RESEARCH PAPER

Cone Beam Computed Tomographic Analysis of the Course and Position of Mandibular Canal

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Abstract

Purpose Estimation of the relative position of infra alveolar nerve (IAN) canal and its relation to the mandibular anatomical landmarks can be clinically useful in minimizing the risk of surgery complications such as neurosensory disturbances that may occur after invasive mandibular surgical procedures. The purpose of the present study was to investigate the anatomic location and radiographic course of the mandibular canal compared to anatomic landmarks on CBCT and to discuss its clinical significance and also to determine the possible correlations between the mandibular position and the age of the patients.

Methods This cross sectional study was conducted on 242 CBCT of patients (99 males and 143 females). The location of canal was evaluated in 4 different regions. The first section in trans-axial view after mental foramen, in which the loop of mandibular canal is formed, was selected as point 1 for measurement and intervals of 10 mm, respectively, points 2, 3, 4 were selected for measurement. On these sections, the shortest linear distances (mm) from the

most buccal and lingual aspects of the canal to the corresponding cortical plates of the mandible and also the minimum linear distance between the inferior aspect of canal and inferior border of mandible in these regions were calculated.

Results There was statistically significant correlation between the anatomic course of the canal and the patients' gender. The mean vertical position of the canal, as measured from the lower border of the IAN canal to the inferior border of the mandible, was 8.50 mm, ranging from 4.80 to 14.50 mm. On average, the mandibular canal was situated more lingually at all sites to the point it reached the mental foramen. However, at the mental foramen region (Point 1), it was located closer to the buccal cortical plate.

Conclusion Assessment of the exact course of the IAN preoperatively along the body of the mandible by using CBCT might contribute to efficient and accurate surgical planning and therefore positively influence the surgical results. The results of this study confirm the necessity of using CBCT before invasive surgical procedures to determine the variations in the relative position and course of IAN canal.

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Introduction

The infra alveolar nerve (IAN) canal is one of the largest branches of the mandibular division of trigeminal nerve which is of particular interest in the field of maxillofacial surgery [1]. The canal passes through the body of the mandible in an anteroposterior direction, however, its position in the buccolingual and vertical directions varies

in each patient [2]. Knowledge of anatomical position of IAN canal is clinically significant because of its susceptibility to the injury during surgical procedures involving the mandible [3]. The variation in the anatomical position of the IAN canal must be always taken into account for avoiding iatrogenic inferior alveolar nerve damage during mandibular invasive surgical procedures such as mandibular osteotomies, fracture repair, fixation screw placement, orthognathic surgeries, third molar extraction, and dental implant therapies [4]. It has been suggested that as much as the distance from the buccal aspect of the IAN canal to the outer buccal cortical margin was shorter, the occurrence of neurosensory disturbances (NSD) of the IAN after bilateral sagittal split osteotomy (BSSO) was the more frequent [2, 5–8]. The incidence of IAN injury during third molar extractions has been reported to be 0.4–13.4 % [9]. The rate of neurosensory disturbances during orthognathic surgeries and dental implant placements were up to 65.1 and 77.8 % respectively [10].

A few studies have evaluated the anatomic position and the course of canal using cone beam computed tomography (CBCT) [7, 11, 12]. The purpose of the present study was to assess whether patient differences in gender were predictive of differences in the relative location of the canal and to evaluate the relative position of the canal in relation to mandibular cortices using CBCT.

Materials and Methods

This study was approved by the Ethical Committee of Shiraz Dental School. CBCT scans of 242 patients (99 males and 143 females) with ages ranging from 18 to 75 years (mean age, 35 ± 3.4 years) were selected from the database of an Oral and maxillofacial Radiology center. The CBCT images were taken by single technician using a New Tom VGi with a field of view 15×15 cm, 120 kV, exposure time of 3.6 s, and 3 mA. Patients who had maxillofacial deformities, any pathologic conditions or history of fracture or any previous manipulation which could alter the position of IAN canal were excluded.

The section in axial plane in which mental foramen was visible has been used for drawing the curve to produce the pseudo panoramic view. The measurements were established on the axial section of the mandible with 0.5 mm slice thickness. The first section in trans-axial view after mental foramen, where the loop of mandibular canal is formed, was selected as point 1 and interludes of 10 mm were selected for subsequent measurements (respectively, points 2, 3, 4). On these sections, the shortest linear distances (in mm) from the most lingual aspect of the canal to the outer lingual cortical plate of the mandible and from the mandibular canal to the inferior border of mandibular body

Fig. 1 Measurement of the shortest linear distances (mm) from the most buccal and lingual aspects of the canal to the corresponding cortical plates of the mandible and also the minimum linear distance between the inferior aspect of canal and inferior border of mandible in an CBCT image

were measured. Furthermore, the minimum distance between the buccal cortices and the mandibular canal were evaluated (Fig. 1). All distances were measured by an expert periodontist. The data were analyzed with the SPSS software version 15. Student test–test at the significance level of $p < 0.05$ was used to evaluate the association of gender to the relative position of the IAN canal.

Results

The mean bone thickness of the female group was significantly smaller in vertical and horizontal distances than that of the male group. Table 1 demonstrates and compares the mean distance from the mandibular canal to the mandibular cortices in females and males. The mandibular canal was located at a mean distance of 8.50 mm above the inferior margin of the mandible ranging from 4.80 to 14.50 mm. The mandibular canal was ascending slightly toward the mental foramen and the mean distance from the mandibular canal to the inferior border of the mandible was 9.73 mm at point 1.

On average, the mandibular canal was situated more lingually at all sites to the point it reached the mental foramen. However, at the mental foramen region (Point 1) was located closer to the buccal cortical plate. The distance

Table 1 The relative position of IAN canal in the mandibular body in the vertical and buccolingual dimensions according to gender

Measured distances	Male				Female				<i>P</i> value
	Mean	SD	Min	Max	Mean	SD	Min	Max	
Point 1									
H1	9.73	1.35	5.80	13.7	8.49	1.16	5.50	12.60	0.00
W1	3.65	1.07	1.20	6.20	3.81	1.10	0.70	6.90	0.25
B1	3.01	0.67	1.30	5.30	2.77	0.76	1.00	5.10	0.01
Point 2									
H2	8.14	1.42	5.40	11.70	7.13	1.38	4.80	11.80	0.00
W2	2.37	3.23	0.60	3.30	2.44	0.83	0.60	4.50	0.83
B2	5.37	0.98	2.50	7.70	5.21	1.13	2.75	7.30	0.26
Point 3									
H3	8.04	1.66	4.80	12.80	7.16	1.54	3.30	11.80	0.00
W3	2.00	1.08	0.50	5.70	2.36	0.86	0.60	5.10	0.00
B3	6.20	1.08	3.10	7.20	6.41	4.87	2.70	6.68	0.67
Point 4									
H4	8.82	2.22	0.10	14.50	8.20	1.90	3.50	12.90	0.00
W4	2.03	1.13	0.60	6.30	2.35	0.93	0.50	4.90	0.22
B4	5.68	5.98	2.40	7.20	4.92	1.21	2.20	6.95	0.14

H, the minimum distance between the mandibular canal and the lower border of the mandible; W, the minimum distance between the mandibular canal and the lingual plate of the mandible; B, the minimum distance between the mandibular canal and the buccal plate of the mandible

Table 2 The relative position of IAN canal in the mandibular body in the vertical and buccolingual dimensions

Measured distances	95 % Confidence Interval					
	Mean	SD	Lower Band	Upper Band	Minimum	Maximum
Point 1						
H1	9.01	1.38	8.84	9.19	5.50	13.70
W1	3.74	1.09	3.60	3.88	0.70	6.90
B1	2.87	0.67	2.78	2.97	1.00	5.30
Point 2						
H2	8.14	1.42	7.38	7.76	5.40	11.70
W2	2.37	3.23	2.13	1.69	0.60	3.3
B2	5.37	0.98	5.14	5.41	2.50	7.70
Point 3						
H3	8.04	1.66	7.34	7.76	4.80	12.80
W3	2	1.08	2.08	2.33	0.50	5.70
B3	6.20	1.08	5.84	6.80	2.70	7.20
Point 4						
H4	8.82	2.22	8.23	8.75	5.10	14.50
W4	1.96	1.13	2.09	2.35	0.60	6.30
B4	5.68	5.98	4.73	5.72	2.20	6.40

H, the minimum distance between the mandibular canal and the lower border of the mandible; W, the minimum distance between the mandibular canal and the lingual plate of the mandible; B, the minimum distance between the mandibular canal and the buccal plate of the mandible

from the mandibular canal to the buccal border of the mandible was ranging quite widely from 1 to 7.70 mm. The minimum distance of the mandibular canal from the outer surface of the buccal cortex was 1 mm at point 1. The

mandibular canal was the farthest from the lingual cortex at point 1 region in this study with a mean of 3.65 mm. The mean distance of the mandibular canal from the lingual cortex decreased gradually until point 4 (Table 2).

Discussion

Impairment of the IAN canal is a known complication occurring in 49–100 % of patients after sagittal split ramus osteotomy (SSRO) which is the most commonly used surgical procedure in treating mandibular asymmetries, mandibular prognathism and retrognathism. It has been reported that the incidence of postoperative hypoesthesia and neurosensory disturbances were related to the position and the course of canal [5–7]. Yoshioka et al. found significant correlation between the position of the canal and the neurosensory disturbance of the IAN canal at 6 months and 1 year after SSRO using computed tomography (CT) images. They concluded that when the distance from the buccal aspect of the IAN canal to the outer buccal cortical margin were less than 6 mm, neurosensory disturbance of the IAN at 1 year after SSRO increased significantly [6]. Similarly, Chiung Shing Huang et al. compared the buccal cortical thickness (BCT) between the mandibular canal and the corresponding external cortical surface in patients with and without neurosensory disturbance after they underwent BSSO. They used preoperative CBCT imaging to assess the BCT every 2 mm from the mandibular foramen to the furcation of the mandibular first molar in the NSD group and the sensory normal (N) group. They concluded that compared with the N group, BCTs in the NSD group were always decreased [7]. Ylikontiola et al. [13] concluded that the risk for neurosensory disturbance was significantly greater if the distance between the mandibular canal and the buccal cortex of the mandible was <2 mm. Therefore, information on the buccolingual, superior and inferior position of the canal could assist surgeons in avoiding injury to the IAN. In the present study, we have evaluated the anatomical position of the IAN canal relative to the adjacent cortices using CBCT.

Awareness of the relative location of mandibular canal enables the oral and maxillofacial surgeon for better informing the patient about the surgical risks and possible complications and subsequently prevents or reduces the damage to the inferior alveolar neurovascular bundle during invasive mandibular surgeries [2]. Conventional anatomy textbooks usually do not give a detailed description of the course of the IAN canal [2]. Various methods have been used to evaluate the relative location of mandibular canal such as dry skulls [3, 14–16], clinical observations during surgery [13], conventional radiographs [2, 17–19], CT [5, 6, 20–23] and CBCT [7, 11, 12]. Cadaver studies may not have adequate sample sizes and enough demographic information such as race, age and gender [4, 24]. Shrinkage of the dry skulls, use of irrelevant landmarks or edentulous mandibles and fracture of subtle structures are other limitations of using cadavers in investigations [21].

Image methods that provide precise localization of the mandibular canal and involve a minimal risk of exposure to ionizing radiation should be selected. Conventional radiographs have several limitations including limited reproducibility, magnification and distortion [21]. These techniques only represent 2 dimensional (2D) position of the canal and do not demonstrate the buccolingual position of the canal [25]. Ylikontiola et al. compared panoramic radiographs, CT, and conventional spiral tomographic radiographs for their ability to locate the mandibular canal in the buccolingual direction. They suggested that the buccolingual location of the mandibular canal is visualized better with CT than with tomography or panoramic radiographs [2]. Similar results have been demonstrated by Tomomi et al. [26] who compared the accuracy of determination of the mandibular contour and the position of the mandibular canal in cadaver mandibles between different modalities. CBCT is a new accurate modality for 3D reconstruction of the maxillofacial complex without any magnification [25]. Kamburoğlu et al. showed that the accuracy of CBCT measurements of various distances surrounding the mandibular canal was comparable to that of digital caliper measurements [27]. Eizenbud et al. [28] suggested that precise locating the IAN using CBCT rather than routine presurgical imaging is a significant means for efficiently minimizing nerve damage during SSO. Balaji et al. [12] assessed the position of IAN canal among South Indians using CBCT. However, their study sample size was small compared to the present study and composed of only 20 patients.

Some previous studies have indicated that the relative position of the IAN canal and its mental and mandibular foramina in adults show sexual dimorphism [25, 29]. Similarly, there was significant correlation between IAN canal position and gender in the present study. The mean bone thickness of the female group was smaller in vertical and horizontal distances than that of the male group. Similarly, de Oliveira Júnior et al. showed slightly lower values for these parameters in females than in males but such differences were not statistically significant [30]. However, Angel et al. demonstrated that the relative location of the inferior alveolar canal and associated foramina in adults remain fairly constant regardless the sex [11].

The mandibular canal is located closer to the lingual surface of the mandible in the posterior part of the body of mandible, and progressively it becomes more superficial in relation to the buccal surface of the mandible where it ends at the mental foramen. Our results were in agreement with some important previous studies [2, 30]. The mandibular canal was the farthest from the buccal cortex at the point 3 region in this study with the mean of the buccal distance was 6.60 and thereby the safest position to place the ver-

tical osteotomy cuts to the BSSO. The vertical buccal cut of the SSRO should be placed in the point 3 region where the bone is thickest and the mandibular canal is farthest from the buccal cortex.

In the vertical dimension, on average, the mandibular canal ran almost 8.50 (range 4.80 - 14.50 mm) above the inferior border of the body of the mandible. Our results showed lesser values than the results of previous studies [15, 31, 32] because of differences in the subjects. According to the report of Ylikontiola et al. [2] the mean distance from the mandibular canal to the inferior border of the mandible was 8.1 mm at the posterior reference point and 6.8 mm at the anterior reference point.

Previous studies used different anatomically risky parameters for evaluation of anatomical position of the canal [20–22]. We used inferior border of the mandible as reference for evaluation of IAN canal position in vertical dimension. Similarly, Ayla Ozturk et al. evaluated the position of IAN canal with reference to the inferior border of mandible and CEJ. They concluded that the inferior border of the body of the mandible seems to be a more predictable reference point compared with CEJ of the teeth. Several studies have shown the inferior border of the mandible to be a valid reference point to determine the course of the mandibular canal. However, some other investigators have evaluated the distance between the superior crest of mandible and the IAN canal. The position of the canal in relation to the alveolar crest was not examined in this study because bone resorption may occur due to tooth loss and periodontal involvement, therefore, the crest of mandible may not be a reliable reference point. Estimation of the distance of the IAN canal from the inferior cortex is helpful when the genioplasty cuts are extended posteriorly. As the mandibular canal descended from the mandibular foramen, it was at its lowest in the point 3 and ascended gradually as it approached the mental foramen.

Some previous studies focused on the second inferior molar region [5, 22], as it is the area of the BSSO and the remaining course of the canal along the mandibular body was not assessed. However, the exact IAN canal location may also show anatomical aberration in this area. The anterior BSSO in the mandibular body may be modified according to an anterior site in order to reduce the risk of IAN impairment. Therefore, in the present study we measured the distance between the mandibular canal to the lingual and buccal cortices and inferior border of the mandible at different locations along the IAN canal pathway.

In Conclusion, a better understanding of the anatomic variation of the mandibular canal position can help the surgeons on a safe treatment planning for those surgical procedures that involves the mandible. CBCT imaging of

the IAN will enhance the identification of the exact location of the IAN and thus prevent severe damage to the IAN during the invasive mandibular surgical procedures.

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Compliance with Ethical Standards

Conflict of interest All authors declare that they had no conflict of interest.

Human and Animal Rights This article does not contain any studies with human participants or animals performed by any of the authors.

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