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. Since the healing potential following root canal therapy is widely recognized, the morphology of root canals typically shows curvature in at least one plane, with straight canals being rare exceptions rather than the norm. 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.

A well-established checklist has been introduced by AAE 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 and separated instruments. Therefore, the radiographic assessment of root curvatures through clinical practice is crucial before treatment commencement. Earlier studies applied different approaches to determine root canal curvature involving periapical radiography, transparent tooth techniques, and microcomputed tomography. In 2008, Estrela et al 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.

Proper disinfection and debridement of the entire pulpal space is a primary goal of root canal therapy. 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. 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.

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 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.](image1)

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:

<table>
<thead>
<tr>
<th>Tooth Type</th>
<th>Slight</th>
<th>Percentage</th>
<th>N</th>
<th>Percentage</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Molar</td>
<td>19</td>
<td>9.9%</td>
<td>15</td>
<td>7.8%</td>
<td>0.478</td>
</tr>
<tr>
<td>2nd Molar</td>
<td>133</td>
<td>69.3%</td>
<td>128</td>
<td>66.7%</td>
<td></td>
</tr>
</tbody>
</table>

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 so, considering case difficulty beforehand is a crucial index to guarantee positive clinical outcomes, 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.

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.

Nonetheless, it depends greatly on the prudence of the endodontist to weigh the gains from employing CBCT with the risks of ionizing radiation. 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. 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.

Recognizing that the diagnostic quality of CBCT is dependent on image resolution and display parameters such as sharpness, density or brightness, and contrast, 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. 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. 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.

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. In our study, these approaches were customized according to the target assessment which was the root canal curvature.

In 1971 Schneider 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 ≤ 30° 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 ≥ 30°. Then again, a minimal angle of ≤10° 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 ≤ 27° and 13% of the roots fall between 27°-35°, 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
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.


