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Custom Focal Trough in Cone-Beam Computed Tomography Reformatted Panoramic Versus Digital Panoramic for Mental Foramen Position to Aid Implant Planning

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ABSTRACT

Objectives: To compare the linear measurements from digital panoramic (DP) radiographs and cone-beam computed tomography (CBCT) volumes for the localization of the mental foramen (MF).

Material and Methods: Thirty-one patients with panoramic and CBCT radiographs depicted on the same machine were analyzed. The vertical and horizontal positions of the MF were compared by the differences in distances measured from reference points to the boundaries (tangents) of the MF in digital panoramic (DP) and CBCT reformatted panoramic (CRP) views. The vertical position of MF was also analyzed on CBCT oblique coronal views (CORO) and compared with its corresponding distances on DP and CRP views.

Results: Statistically significant differences ($P < 0.05$) were found in all compared measurements between CRP and DP views. In addition, the vertical distance (Y1) compared between DP, CRP, and CORO views also showed a statistically significant measurement discrepancy in the mean distance ($P < 0.000$) with the highest mean difference of 1.59 mm ($P < 0.05$) was attained from Y1 (DP-CORO). Inter- and intra-examiner analysis indicated a high level of agreement for all measurements.

Conclusion: The mean values of discrepancies in measurements between DP and CRP views for horizontal and vertical linear measurements were clinically tolerable. Nevertheless, significant differences in the vertical MF position were detected between the panoramic views (DP, CRP) and the coronal views (CORO). This implies that the use of coronal view measurements during implant planning might reduce the risk of neurovascular injuries.

Keywords: Cone-beam computed tomography, Reconstructed, Panorama, Measurements, Accuracy, Implant

INTRODUCTION

Dental radiography is a vital diagnostic tool commonly used during daily dental practice. High quality, appropriately acquired conventional two-dimensional images including panoramic and intraoral periapical radiographs are still very popular and well-established basic approaches for diagnosis and planning of several dental treatments.[1-4]

Cone-beam computed tomography (CBCT) is a relatively recent imaging technique that brought on a new era in dental imaging practice and has become widely used by various dental specialties,

for example, endodontics, implantology, and maxillofacial surgery.[5] By offering a three-dimensional view of the jaws and facial structures, it overcomes the most significant limitation of two-dimensional images, i.e., the lack of cross-sectional views, by providing high-resolution superimposition-free multiplanar images.[6] The CBCT volumes are particularly propitious during the planning of dental implants as these image sets provide a dimensionally accurate depiction of the anatomical structures.[7] Besides these advantages, the CBCT allows for the reconstruction of panoramic views that are superior to the conventional counterparts providing images free of inherent distortions, magnification, and superimposition.[8] Nevertheless, CBCT examinations yield a higher dose of radiation compared to conventional two-dimensional ones but less than CT, raising concerns for this modality not to be misused.[5]

The mental foramen (MF) is a sought-after structure that exists bilaterally as apertures that open on the buccal surface of the mandible, where part of the neurovascular bundles of the inferior dental canal exit.[9,10] The MF constitutes the terminal end of the mental canal that forms inside the mandibular body and runs in various directions.[9,10] Although the location and shape of MF are variable, the pre-operative identification of the foramen is vital before various dental procedures.[9-11]

A proper appreciation of the MF's anatomy and its variations is essential to accurately account for the neurovascular structures during different clinical procedures.[11] The abilities of various radiographic modalities to ideally present the MF may vary.[10]

Published evidence comparing measurements acquired from digital panoramic (DP) radiographs and CBCT reformatted panoramic (CRP) views were found to be scanty. This paper compares the linear dimensions, vertical and horizontal positions of MF on DP and CRP to correlate the radiographic MF's position on these views. A comparison of the MF vertical position on panoramic views (DP and CRP) with the CBCT oblique coronal plane (CORO) is also provided. The null hypothesis of our study is to find no measurement differences between the studied radiographic techniques. This assessment intends to draw practitioners' attention to the presentation of the MF on different views.

MATERIALS AND METHODS

This retrospective study was submitted to the University of the Western Cape, South Africa for degree purposes (Ethical approval: BM/16/5/1). Exploring the virtual patients' database at Qirresh Maxillofacial Radiology Center (in Palestine) revealed 589 examinations from late 2008 to 2016. Only 31 patients' radiographs (panoramic and CBCT) met the inclusion criteria and were included in the study. Inclusion criteria include patients over 18 years old with fully erupted and developed roots of the mandibular teeth (i.e., canine up to second mandibular molars), patients with panoramic radiographs and CBCT volumes depicting the MF area, radiographs (panorama and CBCT volumes) of high-resolution and adequate diagnostic qualities that allow clear demarcation of the MF boundaries and the apices of the reference teeth (mesial and distal to the foramen), and reasonably aligned teeth in the region of interest.

The radiographic examinations (both DP and CBCT volumes) were conducted using the Carestream® CS9000® 3D (Carestream Health, Rochester, NY, USA). Virtual measurements were conducted using Carestream® Dental Imaging Software (v 6.13.1.12) for DP views and Carestream® 3D imaging ® (v 3.3.11) to analyze CBCT volumes.

The radiographic examinations were indicated for various dental treatments and acquired under everyday conditions and settings complying with the appropriate technique. The resultant radiographs are checked on a daily basis by an oral and maxillofacial radiologist (OMFR) who examines all the volumes for quality assurance and diagnostic reporting.

The measurements were compared between DP radiographs, CRP, and CBCT oblique coronal view (CORO). CRP views were reconstructed by selecting multiple anchor points on the axial view and in the middle of the ridge buccolingually (at the level of the MF) with a slice thickness of 15mm (trough area). The reference points were identified and measurements were carried out on the DP initially and then reproduced on the corresponding CBCT views [Figure 1].

In DP and CRP views, the superior (ST), inferior (IT), mesial (MT), and distal (DT) orthogonal tangents were drawn using the software virtual ruler on the outermost borders of the MF. Straight vertical lines (L1, and L2) were dropped from the middle of apices of the reference teeth (the closest teeth found mesial

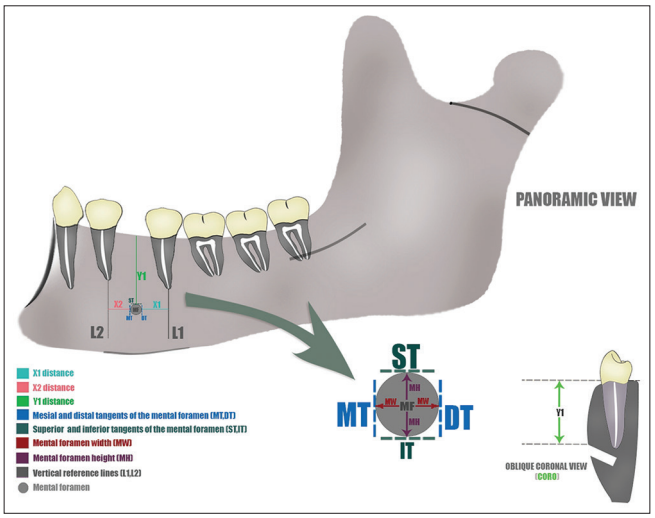

Figure 1: Diagrammatic presentation of measurement recording (Reprinted from Beshtawi, 2017).[21]

and distal to the MF). The distal (X1) and mesial (X2) distances between the MF's mesial and distal tangents and the reference lines (L1 and L2) were measured [Figure 1]. The vertical position (Y1) was assessed by drawing a vertical measured line on the upper margin of the MF (and not the tangent) starting from the middle-distance of the MF's width and up to the alveolar crest superiorly. Such an approach allowed the vertical measurements to be standardized between studied views (as the upper alveolar cortex levels may not conform to a straight pattern along the width of the MF) [Figure 2]. The MF height (MH) and MF width (MW) were also measured (distances between the MF's tangents). The CBCT coronal view was used to compare the Y1 distances obtained from both panoramic views (DP, and CRP) [Figure 1]. The coronal slice that corresponds to the Y1 distance was selected by navigating the crosshair to coincide with the previously measured Y1 vertical line on the CRP view. In the coronal view, the Y1 distance was measured between two horizontal lines; one was drawn crossing the uppermost margin of the alveolar cortex and the other on the uppermost border of the MF [Figure 1].

The *t*-test was used to analyze the differences between any two variables (measurements). ANOVA tests were also employed for testing the differences in means where more than two different techniques were used. All results were deemed statistically significant, if $P < 0.05$.

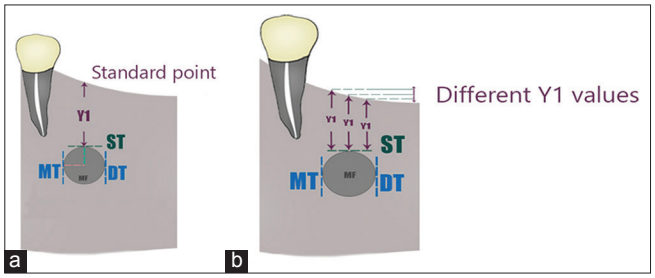

Figure 2: Panoramic views (a and b) showing the Y1 distance measured from a standard point (the middle of the MF's width) versus possible multiple points on the tangent (ST), respectively (Reprinted from Beshtawi, 2017).[21]

Patients were analyzed in batches of 5/day (Each session did not exceed 2 h). The assessment of the radiographs was repeated by the primary observer 2 weeks after the primary analysis. The inter-examiner and intra-examiner agreements were analyzed using the intra-class correlation coefficient (ICC). The second observer (OMFR with 14 years of experience) confirmed the diagnostic quality of each radiograph before analysis. The two observers conducted a pilot session to standardize the analysis procedures.

RESULT

All the mean differences (MD) of the tested distances, i.e., X1, X2, MH, and MW (between DP and CRP) showed a statistical significance with $P < 0.05$ ($P = 0.0412$, $P = 0.0023$, $P = 0.0018$, and $P = 0.0456$, respectively). Consequently, compelling evidence to reject the null hypothesis (MD = 0) is provided. Three patients' analyses were identified as outliers and were removed to achieve normal distribution. The results of the statistical analysis are illustrated in Table 1.

A statistical significance was also elicited from the analysis of the mean vertical distance (Y1) over the three different techniques (DP, CRP, and CORO), $F(2, 54) = 34.97$, MSE = $P < 0.000$. The MD of Y1 between CORO and DP was the highest (1.59 mm, $P < 0.05$). The MD of Y1 between CRP and CORO views was 1.06 mm ($P < 0.05$), and the smallest MD of Y1 was demonstrated between DP and CRP (0.54 mm, $P < 0.05$).

The X1 (CRP) mean distance was shown to be larger than the X1 (DP) of the same distance by 0.34 mm. The X2 (CRP) mean distance was shown to be smaller than the X2 (DP) of the same distance by 0.52mm. The MH (CRP) was shown to be larger than the MH (DP) of the same distance by 0.39 mm. The MW (CRP) was shown to be larger than the MW (DP) of the same distance by 0.16 mm.

Table 1: Summary statistics X1, X2, mental height, mental width, and Y1 difference values (Reprinted from Beshtawi, 2017).[21]

Distance	N*	Technique	Mean difference	Mean (SD*)	CI*	*P*-value
X1	28	DP	−0.34	0.83	[−0.66: −0.15]	0.0412 †
	28	CRP				
X2	28	DP	0.52	0.81	[0.2: 0.83]	0.0023 †
	28	CRP				
Mental height	28	DP	−0.39	0.59	[−0.62: −0.15]	0.0018 †
	28	CRP				
Mental width	28	DP	−0.16	0.39	[−0.31: −0.003]	0.0456 †
	28	CRP				
Y1	28	DP				<0.000 ‡
	28	CRP				
	28	CORO				

†Paired *t*-test, ‡ANOVA, *N: Sample size, SD: Standard deviation, CI: Confidence interval

The distances (X1, X2, Y1, MH, MW, and Y1) maximum and minimum ranges of measurement differences are further demonstrated in Table 2. The greatest discrepancy (5.3 mm) was obtained from Y1 (DP-CORO), followed by Y1 (CRP-CORO), X1 (DP-CRP), Y1 (DP-CRP), X2 (DP-CRP), MH (DP-CRP), and MW (DP-CRP), respectively.

The ranges of differences (in millimeters) for each variable compared with the number of patients showed the ranges demonstrated in Table 2. The largest percentage of patients were within the (>0 mm–0.5 mm) difference ranges for the X1, X2, MH, MW, and Y1 (DP-CRP) variables, while the Y1 (CRP-CORO) and Y1 (DP- CORO) differences showed the largest percentages of patients being within the (>1 mm) difference range.

An "excellent" inter-observer agreement was demonstrated in all the measurements with ICC ranging from 0.938 to 0.999. The 95% confidence intervals were narrow in most measurements except in MH (DP), MH (CRP), and MW (CRP). Moreover, "excellent" intra-observer agreements with ICC ranging from 0.864 to 0.997 were obtained except in MW (DP), X2 (CRP), Y1 (CRP), and MW (CRP) measurements, which indicated "good" reliability.

DISCUSSION

Differences in the measurements between CRP and DP views were found in the distances (X1, X2, MH, MW, and Y1) according to this study. Nevertheless, the obtained ranges of discrepancy were inconsistent among the tested distances.

It is worth mentioning that this analysis does not intend to evaluate the clinical accuracy of the radiographic technique used, but rather to compare the measurements obtained from these radiographic views. To the best of the author's knowledge, published reports investigating the CRP views are scant particularly those comparing MF on CRP and DP views.

It is mentioned that concurrence between the statistical and clinical significance of research findings may not always occur and *vice versa*.[12] The statistical significance of the findings of research stresses the reliability of the found outcomes from the selected analysis and not necessarily clinical importance.[12] The clinical relevance of data is highly reliant on the clinical context of which these data will be utilized.

The clinically tolerable margin of discrepancy attained from various radiographic techniques is mentioned to be less than 1 mm as a requirement for implant planning.[13,14] However, the authors of this paper believe that the clinical importance of this margin of error is relative and influenced by the sensitivity of the intended procedure, the vicinity of vital structures, and the clinical context, for example, procedures planned near vital structure require considerable accuracy of measurements. The current analysis adopted the same error margins mentioned by Ganguly *et al*.[13] and Nikneshan *et al*.[14] and submillimeter discrepancies in all directions are deemed clinically acceptable.

Although they are statistically significant, the MD of the distances (X1, X2, MW, and MH) between the DP and CRP views were considered clinically negligible as they lie below 1 mm (MD). However, the differences of the vertical distance (Y1) between panoramic views (DP, and CRP) and coronal views (CORO) proved to be clinically significant; the MD of Y1 between DP and CORO was the greatest with a MD = 1.59 mm ($P < 0.05$), followed by CRP and CORO with a MD of 1.06 mm ($P < 0.05$). Consequently, the vertical distances Y1 measured on panoramic views (DP, and CRP) showed higher ranges of discrepancy when compared with coronal views for the same distance.

It was surmised in this study that measurements were highly influenced by anatomical variations of the MF structure and assumed radiographic dimensional distortion. The pattern

Table 2: The number of patients versus the ranges of measurement differences, in addition to the maximum and minimum values of these ranges (in millimeters), (Reprinted from Beshtawi, 2017).[21]

	DP-CRP (%)					DP-CORO (%)	CRP-CORO (%)
Difference range	X1	X2	MH	MW	Y1	Y1	Y1
0 mm	2 (7)	1 (4)	2 (7)	1 (4)	3 (11)	2 (7)	1 (4)
>0–0.5 mm	13 (46)	12 (43)	17 (61)	21 (75)	16 (57)	5 (18)	10 (36)
0.6–1 mm	10 (36)	5 (18)	4 (14)	6 (21)	4 (14)	2 (7)	4 (14)
>1 mm	3 (11)	10 (36)	5 (18)	0 (0)	5 (18)	19(68)	13 (46)
Total number of patients	28	28	28	28	28	28	28
Max. difference	2.9 mm	2 mm	2 mm	1 mm	2.6 mm	5.3 mm	5 mm
Min. difference	0 mm (No difference)						

*DP-CRP, DP-CORO, CRP-CORO: Distance difference between digital and CRP views, digital panorama and the CBCT coronal view, and CRP and coronal views, respectively. CBCT: Cone-beam computed tomography

of emergence of the mental canal (e.g., at a slope or a right angle) was noted to be an important factor influencing the radiographic presentation of the MF on panoramic views. The emergence profile of the mental canal may run in various directions, for example, superior, posterosuperior, labial, anterior, and posterior emergence.[15] It was noted that the cortical bone thickness and alignment (in various planes) in the MF boundaries vary with different emergence profiles of the mental canal. This variation in the bone thickness along the mental canal border affected the radiographic presentation of the MF (whether it is DP or CRP views) and resulted in concealing the actual borders of the terminus of the mental canal in vertical [Figures 3-5] and horizontal [Figure 6] dimensions. Furthermore, three of the studied cases presented with accessory mental foramen (AMF), these structures were not detected on DP, and CRP views and were only noticed incidentally on the axial views [Figure 5d and e].

According to the literature, conventional panoramic radiography could demonstrate dimensional discrepancies due to inherent distortions.[16,17] Incorrect head positioning of the patient was mentioned as a cause of dimensional discrepancies encountered in some panoramic radiographs, particularly in the anterior jaw segments.[18,19] In CBCT volumes, the generation of CRP views at different horizontal levels was also shown to result in inconsistent dimensions of implant sites in the mesiodistal direction.[20]

It was observed on DP views that the presentation of the MF contours can be influenced by the architecture and superimposition of minute bone irregularities/structures (along the MF canal) that can be organized enough to present a shadow of a smoothly corticated and integrated false terminus outline [Figure 7]. In addition, the nature of the variable bone marrow architecture adjacent to their borders may additionally add to the incorrect identification of the MF borders [Figure 5a-c]. A mental loop was noted in one of the cases to form an ovoid low density along with corticated borders of its inner curvature resembling MF borders [Figure 8]. This false foramen showed well-defined borders and cortication on the panoramic view (DP) where the loop was not readily evident. In comparison, the CRP proved superior quality and showed the loop pathway.

Handling the MF during radiographic planning of various treatments as canalicular structure (and not a radiographic two-dimensional point) is vital for the safety of the accommodated neurovascular bundles. In the studied sample, the overall radiographic shape of MF was not regularly rounded radiolucencies in all the patients assessed on panoramic views (DP and CR). It is indispensable to appreciate the variations of the MF's structure with regard to architecture, emergence profile, and amounts of bone that may overlie and surround the mental neurovascular bundle. This highlights the need for cross-sectional imaging to competently study the overall anatomy of the mental structure, which might not be envisaged efficiently on two-dimensional views.

Since the accurate demarcation of the MF boundaries makes the foundation of any following measurements, high-quality views that reveal the precise location and allow for optimum visualization of these margins become vital. Nevertheless, inconsistency was found in the potentiality to precisely identify the MF's borders on various views (i.e., DP, and CRP). Poor representation of the MF borders may result in misrepresentation of the actual foramen, and as a consequence, over or underestimation of distances. Moreover, even clearly demonstrated boundaries of the MF on DP and CRP views may differ from the corresponding perpendicular view (i.e., coronal view).

Limitations

- Small sample size mainly due to the limited number of patients' radiographic records that met the inclusion criteria of this analysis.
- The vertical positions of MF were studied on both panoramic views (CRP and DP) and compared with the coronal view. Such dimensional comparison for the horizontal positions of MF with the axial views was not conducted due to technical limitations that hinder the standardization of the corresponding reference points

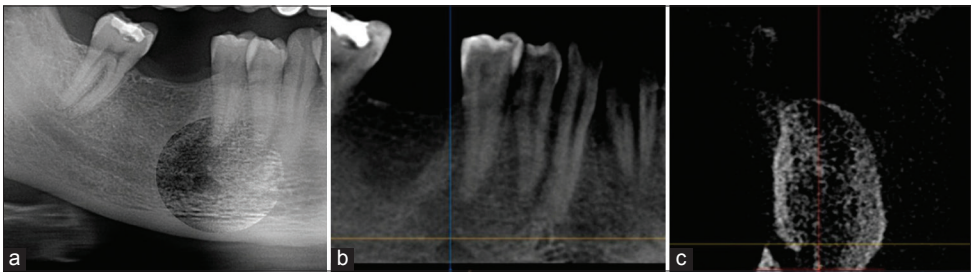

Figure 3: (a-c) Digital panorama, CBCT reformatted panoramic (CRP), and oblique coronal (CORO) views, respectively. In the CRP view, the horizontal plane crosshair (in yellow) was set at the level of the superior border of mental foramen, by contrast, the corresponding crosshair in the CORO view was set at the level of the inferior border of the mental canal terminus (Reprinted from Beshtawi, 2017).[21]

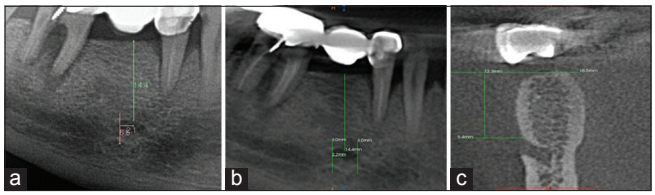

Figure 4: (a) DP and (b) CRP views showing the measurement of the Y1 vertical distance (14.4 mm). The corresponding CORO view (c) for the same distance is 12.3 mm. A distance difference of 2.1 mm is obtained between panoramic views and the coronal view (Reprinted from Beshtawi, 2017).[21]

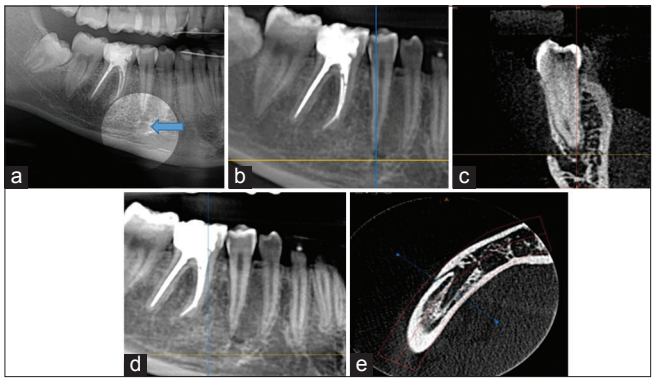

Figure 5: (a) DP, (b and d) CRP, (c) CORO, and (e) Axial view. The MF was identified on DP (arrow), the small irregular radiolucency superior to it was identified as a marrow space (especially that the identified MF confers a regular, non-suspicious, and corticated outline). By contrast, the corresponding CORO view showed that this marrow space was the actual terminus (foramen) of the mental canal. An accessory MF was also noted farther distally on the axial view which was not evident on DP and CRP views, (Reprinted from Beshtawi, 2017).[21]

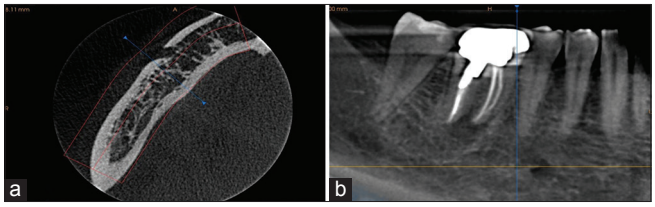

Figure 6: (a) CBCT axial view: The crosshair was set at the distal end of the mental foramen's border (blue line). (b) The CRP view shows the crosshair corresponding to a farther distance distally from the MF identified in the same view (Reprinted from Beshtawi, 2017).[21]

between the panoramic (CRP and DP) and the axial views.

CONCLUSION

Differences in the vertical and horizontal measurements (MF position) were found between conventional panoramic and CRP views; nevertheless, they are still deemed clinically acceptable. Conversely, the vertical measurements when

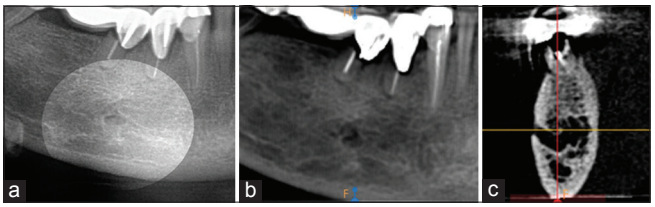

Figure 7: (a-c) DP, CRP, and CORO views, respectively. The DP view reveals a uniform, ovoid, and integrated cortical outline of the MF. A small radiolucency superior to its upper margin was also noted and identified as a marrow space. The CRP view represents the MF borders with a superiorly extended upper margin compared to the DP view. When the crosshair was set at the upper cortical border of MF on the CRP view, the corresponding crosshair in the CORO view was pointing to a osseous structure located internally to the mental canal, (Reprinted from Beshtawi, 2017).[21]

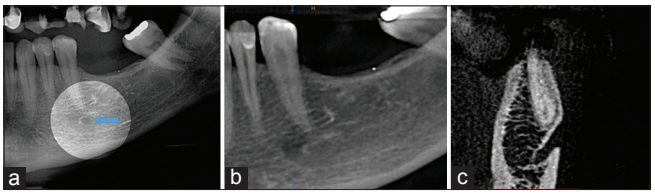

Figure 8: (a) The DP view shows the MF as a regularly ovoid and corticated radiolucency (blue arrow). (b) The CRP view shows the shadow of the mental loop which was not readily evident on the DP view. (c) The CORO view shows the mental canal ascending and overlying #35 tooth's apex (3-4 mm), (Reprinted from Beshtawi, 2017).[21]

compared between panoramic views (DP, and CRP) and the CBCT coronal view revealed statistical and clinical significance. A superior and distinct depiction of the borders of the MF and the path of the mental loop was noted in CRP compared to the DP views. Nonetheless, both DP and CRP views manifested vague presentations of the AMF.

Within the limitation of this study, it is concluded that employing coronal and axial views during the planning of various surgical procedures in the MF region may have a great potential to reduce the risk of jeopardizing the neurovascular structures. Therefore, it is advised to examine at least two perpendicular views scouting the third dimension as, depending solely on one view, even a CBCT panoramic view, poses potential risks.

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Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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