Assessment of open source software for CBCT in detecting additional mental foramina

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Abstract: The purpose of this study was to evaluate which post-processing imaging protocol would be better to analyze the additional mental foramen (AMF) in preoperative planning with cone-beam computed tomography (CBCT) exams, and to test reproducibility of measurements, using open source software (OsiriX). The software was used to detect the cases of AMF from among 58 exams for dental implant planning in edentulous mandible areas—three cases were found. The case images were submitted to qualitative analysis using 2D orthogonal MPR, 3D-MPR and 3D volume rendering protocols by two oral and maxillofacial radiologists. Quantitative analysis used the 3D-MPR protocol; the closed polygon tool measured the mental foramen (MF) and the AMF areas; the length tool measured the distance between foramina. The measurements were performed independently by the examiners, at two different times. Intra- and interexaminer agreement was assessed using the intraclass correlation coefficient. The panoramic view did not show the MF and the AMF clearly. The AMF could be detected in the parasagittal view. 2D Orthogonal MPR was effective to observe the AMF in some cases. The 3D-MPR and 3D view protocols were the most effective to locate and analyze the AMF. In conclusion, a 3D view improves visualization when anatomical points are not clearly visible. 3D-MPR was considered a more effective post-processing imaging protocol to observe foramina relationships. The high reproducibility of measurements for anatomical MF variations was established using specific tools featured in open source software for CBCT. OsiriX is realistic and recommended for preoperative planning.

Descriptors: Cone Beam Computed Tomography; Imaging, Three-Dimensional; Mandible; Tomography, X-Ray Computed.

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Introduction

Knowledge of the distances, location and number of mental foramina is useful in defining safe areas when performing mandible procedures.[1] Anatomical variations of the MF have been reported in many studies. The most common cases are the multiple foramina.[2-4] In rare cases, the mental foramen may not even exist.[5] The double mental foramen is reported in literature as a result of the branching of the mental nerve before it passes through the MF.[6] The reported frequency of AMF varies according to ethnic group:

- 1.4% of 510 sides examined in American Whites,
- 5.7% of 332 sides examined in African Americans, and
- 7% of 157 samples of the Central and South America population.[7,8]

Several studies on MF variations have been published in regard to two-dimensional radiographic techniques and the dissection of dry mandibles.[2,9-11] Three-dimensional reconstructed images from cone-beam computed tomography (3D-CBCT) are more reliable and accurate than two-dimensional radiography of craniofacial structures for diagnosis, and allow multiple imaging post-processing protocols for better and more correct treatment planning and evaluation.[2,12,13]

The aim of this study was to assess cone-beam computed tomography (CBCT) imaging using open source software, by analyzing which post-processing imaging protocol would be better for planning a procedure and for clearly identifying the existence of anatomical variations. Another aim was to test the reproducibility of 3D-CBCT for measuring anatomical landmarks, such as the MF and AMF, using open source software.

Methodology

Subjects

Data from the CBCT examinations of 71 patients (29 males and 42 females) who had undergone dental implant treatment planning in edentulous mandible areas from December 2010 to February 2011 were analyzed. Nine CBCT examinations with excessive artifacts in the mandible area were excluded. Four exams with CBCT acquisition problems were excluded because of poor image quality. Anatomic variation with clinical consequences was observed in a total of 58 exams, which were set aside for analysis with open source software for preoperative planning. Three cases of AMF were detected (5.17%), and were analyzed with different post-processing protocols of the open source software.

Data acquisition

The CBCT scans were taken by i-CAT Classic (Imaging Sciences International, Hatfield, USA), using the following acquisition protocol: 120 kVp, 36.12 mAs, field of view (FOV) measuring 60 mm in height and 160 mm in diameter, and 0.25 mm voxel reconstruction. After image acquisition, the data were stored in a digital imaging communication in medicine (DICOM) file format and imported to an independent workstation (iMac 27, Mac OsX 10.6, Apple, Inc., Cupertino, USA) with open-source DICOM viewer OsiriX 4.0 (Pixmeo, Geneva, Switzerland; www.osirix-viewer.com). OsiriX software can be used to view volumetric images that capture, store, communicate, process and display DICOM (.dcm file) images. It also generates 3D reconstructed images. All the study cases were analyzed by two oral and maxillofacial radiologists[12,14-16] using different OsiriX software tools. Two views were made for implant planning:

- first, a panoramic view (3D Curved MPR, at mean mode 10.15 mm thick),
- and then, a parasagittal view (3D Curved MPR).

Imaging analysis

The three cases of AMF were detected in implant planning and subsequently analyzed in three different imaging visualization protocols offered specifically by the OsiriX software. The following protocols were used to conduct the qualitative analysis and to observe the anatomical aspects of this landmark:

- multiplanar reconstruction (2D Orthogonal MPR),
- 3D multiplanar reconstruction (3D-MPR), and
- 3D view (3D volume rendering with low contrast, 16-bit and CLUT editor to reduce red scale).

Qualitative analysis was conducted to observe the location of the additional foramen and describe aspects of the additional foramen relationship to adjacent structures, to intraosseous communication and to the MF. The image analyses were performed in random order to reach an agreement. The examiners were asked to identify the main MF and the AMF, by describing the characteristics of these anatomical landmarks. The observers could use all available tools and functions in each protocol. In the 2D Orthogonal MPR, the same position of each one plane is showed on the other two planes, with a thin cross reference line. The 3D-MPR enables the examiner to change the position or orientation of one of the three planes (coronal, sagittal, and axial) to obtain two reconstructed planes. The 3D view protocol displays images with one-point linear perspective projection, increasing the potential of locating and observing the relationship of adjacent structures. The descriptions obtained for each case were collated and ultimately generated the final qualitative analysis.

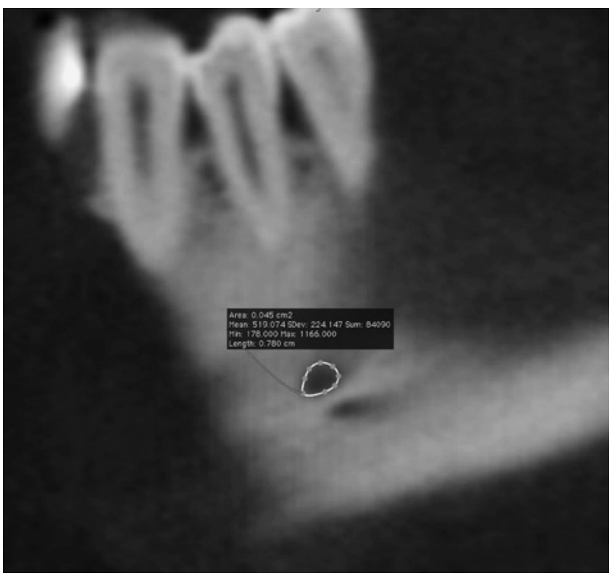

Figure 1 - Closed polygon ROI used for measuring MF area.

Quantitative analysis was performed to measure the area of the additional foramen in relation to the MF and the distance between both. OsiriX tools were used to perform measurements:

- the closed polygon ROI (region of interest) (Figure 1), allowing polygons to be drawn by clicking on as many corners as needed and displaying information such as area and perimeter instantly, and
- the length ROI (Figures 2a, b), allowing the drawing of simple lines to compute linear measurements.

The 3D-MPR view was used to obtain the foramen area by marking its limits to the outermost part of the cortical bone, using the closed polygon. The distance between the foramina (the main MF and the AMF) was calculated with the length tool in this view, by measuring the outermost part of the cortical bone located in this region, in a reconstructed image that allows viewing the two foramina. The measurements were made by two oral and maxillofacial radiologists, independently, at two different times. Intraexaminer (at an interval of two weeks) and interexaminer (the first time and after the second time) agreement was assessed according to the intraclass correlation coefficient (ICC).

Figure 2 - a: Length ROI used for measuring the distance between foramina. **b:** Length ROI used in the case of a distal AMF, to measure the outermost part of the cortical bone between foramina.

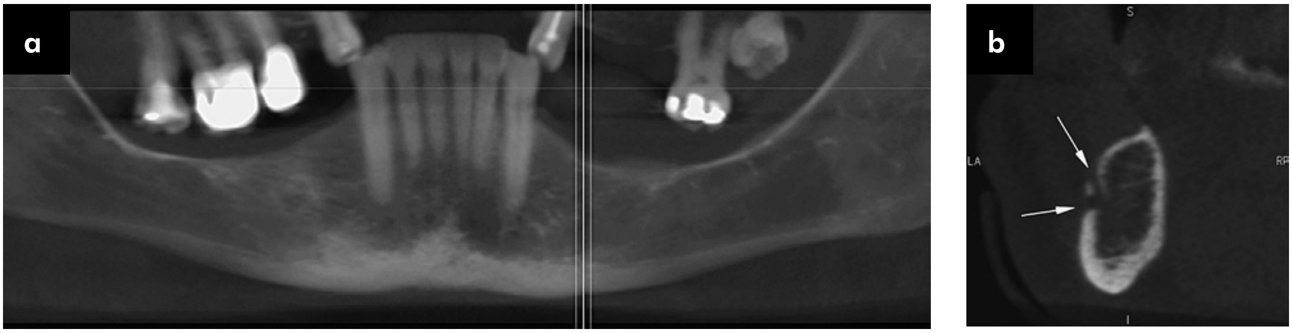

Figure 3 - a: Panoramic view (3D curved MPR, at mean mode 10.15 mm thick) showing the area demarcated for obtaining the parasagittal view. **b:** The MF and the AMF (arrows) with the presence of bone trabeculae in the parasagittal view.

Results

Implant planning

The panoramic view did not show the main foramen or the additional foramen clearly in any case analyzed (Figure 3a). In the parasagittal view (Figure 3b), a trabecular bone dividing the output of the mandibular canal caused the two foramina to branch out, observed in case 1 and case 2. In case 3, the branching out was noted along the course of the mandibular canal, and an accessory branch could be identified distally to the main MF. No other cases of AMF were detected.

Qualitative analysis

The additional foramen could be located in all three cases using the 2D Orthogonal MPR view, corresponding to a coronal, sagittal, and axial image. In the coronal view, a trabecular bone separating the foramina was observed in cases 1 and 2. This pattern was not observed in case 3. In the sagittal view, the branching out at the canal output was evident in case 1. In case 2, the separation of the mandibular canal into two mental foramina could be clearly seen. In case 3, the two foramina could be discerned on the same slice. In case 1, the MF was observed superiorly, and the additional foramen, inferiorly, in the axial view. However, in case 2, it was difficult to distinguish which foramen should be classified as additional, whether that appearing superiorly or inferiorly. In case 3, the branching out of the mandibular canal along its course was evident, and the two foramina were observed on the same slice. The advantage of this post-processing imaging protocol is that it enables easy navigation through the tomographic slices because the orientation planes are locked. However, the location and the relationship to adjacent structures of the AMF are limited.

3D-MPR allowed the imaging views to be manipulated freely, resulting in a reconstructed sagittal view depicting two foramina (Figures 4a, b). In case 1, two foramina were easily detected, with a trabecular bone separating one foramen superiorly and the other, inferiorly. In case 2, the two foramina were more difficult to detect clearly in the same view, with a trabecular bone separating one foramen superiorly and the other foramen, inferiorly. In case 3, the AMF could be observed distally to the MF. The advantage of this post-processing imaging protocol was the ability to change the position or orientation of one plane to obtain reconstructed images showing the two foramina, thereby enabling more reliable measurements.

The 3D view showed the location of the AMF in relationship to the MF (Figure 5), whereby the location was classified as distal-inferiorly in case 1, inferiorly in case 2, and distal-inferiorly in case 3. Both mental and additional foramina were clearly visible. The advantage of this post-processing imaging protocol was its ability to locate MF and AMF immediately.

Quantitative analysis

Table 1 shows the measurements of the MF and AFM areas, the distance between the superior and the inferior foramina, and between the mesial and

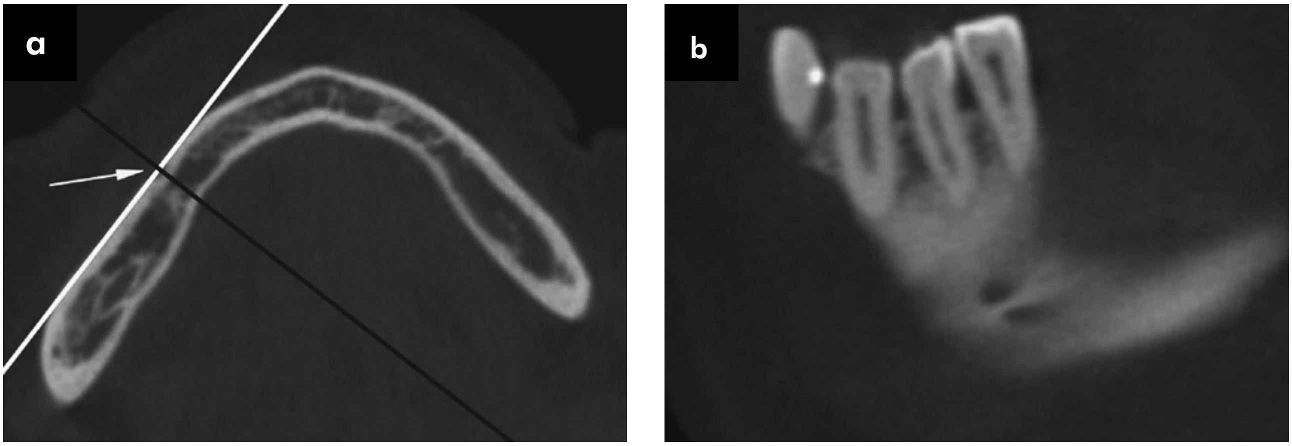

Figure 4 - a: Crosshair (black and white) tool of 3D-MPR in an axial view positioned at the foramen output (arrow) to generate a reconstructed image. **b:** Reconstructed sagittal image depicting two foramina.

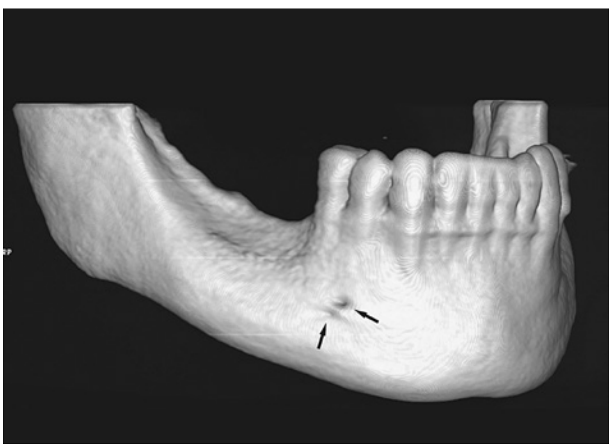

Figure 5 – 3D view (3D volume rendering with low contrast, 16-bit and CLUT editor) with improved visualization of AMF and MF location.

Table 1 - Measurements of the MF and AMF areas and the distance between the main mental foramen and the additional mental foramen, made by two observers in two different analyses.

1st Analysis		Case 1 (SF and IF)	Case 2 (SF and IF)	Case 3 (MF and DF)
Observer 1	Area (sq. cm)	0.050	0.077	0.076
		0.025	0.034	0.013
	Distance (cm)	0.126	0.186	0.585
Observer 2	Area (sq. cm)	0.054	0.060	0.052
		0.015	0.042	0.009
	Distance (cm)	0.138	0.242	0.465
2nd Analysis		Case 1 (SF and IF)	Case 2 (SF and IF)	Case 3 (MF and DF)
Observer 1	Area (sq. cm)	0.051	0.054	0.061
		0.018	0.048	0.013
	Distance (cm)	0.120	0.142	0.466
Observer 2	Area (sq. cm)	0.045	0.071	0.064
		0.023	0.031	0.013
	Distance (cm)	0.135	0.200	0.592

SF: superior foramen; IF: inferior foramen; MF: mesial foramen; DF: distal foramen.

the distal foramina, made by two observers at two different times. The statistical results comparing the measurements made by the observers are shown in Table 2.

According to the classification system proposed by Fleiss[17], the replicability of the method adopted may be considered as excellent. The p-value ranged from p = 0.0009 to p = 0.0331 in the interexaminer analysis. The intraexaminer analysis obtained a variation of p = 0.0011 to p = 0.0052 for observer 1 and p = 0.0014 to p = 0.0040 for observer 2. The intraclass correlation (ICC) statistic used to make the comparison between measurements showed coefficients ranging from 0.9032 to 0.9565 (maximum value = 1) for the interobserver analysis, and ranging from 0.9184 to 0.9666 for the intraobserver analysis (maximum value = 1).

Discussion

Unlike other studies, our methodology was stan-

Table 2 - Statistical results comparing the measurements made by the two observers.

Interobservers		p-value	ICC
Area	1st analysis	p = 0.0019	0.9032
	2nd analysis	p = 0.0009	0.9322
Distance	1st analysis	p = 0.0138	0.9565
	2nd analysis	p = 0.0331	0.9458
Intraobserver		p-value	ICC
Area	Observer 1	p = 0.0011	0.9264
	Observer 2	p = 0.0014	0.9184
Distance	Observer 1	p = 0.0052	0.9647
	Observer 2	p = 0.0040	0.9666

ICC: intraclass correlation coefficient.

dardized to obtain the reconstructed images for measurements, thus preventing changes in the orientation of planes from interfering with the results obtained. In 3D-MPR, the observer in our study manipulated the image view to obtain an angle of the MF at the outermost section of the buccal surface bone, in order to measure the diameter of the foramen. This pattern was used in all measurements. Naitoh *et al.*[14] obtained the diameter measurement by calculating the long and short axes (a and b) of each foramen according to the elliptic area formula:

$$Area = \pi \times \frac{a}{2} \times \frac{b}{2}$$

No specification regarding the image view used to perform the measurements was cited. In this study, the area was calculated with the closed polygon ROI feature of the OsiriX system, which gives the result for the area immediately after the user marks the limit points of the foramen. The measurements of the foramina area are used in some classifications to determine which AMF could be classified as double mental foramen or accessory mental foramen according to size.[3]

Naitoh *et al.*[14] calculated the distance between foramina by marking a horizontal axis and a vertical axis starting at the center of the largest foramen and then calculating the distance to the center of the other foramen, using the formula:

$$Distance = \sqrt{(x^2 + y^2)}\ .$$

Conversely, in this study, the distance between the foramina was calculated by measuring the trabecular bone or the outermost cortical bone (in the 3D-MPR reconstructed images) with a straight line drawn by the length ROI tool, which gives the result for the linear measurement immediately and can be useful to estimate a safe area.

Noninvasive methods, like CBCT, enable observations of anatomical investigation to be more accurate. Accordingly, more cases of multiple mental foramina will be detected. This type of mandible image is very effective in identifying the location of such mandibular landmarks as the canal and both mental and mandibular foramina, as well as the course and branches of inferior alveolar nerves and vessels.[4]

Good knowledge of mental nerve anatomy and branches is very important for conducting surgical procedures, nerve block and local anesthesia,[1] implant insertion[14] and periapical surgery, and for better understanding endodontic-related pain and paresthesia.[18] Knowing where the additional mental foramen is located may prevent nerve and vascular injury.[1,19] The double mental foramen may innervate and vascularize a distant area, like that of case 3. It may also interfere in anesthetic techniques, and its unusual location may further complicate surgical procedures, causing traumas, hemorrhage and paresthesia. Implant planning should be carried out very carefully, especially in an edentulous premolar area.

Typically, the AMF is smaller than the mental foramen; hence, it is more difficult to visualize. In cases where the existence of the additional foramen is not certain, or where the mental foramen is not displayed on the panoramic radiograph, examination by CBCT is recommended.

According to Yamauchi *et al.*[15] and Costa *et al.*[20] and also Cavalcanti,[21] OsiriX is easy-to-use open source software, offering advanced and useful post-processing imaging protocols, thus making it a versatile DICOM viewer offering regular updates. In our opinion the post-processing method used in this software is a new and important tool for the dental preoperative planning of procedures like implant placement and oral surgery, mainly for cases with anatomical variations that could interfere in the final result, and that are scarcely detected with two-dimensional radiographic techniques.

Cavalcanti[21] reported that 3D-CBCT using OsiriX open source DICOM viewer has a potential application for craniofacial surgical planning and also for qualitative and quantitative analyses. Based on this statement,[21] our study demonstrated the assessment of MF and AMF for implant planning. Because CBCT is a volumetric imaging tool, special focus should be directed toward medical information technology. The tools provided in visualization programs are new to many professionals. This makes the learning curve more complex—the learning task requires effort. This issue must be analyzed with deep and critical insight.[21]

In our opinion, 3D-CBCT imaging using OsiriX software is an effective digital analysis tool, and a valuable imaging modality for improving diagnosis and treatment planning, thus ensuring the best guidance for dental implant surgical interventions. Keeping abreast of the recent developments in medical imaging is essential, and interactive hardware-software should be prioritized.

Conclusion

In conclusion, the 3D view protocol improved visualization when anatomical points were not clearly visible, thus affording the means to obviate surgery failure. 3D-MPR was considered a more effective post-processing imaging protocol to observe the relationship between the MF and the AMF, and also made it possible to locate these points to conduct further measurements. However, it is necessary to establish a standard protocol to analyze this anatomical variation. A high reproducibility of measurements to ascertain anatomical MF variations was established using specific tools featured in open source software for CBCT.

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