominent difference of 0.1 mm was found between the lateral and central and 5 mm from the apex in a BL direction.

When the maxillary central and lateral incisors were compared, the diameter of the central incisor was always larger than the lateral incisor. The results are presented in Figure 1.

The canals were always tapered toward the apex.

The taper was larger in the BL direction than in the MD direction (Figure 1).

Mean Diameter According to Patient's Age

The mean diameter of the root canals according to age groups was larger in group A compared to group B in all the measurements. The largest difference was found in the BL direction 5 mm from the apex (0.1 mm) and the most negligible difference was 0.02 mm, which was 1 mm from the apex (Figure 2).

Although some difference was found between the age groups, it was not statistically different. $P > .05$. Measurements were least different in the MD direction 3 mm from the apex (Figure 3).

Mean Diameter According to Gender

The mean diameter of the root canals according to gender was larger in males in all the measurements. The largest difference was found in the BL direction 5 mm from the apex (0.1 mm) and the most negligible difference was 0.02 mm, which was 1 mm from the apex. No statistically significant difference was found between the gender in any of the directions tested (Figure 3).

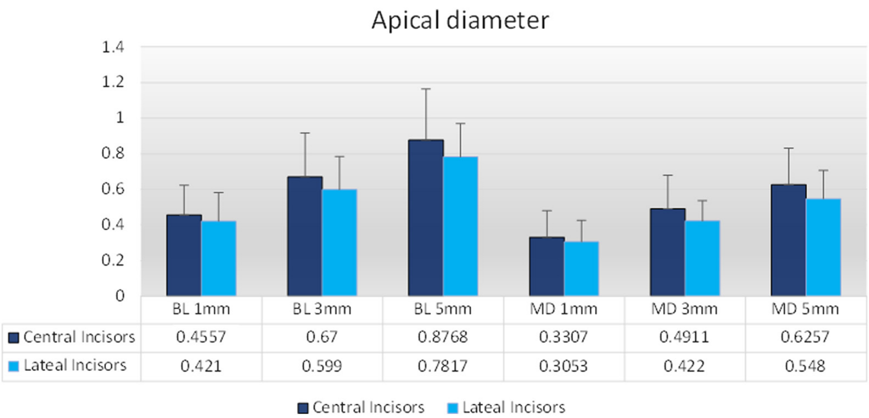

Figure 1. The mean diameter of the root canals. The BL diameter was wider than the MD diameter for both teeth types in all the distances, thus demonstrating an oval and tapered shape in the apical 5 mm of the canals. MD, mesiodistal; BL, buccolingual.

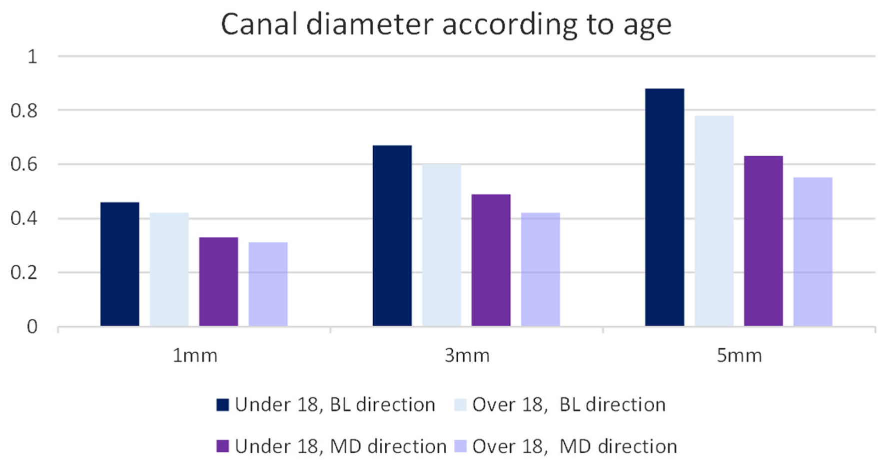

Figure 2. Change in the diameter according to age. A constant decrease in the diameter of the canals can be observed for both tooth types and in both directions with age. The diameters of the canals in both BL diameters and MD diameters were consistently larger in younger patients than those older than 18. MD, mesiodistal; BL, buccolingual. $P < .05$.

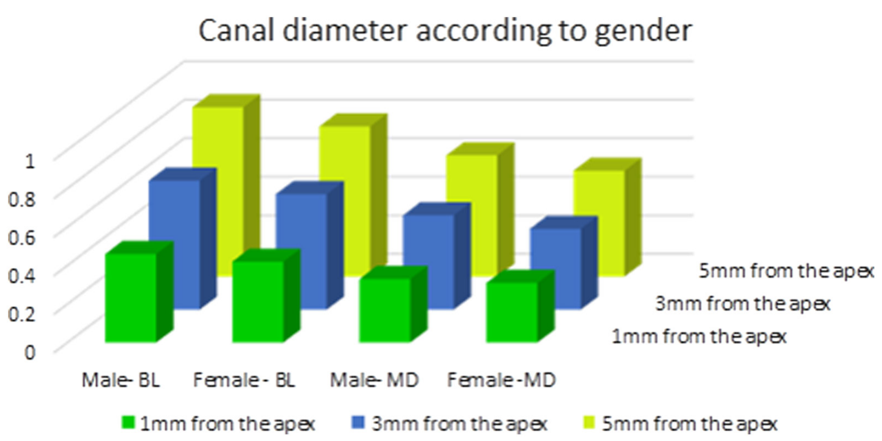

Figure 3. Canal diameter according to gender. A difference in the diameter was observed between the genders. The size of the canals was larger for male patients in comparison to female patients in all sites. $P > .05$.

DISCUSSION

Understanding the shape of the root canal can help in treatment planning, choosing the appropriate instruments for the preparation of the canal, and the obturation technique suitable for treatment. Cone-beam computed tomography has been used for the evaluation of the length of root canals. In the study by Tchorz et al.[10] the root canal length was calculated from the CBCT scans of 40 extracted human molars and compared with the readings of Raypex Electronic apex locator. The results of this study demonstrated the accuracy of the CBCT scan in the determination of the correct working length. Similar results were demonstrated in another study, which compared the length measurements in CBCT scans using OnDemand3D (Cybermed, Seoul, Korea) software, 3D Endo software (Dentsply Sirona), and the readings of the Root ZX electronic apex locator.[11] The shape of the canal has a significant impact on the shape and chemo-mechanical preparation. The diameter of the canals was evaluated using CBCT scans. A recently published micro-CT study has demonstrated that while gauging the apical size of the canal by the "first file to bind" may be misleading and can be influenced by interferences within the canal, CBCT measurement of the canal diameter is considered reliable.[5] The results demonstrate a difference between the MD diameter and the BL diameter in all the study groups. It may be said that the shape of the canal at the 5 apical mm is oval and becomes rounder as we advance to the apex of the tooth. The preparation of oval canals with round instruments may lead to either under-instrumentation or over-enlargement of the canal.[5] In oval canals, both the circumferential filing and the balanced force techniques left large areas of the canal wall uninstrumented.[12] Unfortunately, the use of rotary file systems was also not effective in the instrumentation of oval canals, leaving unprepared walls.[13-15] Under-instrumentation may enable persistent bacterial infection in the canal, leading to post-treatment apical periodontitis.[16]

The measured diameter of the canals in the central incisor and lateral incisor teeth 1 mm from the apex in the BL direction was 0.45 and 0.43 mm, respectively. The results obtained in our study regarding the diameter of the apical constriction are comparable with the results of the study of Mizutani et al[6] that found that the buccolingual diameter of the AF in central and lateral incisors was 0.425 mm and 0.369 mm, respectively. Whereas another study that measured the AF under optical microscopy found that the diameter of the AF was larger for lateral incisors than central incisors, but their study included only 5 lateral incisors and 6 central incisors.[8] Nevertheless, the AF does not necessarily coincide with a distance of 1 mm from the apex.[21]

The canal diameters were similar among female and male patients. This is despite sexual dimorphisms demonstrated in other studies.[5,22]

Age-induced changes in the teeth are associated with the deposition of dentin.[4,23] Although some difference in canal diameter was found between patients under and over 18, this difference was not statistically significant. Nonetheless, only 12.1% of immature teeth were included in this study. Complying with the ALARA law and the ESE position statement,[3] younger patients are less often referred for CBCT, to avoid unnecessary radiation. The most prominent change in canal's diameter occurs 5 years after apical closure.[4] It may be assumed that if the study population included younger patients in earlier phases of tooth development, a more prominent difference would have been found. Large-scale research is recommended to examine the change in canals' diameter with aging.

32.8% of the patients reported previous trauma. Andreasen et al[24] reported the development of pulp canal obliteration in 10% of the teeth following different types of luxation injuries. According to Queiroz et al.[25] calcific metamorphosis often occurs after extrusive luxations, and the reparative dentin is deposited in the pulp space as a result of hypoxia during the trauma. This may have had an impact on the diameter of the canal[26] and can explain differences between the right and left sides, but records are missing regarding the exact nature of the trauma. Another limitation of the current study is the fact that some of the patients referred for CBCT had a pathologic lesion associated with the tooth, which may have affected its morphology. Large-scale research is suggested to verify the results of the current study.

The apical part of the canals is oval and tapered. The size of the canals decreases with age. The buccolingual diameter in the apical segment of the canals is wider than the mesiodistal width. In view of the results, adjustments to an appropriate chemo-mechanical preparation and obturation technique must be made.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of Hadassah Medical Center (Date: January 14, 2018, approval code 0322-17-HMO).

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