RESEARCH ARTICLE

Evaluation of the diagnostic efficacy of two cone beam computed tomography protocols in reliably detecting the location of the inferior alveolar nerve canal

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Objectives: Reliable three-dimensional localization of the inferior alveolar nerve canal (IANC) is valuable for a variety of dentoalveolar procedures. Although conventional CBCT offers three-dimensional information at a reasonably low dose, it is still a significant amount of radiation. In this *ex vivo* study, we evaluated the ability of a 180° rotational CBCT acquisition protocol with lower number of basis projections to create a CBCT data set for reliable localization of the IANC compared with a conventional 360° rotational CBCT acquisition.

Methods: 50 dry human skulls were imaged using 180° and 360° rotational CBCT protocols. Measurements of the IANC throughout its course in the mandible were carried out. Two raters evaluated the measurements and rated the scans based on their ability to visualize the IANC, and the measurements were carried out.

Results: The IANC length measurements for the 180° and 360° protocols were identical. There was no difference between evaluations by the two raters for the two protocols. Interexaminer reliability values were >90% for the two protocols. The sensitivity values for the two protocols were >95%. The specificity for both protocols was 100%.

Conclusions: 180° CBCT acquisition protocol is able to accurately locate the IANC with high reliability and is comparable to a conventional 360° protocol.

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Introduction

CBCT is increasingly being used in dentistry to obtain three-dimensional (3D) images of the maxillofacial region for a variety of clinical applications. Over the past few years, several dental applications have leveraged the use of 3D imaging.¹ Pre-operative evaluation of the location and proximity to the inferior alveolar nerve

canal (IANC) is essential for placing dental implants and for surgical extraction of impacted third molars to avoid nerve paraesthesia and other potential complications. Although the use of 3D imaging in the past was limited due to the radiation dose delivered by multislice medical CTs, the coming of low-dose alternatives such as CBCT has significantly shifted this paradigm.^{1–3} CBCT offers a low radiation dose and high-spatial-resolution multiplanar images. It also eliminates the drawbacks of superimposition and distortion that accompany other two-dimensional radiographic methods, such as panoramic radiography.^{4,5}

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Most CBCT acquisition protocols have a 360° rotation around the subject. During this rotation, the scanner acquires multiple basis images of the area of interest and then reconstructs multiplanar images based on image reconstruction algorithms.⁶ The advent of CBCT has significantly reduced the radiation dose, but it would be desirable to develop acquisition protocols that deliver lower doses than currently existing methods and yet not compromise diagnostic efficacy.⁷ The major advantages of the 180° scan are significant reduction in the radiation dose to the patient, basis projections, the time to acquire and reconstruct the scan due to fewer basis projections and smaller file sizes which facilitate image transfer and archiving. These advantages can be optimized with modified acquisition parameters such as the field of view, kVp and mA which can further contribute to reduction of patient dose.^{8,9}

The ability to localize and trace the IANC is important during implant treatment planning, implant placement and any surgical procedures that involve the mandible.^{10,11} The position and course of the mandibular canal varies among individuals. Thus, clinicians must take into consideration the unique morphological location of the IANC in each patient's treatment plan.¹² Consequences of perforating the IANC include pain or loss of tactile sensation of the lower lip and chin, and partial to complete loss of sensory function.¹³ To effectively treat patients without causing such injury, a radiographic examination is helpful to determine the location of the IANC. Conventional two-dimensional imaging has a potential limitation in that it cannot

provide cross-sectional or buccolingual location of the IANC. By contrast, CBCT enables practitioners to accurately localize and mark the nerve canal. In this study, the efficacy of a 180° rotational protocol was compared with that of a conventional 360° rotational protocol in determining the location of the IANC.

Methods and materials

50 dry human skulls were obtained from the Department of Anatomic Sciences at the University of Connecticut Health Center. The study was given an exempt status from the University of Connecticut Health Center's institutional review board, as it was not deemed human subject research. The sample consisted of dentate and partially dentate skulls with no identifiable markers such as age, sex or ethnicity. To simulate the soft tissue on the skulls, white utility wax was placed prior to all image acquisitions. The skulls were imaged using a 3D Accutomo™ CBCT scanner (J Morita Corp., Kyoto, Japan) using a 180° and 360° rotational protocols. A 0.4-mm voxel was used for all scans. For each individual skull, a total of two CBCT scans were acquired with a large field of view (140 × 40 mm): (1) 360° protocol and (2) 180° protocol. The scans were obtained at 80 kVp and 5 mA with a focal spot size of 0.5 mm for the 360° scan. The 180° scan was acquired with 60 kVp and 2 mA. The image acquisition times were 17.5 s for the 360° scans and 9.0 s for the 180° scans.

The images were randomly assigned numbers, and a board-certified oral and maxillofacial radiologist (AT) and a board-certified orthodontist (SY) experienced in evaluating CBCT scans blindly evaluated the scans. The images were viewed using the i-Dixel (J Morita Corp) acquisition program. The examiners initially reviewed 10 scans, which were calibrated in terms of interexaminer reliability. The images were viewed and measured using a CBCT reconstruction software Invivo-5 (Anatomage, San Jose, CA).

For each CBCT scan, cross sections were made by first generating a reconstructed panoramic view. All panoramic images were reconstructed using a standardized virtual focal trough in the arch section mode of the CBCT reconstruction program Invivo-5 (Anatomage). The panoramic images had a slice thickness of 10 mm and a pitch distance of 1 mm. Using the localizer tool in the software program, cross-sectional images were evaluated to mark the nerve canal.

For each CBCT scan, five landmarks were evaluated based on the cross-sectional images generated for each site. Based on the reconstruction algorithm, each landmark spanned approximately three cross sections. Using the localizer tool, the middle cross section that marked the centre of the site was selected for measurement. This was carried out at the following four cross-sectional locations: (1) mental foramen, (2) middle of the first molar, (3) middle of the second molar, (4) middle of the third molar

Figure 1 Locations of cross sections used for length measurements: A, mental foramen; B, middle of the first molar; C, middle of the second molar; D, middle of the third molar.

Figure 2 Coronal section at the level of the mental foramen showing measured distance MFa (from inferior cortical border of the mandible to the top of the mental foramen) and measured distance MFb (from inferior cortical border of the mandible to the top of the IANC). Note: this image was derived from a CBCT scan acquired with the 360° rotation protocol.

(Figure 1). For each of these sites, the superoinferior length measurement was made from the inferior cortical border of the mandible to the top of the IANC. A fifth superoinferior length measurement was made from the inferior cortical border of the mandible to the top of the mental foramen using the cross-sectional image at the level of the mental foramen (Figures 2–4).

The two raters (AT and SY) evaluated the scans. The raters evaluated the scans based on the ability to clearly visualize the IANC at all the important locations, including the entry of the canal on the lingual aspect at the lingual foramen, the course of the canal and its exit at the mental foramen. The raters also evaluated the location of the canal with respect to its distance from the inferior cortical border of the mandible to the roof of the IANC at four locations: (1) mental foramen, (2) middle of the first molar, (3), middle of the second molar, (4) middle of the third molar. In addition, the raters evaluated the distance from the inferior cortical border of the mandible to the top of the mental foramen at the level of the mental foramen. The results from the two raters were then compared to detect if there was a significant difference between the protocols, and statistical analysis was performed.

Statistical analysis

Statistical analysis was carried out using prism GraphPad® software (GraphPad Software, Inc., La Jolla, CA). The interexaminer reliability was calculated using Cronbach alpha test. The sensitivity and specificity of 180° and 360° protocols in locating IANC were recorded as percentages and were compared using the McNemar test. The difference between the two acquisition protocols was calculated using two-tailed Student's *t*-test.

Results

Comparison of the IANC length measurements for the two protocols revealed no significant difference. Length measurements were identical when comparing the 180° and 360° protocols. The mean and standard deviation values were calculated for each measured distance for both of the protocols and compared (Table 1). The mean length from the top of the mental foramen to the inferior cortical border of the mandible at the level of the mental foramen for the 180° protocol was 16.20 mm and for the 360° protocol was 16.21 mm (Table 1, A).

Figure 3 CBCT scans acquired with a 180° rotation protocol: reconstructed panoramic image (a); coronal section showing measured distance at middle of first molar (b).

Figure 4 CBCT scans acquired with a 360° rotation protocol: reconstructed panoramic image (a); coronal section showing measured distance at middle of first molar (b).

The mean length from the top of the IANC to the inferior cortical border of the mandible at the level of the mental foramen for the 180° protocol was 12.36 mm and for the 360° protocol was 12.41 mm (Table 1, B). The mean length from the top of the IANC to the inferior cortical border of the mandible at the level of the middle of the first molar for the 180° protocol was 11.08 mm and for the 360° protocol was 11.03 mm (Table 1, C). The mean length from the top of the IANC to the inferior cortical border of the mandible at the level of the middle of the second molar for the 180° protocol was 11.29 mm and for the 360° protocol was 11.33 mm (Table 1, D). The mean length from the top of the IANC to the inferior cortical border of the mandible at the level of the middle of the third molar for the 180° protocol was 13.10 mm and for the 360° protocol was 13.10 mm (Table 1, E). The overall interexaminer reliability value was >90% for the imaging protocols. Cronbach’s alpha was 95% for the 180° protocol and 97% for the 360° protocol. The overall sensitivity value was 95.5% for the 180° protocol and 97.5% for the 360° protocol. The overall specificity for both the imaging protocols was 100%.

Discussion

In this study, we found that the location of the IANC can be assessed with equal efficacy with both 180° and

360° acquisition protocols. Although fewer basis projections technically lead to a slight drop in the resolution, it did not affect the ability to either localize the IANC or make any measurements. An important consideration about the 180° rotational protocol is that phantom-based studies have shown that the radiation dose with the 180° scan is significantly less than with the 360° protocol.⁸ IANC localization is important for implant treatment planning, implant placement and any surgical procedures that involve the mandible. Numerous studies have documented the reliability of the 180° CBCT protocol compared with the 360° CBCT protocol in clinical applications. Yadav et al¹⁴ performed a study evaluating the arthritic changes in the temporomandibular joint and demonstrated that the 180° rotation protocol was as effective as the 360° rotation protocol in detecting small and large defects in the mandibular condyle. De-Azevedo-Vaz et al¹⁵ observed that 180° CBCT scans were reliable in detecting peri-implant fenestration. In a study evaluating the detection of simulated periapical lesions in human dry mandibles, there was no significant difference in diagnostic accuracy of CBCT scans taken with a 180° protocol and 360° protocol.¹⁶ Lukat et al¹⁷ observed no significant differences in the sensitivity and specificity values of 180° and 360° CBCT scans in detecting artificially created apical lesions.

In our study, we examined the influence of rotation on the efficacy of the CBCT scan’s ability to detect the

Table 1 Mean and standard deviation values for the 180° and 360° protocols

Location	Measured distance	180° protocol (n = 50)		360° protocol (n = 50)	
		Mean	Standard deviation	Mean	Standard deviation
A	MF to ICBM (MFa)	16.20	1.92	16.21	1.94
B	IANC to ICBM (MFb)	12.36	1.24	12.41	1.26
C	IANC to ICBM (M1M)	11.08	2.07	11.03	2.10
D	IANC to ICBM (M2M)	11.29	1.91	11.33	1.89
E	IANC to ICBM (M3M)	13.10	2.24	13.10	2.28

A, mental foramen; B, mental foramen; C, middle of the first molar; D, middle of the second molar; E, middle of the third molar; IANC, inferior alveolar nerve canal; ICBM, inferior cortical border of the mandible; M1M, middle of the first molar; M2M, middle of the second molar; M3M, middle of the third molar; MF, mental foramen; MFa, measurement at the level of MF to the top of mental foramen; MFb, measurement at level of MF to the top of IANC

Note: the abbreviation in parenthesis indicates the cross-sectional location at which the distance was measured.

location of the IANC. Our study showed that even with a lower resolution 180° scan, it is possible to reliably identify the IANC at all locations in the mandible. The results of this *ex vivo* study can be used to do further *in vivo* studies in developing imaging protocols of the head and neck using CBCT scans with the goal of further reducing the radiation dose without compromising diagnostic efficacy. Although there is a slight drop in image resolution, in diagnostic tasks that do not require very high resolution images, this protocol will serve as a good low-dose option. We would have to point out that *ex vivo* studies such as ours have the limitation where all bone quality and types cannot be studied thoroughly and in entirety. But this does articulate a proof of concept that could potentially lead to future

clinical studies in a clinical environment. Overall as shown in this study, a 180° CBCT scan can provide the necessary information to accurately detect the location and course of the IANC, an important task for many routine dental procedures.

Conclusions

In conclusion, this *ex vivo* study using dry human skulls demonstrates that the 180° rotational CBCT acquisition protocol is able to accurately evaluate the location and to track the IANC with very high reliability and is comparable to a 360° rotational CBCT acquisition.

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