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Assessment of Mesiobuccal Root Canal Curvature in Maxillary Molars of Egyptian Population: A Standardized CBCT-Based Radiographic Protocol

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Aim: This cross-sectional study aims to analyze the mesiobuccal (MB) root canal curvature in maxillary molars of the Egyptian population using cone-beam computed tomography (CBCT).

Material and methods: DICOM files were retrieved anonymously from three different radiology centers according to specific selection criteria. Untreated MB roots with varying degrees of curvature were assessed in the sagittal plane for angle determination. Based on Schneider's method for root canal curvature assessment, a standardized protocol was developed by an oral and maxillofacial radiologist and was applied by two endodontists independently. The degree of severity was defined according to the American Association of Endodontists (AAE) case difficulty assessment form. Data was tabulated and analyzed, and its clinical relevance was assessed. Data from 192 CBCT scans were collected and statistically analyzed using chi-square and independent t-tests.

Results: The average angle of curvature of the mesiobuccal (MB) root of the maxillary first molar (MFM) in the sagittal plane was 22.8 degrees with a standard deviation of 9.8. In contrast, the maxillary second molar (MSM) was 24.3 degrees with a standard deviation of 10.5. No significant difference between the mean angles of the two molars was detected ($p = 0.157$). Most roots showed a moderate curvature, falling between 10 and 30 degrees (69.3% for MFM and 66.7% for MSM).

Conclusion: In the Egyptian population, most MB roots of the upper first and second molars showed moderate to severe curvatures.

Keywords: Maxillary molars, cone beam computed tomography, Root canal curvature, Schneider's method, Mesiobuccal root.

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Introduction

Dental decay is the most extensive chronic infectious disease in the human race, instigating inflammation of the dental pulp, the periodontium, and the periradicular bone. [1] Since the healing potential following root canal therapy is widely recognized, [2] the morphology of root canals typically shows curvature in at least one plane, with straight canals being rare exceptions rather than the norm. [.3] This means that preparing these canals can be quite challenging, requiring skilled clinicians to assess canal complexity beforehand, alongside their aptness for treatment or the necessity for referral. [4 5]

A well-established checklist has been introduced by AAE [5] to review the degree of case complexity before endodontic intervention. Earlier studies associated inaccurate assessment of the degree of root curvature and case difficulty resulting in inauspicious clinical complications, and iatrogenic blunders as ledges [6] and separated instruments. [7] Therefore, the radiographic assessment of root curvatures through clinical practice is crucial before treatment commencement. [8] Earlier studies applied different approaches to determine root canal curvature involving periapical radiography, transparent tooth techniques, and microcomputed tomography. [9] In 2008, Estrela et al [10] suggested the utilization of cone beam computed tomography (CBCT) for finding anatomical and pathological changes, as opposed to periapical radiography, which fails to show curvatures in a three-dimensional direction.

Despite the importance of the low-dose routinely used intraoral periapical radiography in endodontics, its diagnostic accuracy is limited by geometric distortion, superimposition, and anatomical factors. On the other hand, CBCT overcomes these limitations and reveals reliable information about the root anatomy and canal morphology at the expense of increased radiation dose. Moreover, in CBCT, the operator can select the most relevant slice orientation and control the display parameters of the needed anatomical area to improve diagnostic accuracy dramatically compared to conventional images. [11–14]

Proper disinfection and debridement of the entire pulpal space is a primary goal of root canal therapy. [15] Accordingly, a comprehensive examination of root canal internal anatomy is necessary for clinicians to provide the intended treatment outcomes effectively. Consequently, predicting the probable anatomic variations while considering the ethnic profile and racial group is helpful for the clinician. [16] Hence, this study gathered data on the maxillary first and second molar teeth of the Egyptian population, to examine root canal curvature using Schneider's method. [17]

Material and Methods

Study design:

The protocol of this cross-sectional study was preapproved by the Ethics Review Committee at Beni-Suef University (# REC-FDBSU/07122023-05/EM). A sample size of 190 was calculated from a pilot study using G power analysis software with an effect of size 0.5422, power 98%, and alpha error 0.5.

Collection of samples

The CBCT DICOM files were collected from three different radiology centers at three different universities (Beni-Suef University, Ain Shams University, and Egyptian Russian University) with three different CBCT machines (CS 8100 3D, Carestream Dental, USA), (i-CAT, Imaging Science International, USA), and (Planmeca 3D Mid, Planmeca Oy, Finland). 210 scans were randomly collected after primary screening to match the eligibility criteria. High-quality CBCT images (no major artifacts – voxel size of 0.2 mm or less), acquired for reasons unrelated to the tooth under the present study investigations were included in the field of view. They showed both upper first and second molars with no earlier root canal treatment or coronal restorations. CBCT images where roots were immature, resorbed, or calcified as well as cases with root anomalies or fractures were excluded. All scans were anonymous, no personal data were collected except for the patient's gender to detect any relation between gender and angle severity.

Radiographic protocol:

The radiographic assessment protocol was developed by an experienced oral and maxillofacial radiologist and applied independently by two experienced endodontists after calibration. Both inter- and intra-examiner reliability were measured.

First, the image display parameters were adjusted as shown in Figure (1), and the assessor was only allowed to lower the density of the image (brightness).

After image enhancement, axial view navigation was done starting from the crown going apically till reaching the first clear buccolingual orientation of the mesiobuccal root (MB) where the green coronal reference line was adjusted to match with the root orientation before going coronally. At the level of the MB1 canal orifice, the red sagittal reference line was adjusted to intersect the green coronal reference at the canal orifice (Figure 2).

Correction of the sagittal reference line was done at the coronal view till reaching a clear identification of the full length of the MB1 canal in the sagittal view after increasing its slice thickness to 1 mm (Figure 2). The clear appearance of MB1 in the sagittal view was confirmed by the axial view navigation so that always the red sagittal reference line was crossing the MB1 canal from the orifice to the apical foramen. The sagittal view was then enlarged.

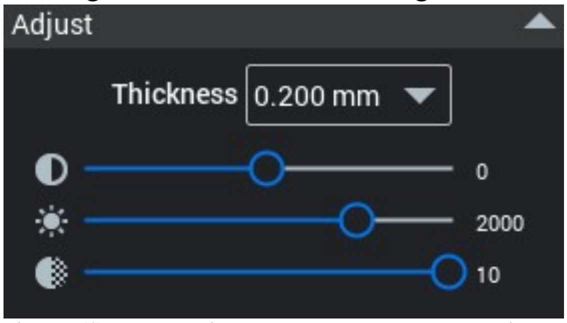

Figure (1): Image display parameters as shown in the software (from top to bottom): Slice thickness, contrast, density (brightness), and sharpness.

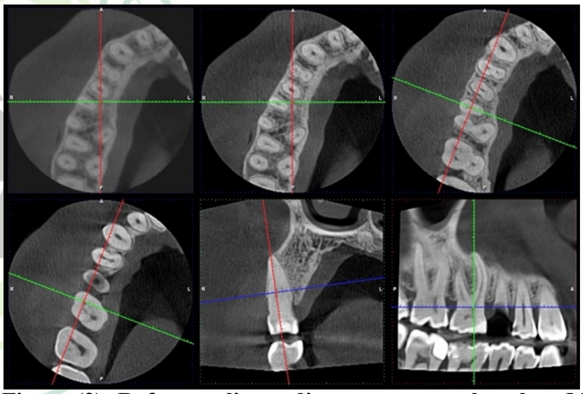

Figure (2): Reference lines adjustment to reach a clear MB1 in the sagittal view. Note the effect of image display parameters adjustment on the first two axial cuts.

In the sagittal view, the blue axial reference line was leveled at the pulpal floor and the green coronal reference line was adjusted to intersect with it at the MB1 orifice (Figure 3). A linear measurement line was drawn so that the intersection between the axial and the coronal references was the first point of the line. The second point of the line was placed mesially and apically. After releasing the second point and canceling the activation of the ruler, it was dragged and moved so that the measurement line matched with the coronal straight part of the MB1 canal, and the first point was dragged more coronal and distally so that the measurement line was fine-tuned to cross the point of intersection between the axial and coronal reference lines (Figure 3).

The same previously explained procedures were repeated apically so that the apical straight part of the canal had its reference line (Figure 3). After that, an angular measurement was done where the angle head was the apical point of intersection between the two drawn measurement reference lines (Figure 4). The other two starting points of the angle were dragged more apically than the reference lines to be tangent with the reference lines without interference (Figure 4).

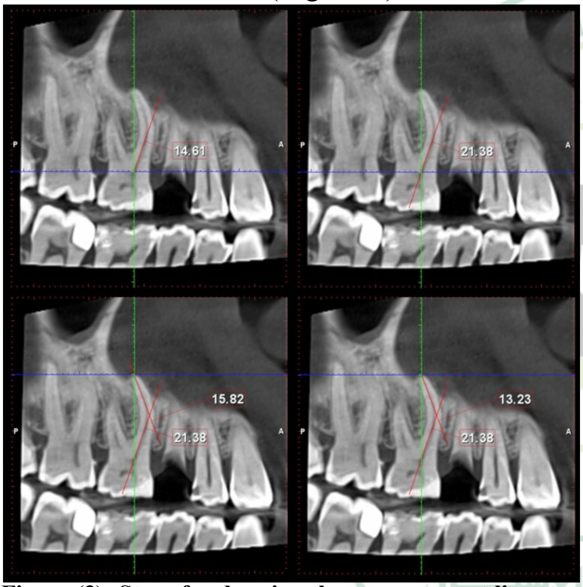

Figure (3): Steps for drawing the measurement lines to function as references for forming the target angle.

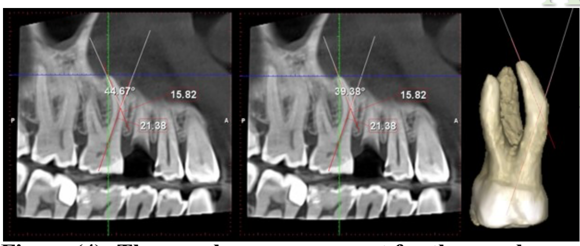

Figure (4): The angular measurement for the canal curvature.

Statistical analysis:

Continuous data were summarized using mean, standard deviation (SD), median, minimum, and maximum values, and were analyzed using an independent t-test. Categorical data were presented as frequencies (N) and percentages and analyzed using the Chi-square test.

Results

Of the retrieved 210 scans, 18 were excluded for not matching the inclusion criteria, and 192 scans were assessed for the severity of root curvature. Both Inter and intra-observer inter-class correlation coefficients were high at 0.888 and 0.926, respectively.

The mean (sd) angle of curvature of the mesiobuccal roots of maxillary first molars in the sagittal view was 22.8(9.8) ° with a median of 22.2 ° and a range from 0.8 ° to 49.9 ° while that mean (sd) in the second molar was 24.3(10.5) ° with a median of 23.4 ° and a range from 1.3 ° to 57.6 °. The independent t-test revealed that there was no significant difference in the mean angle of curvature between the two molars (p = 0.157). Data for frequencies (N), percentages, and the results of the Chi-square test for comparison of the severity of canal curvature between the two tooth types is represented in Table (1).

The study included 79 (41.1%) males and 113 (58.9%) females. The angle of curvature for the first molar was 23.2 (8.9) ° in males and 22.5 (10.5) ° in females, while for the second molar, it was 24.6 (9.9) ° in males and 24 (11) ° in females. The independent t-test indicated no significant difference between genders for either the first molar (p = 0.637) or the second molar (p = 0.7) concerning curvature angle.

Table 1: frequencies (N), percentages, and the results of the Chi-square test for comparison of the severity of canal curvature between the two tooth types:

	1st Molar		2nd Molar		
	N	Percentage	N	Percentage	*p*-value
Slight	19	9.9%	15	7.8%	0.478
Moderate	133	69.3%	128	66.7%	
Extreme	40	20.8%	49	25.5%	

Discussion

Limited knowledge of the internal anatomy of the mesiobuccal root, evokes failed treatment, as it is clinically acclaimed to have varying degrees of curvature[8,18,19,20,21] so, considering case difficulty beforehand is a crucial index to guarantee positive clinical outcomes, [22] and for targeting better patient-centered care for the Egyptian population. Therefore, the present study aimed to assess the range of mesiobuccal root curvature in maxillary molars among individuals from the Egyptian population.

In the standard endodontic practice, periapical radiographs are still a common diagnostic tool, which if taken with multiple projections, can stand for a diagnostic two-dimensional image of three-dimensional structures. Typically, these two-dimensional (2D) images primarily offer visualization of curvature in the mesiodistal plane. However, they do not provide a comprehensive depiction of the root canal's topographic characteristics in the bucco-lingual plane. Consequently, this limitation obscures root canal complexities, resulting in a less predictable treatment. [23 ,24]

The present study was based on CBCT, a noninvasive resort, which has perceived extensive usage in both clinical practice and research in the past few years; particularly for investigating internal root anatomy with three-dimensional diagnostic precision for pre-intervention analysis and treatment planning.[22,24,25,26,27,28,29]

Nonetheless, it depends greatly on the prudence of the endodontist to weigh the gains from employing CBCT with the risks of ionizing radiation. [30] Being an in-vivo technique, it offers descriptive data when tracing the prevalence of anatomic variations compared to other in-vitro techniques such as micro-CT. Even though micro-CT provides impeccable image quality, it is not suitable for clinical use. [16] Furthermore, CBCT scans were found reliable for examining the Vertucci root canal classification compared to micro-CT imaging, it allows analysis of larger samples, is cost-effective, and is much simpler to obtain. [31 32]

Recognizing that the diagnostic quality of CBCT is dependent on image resolution and display parameters such as sharpness, density or brightness, and contrast, [26] a special visualization technique was employed to enhance the visibility of the root canal. The slice thickness of 0.2 was selected to reach a balance between the small slice thickness with detailed visualization and the smoother increased slice thickness.[33,34] However, raising the slice thickness to 1 mm in the sagittal view before the assessment was done to guarantee including all the pathways of the mesiobuccal canal in the same slice. Sharpness was increased to the maximum while contrast was balanced to improve the canal definition. [33, 35] The assessor was allowed to change the density to compensate for the individual patient-related characteristics that affect the density of the image and hence improve the image visualization. [35]

Using the measurement tool of the software to easily create reference lines for another assessment, making an identified point of start by the intersection of two references, and making lines more prominent in certain directions for ease of dragging and corrections were previously described. [36] In our study, these approaches were customized according to the target assessment which was the root canal curvature.

In 1971 Schneider [17] introduced a method for assessing the degree of root curvature, which involves measuring the angle formed by two straight lines: one parallel to the long axis of the root canal, and the other passing through the apical foramen, intersecting the first line at the point where the curvature begins. This angle (α) is then categorized based on the degree of root canal curvature. Schneider’s method was utilized in the present study to evaluate the degree of curvature because of its established reliability, simplicity, and widespread use in existing literature. [37] Categorization of root curvatures, however, was done according to the ranges suggested by the AAE in their case difficulty assessment checklist. This way, it can directly and more effectively reflect the complexity of the clinical situation.

In this study, an assessment of 192 mesiobuccal roots revealed a dominance of the moderately curved roots with an angle of ≤ 30º in the maxillary first (69.3%) and second (66.7%) molars within the Egyptian population. While only 20.8% and 25.5% of each of the respective maxillary molars examined were present with extreme root angulation of ≥ 30º. Then again, a minimal angle of ≤10º was displayed in only 9.9% and 7.8% of the roots of each of the molar types studied. Our findings came in agreement with Schäfer et al [18] who found that 65% of the studied cases displayed an angle ≤ 27º and 13% of the roots fall between 27º-35º, and in partial agreement with Qiao et al [8] who reported that the root canals of maxillary molars exhibited moderate-to-severe bending in the Guizhou population. Contrary to that, Estrela et al [38] found that root canals with a mild bend were notably more prevalent compared to other types. Curvature rates of the first molar did not differ significantly from the second molar which is consistent with results found by Levenets et al [39] in the Krasnoyarsk population. No differences were observed in the variance of the mean angle of root canal curvature between the left and right sides ($p > .05$) which is consistent with Wang et al [9] and Tzeng et al who asserted symmetry in bilateral maxillary molars. [40] In summary, root canal curvature in maxillary posterior teeth varies in the Egyptian population, hence raising treatment difficulty. Clinicians are committed to advancing their ability to carefully study and cautiously prepare challenging root canals for predictable treatment protocols and successful outcomes.

Considering the constraints of the present study, although arithmetically the radius of the curve of a circle most accurately defines its curvature, however, the literature mostly uses the Schneider method [17] and defines the curves only employing an arbitrary angle. Thus, these studies simply applied one parameter to illustrate the root canal curvature. [41] The standardized protocol used in this study may be considered a base for a stepwise approach that could help to avoid general dentists' uncertainty about CBCT software manipulation protocol despite the widespread implementation of CBCT in dentistry. [42]

Conclusion

The Egyptian population reveals a dominance of moderate (69.3%-66.7%) to severe (20.8%-25.5%) curvature of the mesiobuccal root of maxillary first and second molars respectively; imposing a challenge for dental experts when executing root canal treatment.

Ethics approval and consent to participate:

The protocol of this cross-sectional study was preapproved by the Ethics Review Committee at Beni-Suef University (# REC-FDBSU/07122023-05/EM)

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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None

Authors contributions

AF: *Developed the standardized CBCT visualization protocol employed in the study.* ***ME:*** *Interpreted and measured the angles of curvature of the mesiobuccal roots in the CBCT scans.* ***MN:*** *Interpreted and measured the angles of curvature of the mesiobuccal roots in the CBCT scans.*

References

1. Pan J, Wang J, Hao L, et al. The Triple Functions of D2 Silencing in Treatment of Periapical Disease. *J Endod* 2017; 43: 272–278.
2. Franciscatto GJ, Brennan DS, Gomes MS, et al. Association between pulp and periapical conditions and dental emergency visits involving pain relief: epidemiological profile and risk indicators in private practice in Australia. *Int Endod J* 2020; 53: 887–894.
3. Chaniotis A, Ordinola-Zapata R. Present status and future directions: Management of curved and calcified root canals. *Int Endod J* 2022; 55: 656–684.
4. Nature T, Infections E. Colleagues for Excellence. *Pain* 2006; 1–6.
5. Information P. Guidelines for Using the AAE Endodontic Case Difficulty Assessment Form The AAE designed the Endodontic Case Difficulty Assessment Form for use in endodontic curricula.
6. Greene KJ, Krell K V. Clinical factors associated with ledged canals in maxillary and mandibular molars. *Oral Surgery, Oral Medicine, Oral Pathology* 1990; 70: 490–497.
7. Chandak M, Sarangi S, Dass A, et al. Demystifying Failures Behind Separated Instruments: A Review. *Cureus*; 14. Epub ahead of print 2022. DOI: 10.7759/cureus.29588.
8. Qiao X, Xu T, Chen L, et al. Analysis of root canal curvature and root canal morphology of maxillary posterior teeth in Guizhou, China. *Medical Science Monitor* 2021; 27: 1–12.
9. Wang L, Wang Z, Wang Q, et al. The analysis of root canal curvature and direction of maxillary lateral incisors by using cone-beam computed tomography A retrospective study. *Medicine (United States)* 2022; 101: E28393.
10. Estrela C, Bueno MR, Sousa-Neto MD, et al. Method for determination of root curvature radius using cone-beam computed tomography images. *Braz Dent J* 2008; 19: 114–118.
11. Patel S, Dawood A, Mannocci F, et al. Detection of periapical bone defects in human jaws using cone beam computed tomography and intraoral radiography. *Int Endod J* 2009; 42: 507–515.
12. Aminoshariae A, Kulild JC, Syed A. Cone-beam Computed Tomography Compared with Intraoral Radiographic Lesions in Endodontic Outcome Studies: A Systematic Review. *J Endod* 2018; 44: 1626–1631.
13. Mustafa M, Batul R, Karobari MI, et al. Assessment of the root and canal morphology in the permanent dentition of Saudi Arabian population using cone beam computed and micro-computed tomography – a systematic review. *BMC Oral Health* 2024; 24: 1–29.
14. Mahmoud A, Abu Elsadat S, Al-Din Saber S. Measurement of mandibular canal diameter using cone beam computed tomography. An experimental pilot study. *JOURNAL AIN SHAMS DENTAL JOURNAL Official Publication of Ain Shams Dental School*.
15. Wong J, Manoil D, Näsman P, et al. Microbiological Aspects of Root Canal Infections and Disinfection Strategies: An Update Review on the Current Knowledge and Challenges. *Frontiers in Oral Health*; 2. Epub ahead of print 2021. DOI: 10.3389/froh.2021.672887.
16. Martins JNR, Gu Y, Marques D, et al. Differences on the Root and Root Canal Morphologies between Asian and White Ethnic Groups Analyzed by Cone-beam Computed Tomography. *J Endod* 2018; 44: 1096–1104.
17. Schneider SW. A comparison of canal preparations in straight and curved root canals. *Oral Surgery, Oral Medicine, Oral Pathology* 1971; 32: 271–275.
18. Schäfer E, Diez C, Hoppe W, et al. Roentgenographic investigation of frequency and degree of canal curvatures in human permanent teeth. *J Endod* 2002; 28: 211–216.
19. Zheng Q hua, Zhou X dong, Jiang Y, et al. Radiographic Investigation of Frequency and Degree of Canal Curvatures in Chinese Mandibular Permanent Incisors. *J Endod* 2009; 35: 175–178.
20. Den- P. Root Curvature in the Maxillary First Permanent Molars in a. 2016; 1: 12–14.
21. Buchanan GD, Gamieldien MY, Tredoux S, et al. Root and canal configurations of maxillary premolars in a South African subpopulation using cone beam computed tomography and two classification systems. *J Oral Sci* 2020; 62: 93–97.
22. Fu Y, Deng Q, Xie Z, et al. Coronal root canal morphology of permanent two-rooted mandibular first molars with novel 3D measurements. *Int Endod J* 2020; 53: 167–175.
23. Choi MR, Moon YM, Seo MS. Prevalence and features of distolingual roots in mandibular molars

analyzed by cone-beam computed tomography. *Imaging Sci Dent* 2015; 45: 221–226.
24. Sousa TO, Haiter-Neto F, Nascimento EHL, et al. Diagnostic Accuracy of Periapical Radiography and Cone-beam Computed Tomography in Identifying Root Canal Configuration of Human Premolars. *J Endod* 2017; 43: 1176–1179.
25. Mirah MA, Bafail A, Baik A, et al. Root Canal Morphology of Premolars in Saudis. *Cureus* 2023; 15: 1–8.
26. Yazdizadeh M, Alavinezhad P, Sadrishahrezaei A, et al. Root canal morphology of mandibular first molars: Comparison of the diagnostic accuracy of cone-beam computed tomography and the sectioning technique. *Dent Res J (Isfahan)* 2023; 20: 103.
27. Zhang Q, Chen H, Fan B, et al. Root and root canal morphology in maxillary second molar with fused root from a native Chinese population. *J Endod* 2014; 40: 871–875.
28. Guo J, Vahidnia A, Sedghizadeh P, et al. Evaluation of Root and Canal Morphology of Maxillary Permanent First Molars in a North American Population by Cone-beam Computed Tomography. *J Endod* 2014; 40: 635–639.
29. Kim SY, Kim BS, Kim Y. Mandibular second molar root canal morphology and variants in a Korean subpopulation. *Int Endod J* 2016; 49: 136–144.
30. Scarfe WC, Levin MD, Gane D, et al. Use of Cone Beam Computed Tomography in Endodontics. *Int J Dent* 2009; 2009: 1–20.
31. Zhang D, Chen J, Lan G, et al. The root canal morphology in mandibular first premolars: a comparative evaluation of cone-beam computed tomography and micro-computed tomography. *Clin Oral Investig* 2017; 21: 1007–1012.
32. Zhang D, Chen J, Lan G, et al. The root canal morphology in mandibular first premolars: a comparative evaluation of cone-beam computed tomography and micro-computed tomography. *Clin Oral Investig* 2017; 21: 1007–1012.
33. Pauwels R, Araki K, Siewerdsen JH, et al. Technical aspects of dental CBCT: State of the art. *Dentomaxillofacial Radiology* 2015; 44: 1–20.
34. Chadwick JW, Lam EWN. The effects of slice thickness and interslice interval on reconstructed cone beam computed tomographic images. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology* 2010; 110: e37–e42.
35. Issa J, Riad A, Olszewski R, et al. The Influence of Slice Thickness, Sharpness, and Contrast Adjustments on Inferior Alveolar Canal Segmentation on Cone-Beam Computed Tomography Scans: A Retrospective Study. *J Pers Med*; 13. Epub ahead of print 2023. DOI: 10.3390/jpm13101518.
36. Fahd A, Temerek AT, Ellabban MT, et al. Cone-beam computed tomography-based radiographic considerations in impacted lower third molars: Think outside the box. *Imaging Sci Dent* 2023; 53: 137–144.
37. Hartmann RC, Fensterseifer M, Peters OA, et al. Methods for measurement of root canal curvature: a systematic and critical review. *Int Endod J* 2019; 52: 169–180.
38. Estrela C, Bueno MR, Barletta FB, et al. Identification of apical and cervical curvature radius of human molars. *Braz Dent J* 2015; 26: 351–356.
39. O A Levenets, V V Alyamovskiy, A A Levenets SAO. *Evaluation of main and additional root canal curvature in maxillary molars*. 2017.
40. Tzeng LT, Chang MC, Chang SH, et al. Analysis of root canal system of maxillary first and second molars and their correlations by cone beam computed tomography. *Journal of the Formosan Medical Association* 2020; 119: 968–973.
41. Pruett, John P.; Clement, David J.; Carnes DL. SCIENTIFIC ARTICLES Cyclic Fatigue Testing of Nickel-Titanium Endodontic Instruments. 1997; 23: 77–85.
42. Brown J, Jacobs R, Levring Jäghagen E, et al. Basic training requirements for the use of dental CBCT by dentists: A position paper prepared by the European Academy of Dento Maxillo Facial Radiology. *Dentomaxillofacial Radiology* 2014; 43: 1–7.