Utilization of cone beam computed tomography to determine the prevalence and anatomical characteristics of bifurcated inferior alveolar nerves

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The primary purpose of this study was to evaluate the prevalence of inferior alveolar nerve (IAN) bifurcations through the utilization of cone beam computed tomography (CBCT). The secondary purposes of this study were to analyze the average distance from the main trunk to its branch at the greatest point, to calculate the average distance of the bifid IAN from the apices of the teeth, and to determine the appropriate classification for each IAN bifid nerve according to the types described by Nortjé et al: type 1, 2 canals originating from a single foramen with a narrower inferior canal; type 2, 2 canals originating from a single foramen with a superior canal extending to the second or third molar; type 3, 2 canals of equal size that arise from 2 mental foramina that may link into a single canal near the molars. Examination of 194 CBCT scans revealed that IAN bifurcations were present in 13.4% (n = 26) of the study population. Bifurcation was bilateral in 4 individuals. For left bifurcated IANs, the average distance between the superior border of the main branch and inferior border of the bifurcated IAN (GDN) was 3.41 mm. The average distance from the superior border of the bifurcated IAN to the apex of the closest root (NAP) was 3.45 mm. For right bifurcated IANs, the average GDN was 4.01 mm, and the average NAP was 4.85 mm. Fourteen bifid nerves were type 1, and 16 were type 2. Preoperative CBCT studies can determine the presence of a bifurcated IAN, thereby reducing the chances of neurologic damage.

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The mandibular canal is an intraosseous duct found within the body of the mandible. The canal initiates in the mandibular foramen, found on the lingual aspect of the ramus, and terminates at the mental foramen. Within this canal lies the inferior alveolar neurovascular bundle. This bundle consists of the inferior alveolar nerve (IAN), artery, and vein.[1] The IAN supplies innervation to the mandibular posterior dentition, surrounding bone structure, and mucosa of the posterior tongue. Due to the diffuse innervation, maintaining structural integrity of the nerve during oral surgical procedures is of utmost importance.

The orientation and configuration of the IAN canal have been thoroughly researched in historical dental literature. Nortjé et al categorized the anatomy of the IAN into 4 broad groups: 1, bilateral, single, high mandibular canals (defined as being within 2 mm of the apices of the permanent first and second molars or, if the teeth had been extracted, within 2 mm of where the apices would have been); 2, bilateral, single, intermediate mandibular canals; 3, bilateral, single, low mandibular canals (defined as being within 2 mm of the cortical plate of the lower border of the mandible); and 4, other variations.[2] Within the fourth group, the authors described an anomaly involving duplication or division of the IAN (known as *bifurcations* or *bifid canals*), which they further classified into 3 types.[2] Type 1 has 2 canals originating from a single foramen; the inferior canal is typically narrower than the superior. Type 2 has 2 canals originating from a single foramen; the superior canal extends to the second or third molar. Type 3 has 2 canals of equal size that arise from 2 mental foramina and may link via anastomosis into a single canal near the molar region in the mandibular body.[2]

Bifurcated IANs are a crucial consideration with regard to anesthesia, mandibular surgery, implant placement, and endodontic procedures.[3,4] Damage to a branch of a bifurcated IAN can cause paresthesia, dysesthesia, or a complete loss of feeling in the affected mandible.[5] Traditionally, practitioners have diagnosed bifid IANs via panoramic radiographs. However, with the advent of cone beam computed tomography (CBCT) technology, the detection rate of bifid IANs has risen dramatically.[6]

The primary purpose of this study was to evaluate the prevalence of bifid IANs through the utilization of CBCT. The secondary purposes of this study were to analyze the average distance from the main trunk to its branch at the greatest point, to calculate the average distance of the bifid nerve

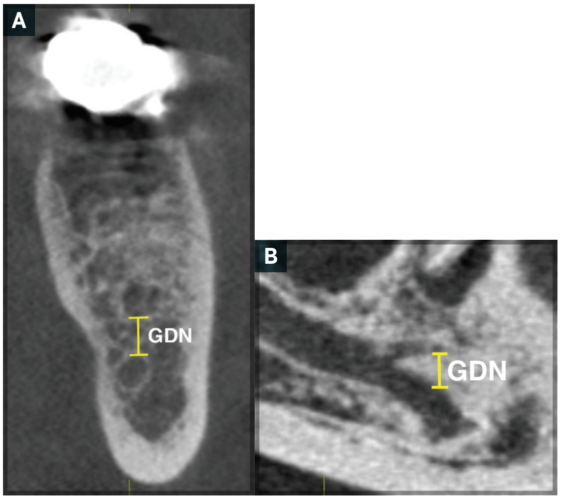


Fig 1. Measurement of the greatest distance between the superior border of the main branch and inferior border of a bifurcated inferior alveolar nerve (GDN). A. Cross-sectional view. B. Lateral view.

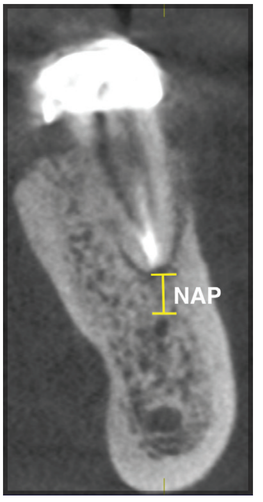


Fig 2. Measurement of the distance from the superior border of a bifurcated inferior alveolar nerve to the apex of the closest root (NAP).

from the apices of the teeth, and to determine the appropriate classification for each IAN bifid nerve according to the types defined by Nortjé et al.[2]

Materials and methods

All procedures followed were in accordance with ethical standards for human experimentation and with the Helsinki Declaration of 1975, as revised in 2013.[7] Informed consent was obtained from all patients in the study. This study was approved by the Institutional Review Board of Lake Erie College of Osteopathic Medicine (LECOM), School of Dental Medicine, Bradenton, Florida (protocol 23-106).

CBCT images taken for treatment planning purposes were acquired retrospectively from a private practitioner affiliated with LECOM, School of Dental Medicine. All images were taken with a Sirona XG3 CBCT (Dentsply Sirona). Imaging parameters for all scans were as follows: area dose, 693 mGy × cm^2; tube current, 6 mA; and tube voltage, 85 kVp. The field of view was set at 8 × 8 cm for each patient. The total radiation received by each patient was set to 166 µSv. The images were analyzed with an implant planning software program (Galaxis/Galileos Implant Viewer, Dentsply Sirona).

A total of 200 CBCT images were analyzed for purposes of this study. During the study, 6 images were discarded due to corrupt Digital Imaging and Communications in Medicine (DICOM) data. All the measurements from the CBCT scans were completed by 3 calibrated examiners under the supervision of a board-certified diagnostic radiologist.

Scans were assessed in panoramic, tangential, cross-sectional, and axial planes for the presence of bifurcated IAN canals. The mental foramen served as a starting reference point. From the foramen, the canal was mapped distally through the mandible and examined for the presence of bifurcations. An IAN bifurcation was recorded if it was clearly visible within 2 CBCT views. If an IAN bifurcation was noted, a second examiner reviewed the scan to verify the location and presence of the bifurcation. All IAN bifurcations were finally verified by both a board-certified periodontist and a board-eligible endodontist.

If an IAN bifurcation was noted, the location was recorded based on proximity to the nearest tooth root, unless the bifurcation was noted in an edentulous area. If the IAN bifurcation was noted in an edentulous area, the measurement was not recorded. The location of the IAN bifurcation was utilized to classify the nerve according to the types defined by Nortjé et al.[2] On both cross-sectional and lateral views, a measurement was taken at the greatest distance between the superior border of the main branch and inferior border of the bifurcated IAN (GDN) (Fig 1). When applicable, the distance from the superior border of the bifurcated IAN to the apex of the closest root (NAP) was also measured on the cross-sectional views (Fig 2).

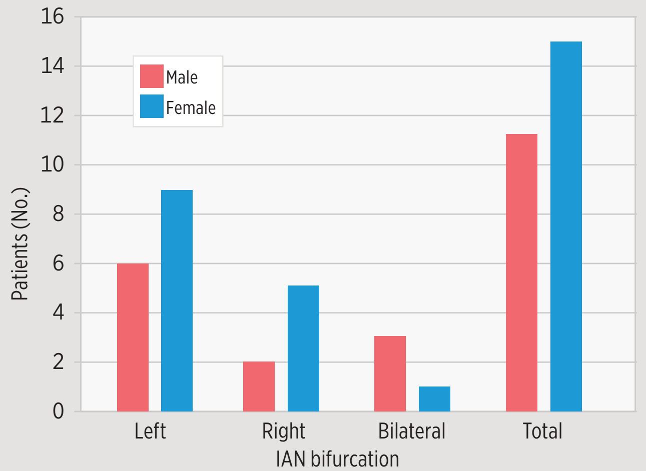
The demographic information of the patients in the study was obtained from their charts and recorded. To assess whether any of the different demographic groups were more likely to exhibit bifid IANs than the overall sample, a series of chi-square tests were conducted.

Results

A total of 194 scans were evaluated for the presence of a bifurcated IAN. Within this study set, 86 scans were from male patients and 108 were from female patients. The patients had a mean age of 55 years (range of 13-103 years). Data obtained from the charts indicated that 121 scans were from white patients, 32 from Hispanic patients, 24 from African American patients, and 17 from Asian patients.

The total proportion of CBCT scans that demonstrated bifurcated IANs was 13.4% (n = 26). Bifurcations were found in 11 male (5.7%) and 15 female (7.7%) patients (Chart). The bifurcated

Chart. Distribution of IAN bifurcation by sex.



Abbreviation: IAN, inferior alveolar nerve.

Fig 3. Examples of IAN bifurcations (arrows) observed in the sample (classification according to Nortjé et al[2]). A. Type 1. B. Type 2.

IANs were in only the left side of the mandible in 7.7% of patients (6 male and 9 female), in only the right side of the mandible in 3.6% of patients (2 male and 5 female), and bilateral in 2.1% of patients (3 male and 1 female). The prevalence of IAN bifurcation for each racial/ethnic group is presented in the Table. Results of chi-square tests indicated that sex and race/ethnicity were not significant predictors of a greater prevalence of IAN bifurcation.

The average GDN was 3.41 mm for left bifurcated IANs and 4.01 mm for right bifurcated IANs. When scans that exhibited IAN bifurcations in an edentulous region were eliminated, the average left NAP was 3.45 mm and the average right NAP was 4.85 mm.

Table. Prevalence of bifurcated inferior alveolar nerves, by racial or ethnic group.

Racial or ethnic group	n	Prevalence (%)	
		Left side	Right side
White	121	13.0	4.6
Hispanic	32	6.3	9.4
African American	24	7.7	7.7
Asian	17	5.9	0.0

The bifurcated IANs were classified according to the types reported by Nortjé et al (Fig 3).[2] Among the left bifurcated IANs, 8 were type 1 (single foramen; narrower inferior canal) and 11 were type 2 (superior canal extending to second or third molar). Among the right bifurcated IANs, 6 were type 1 and 5 were type 2. In each of the patients with bilateral bifurcated IANs, the canals on the left and right sides were classified as the same type.

Discussion

The morphology of the IAN and the potential for bifurcation have been studied using a variety of methods. The 3 main study methods consist of cadaver and dry mandible studies, panoramic radiographic studies, and CBCT studies. Study methods can have a profound impact on the reliable detection of bifurcated IANs.

Cadaver and dry mandible studies are considered to be the most accurate method for bifurcated IAN analysis, but they are not a practical means for clinical practice. Thus, most studies are performed using radiographs. The validity of 2-dimensional radiographs as a study method for bifurcated IAN analysis has been called into question due to the low rates of observation. Nortjé et al reviewed 3612 panoramic images and reported an IAN bifurcation rate of only 0.9%.[2] Sanchis et al evaluated 2012 panoramic images and found bifurcated IANs in 0.35% of all radiographs.[8] These results were confirmed by Bogdán et al when they compared observations of IAN bifurcations in dry mandibles and panoramic radiographs.[9] The authors found an IAN bifurcation rate of 19.6% in dry mandibles compared to only 0.2% shown in corresponding panoramic radiographs.

Recently, CBCT scans have become a more common method to determine the presence of bifurcated IANs. CBCT images produce minimal distortion, have almost no magnification, and allow for imaging in a 3-dimensional view.[10] Thus, bifid IANs are reported more frequently in CBCT studies than in panoramic studies. Kuribayashi et al evaluated the CBCT scans of 252 patients.[11] Their results showed the prevalence of bifid IANs to be 15.6%. Muinelo-Lorenzo et al examined 225 CBCT scans and panoramic images for the presence of bifid IANs.[12] Their results revealed that 36.8% of CBCT scans presented with bifid IANs. Only 37.8% of the IAN bifurcations viewed on the CBCT scans were found on panoramic radiographs. This supports the assertion that CBCT is more accurate than panoramic radiography for the detection of bifurcated IANs.

The accurate diagnosis of bifid IANs is particularly relevant prior to surgical procedures that could involve the IAN, including the placement of mandibular implants, endodontic procedures, and third molar surgery. The IAN is the nerve most commonly injured during implant placement.[13] Injury to this nerve may cause a neurosensory deficit of the mandible, including the soft tissue and dentition.

Current guidelines state that the implant should remain a minimum of 2 mm from the superior border of the IAN.[14] The position of a bifid nerve could affect the proposed length of a dental implant. In the present study, the average GDN was 3.41 mm on the left side of the mandible and 4.01 mm on the right. If an IAN bifurcation is unnoticed and a dental implant is placed within 2 mm of the main IAN, neurologic damage may result. Thus, careful treatment planning to fully identify the presence of bifid IANs should be considered prior to implant placement.

Altered sensation from a bifid IAN may also result from mandibular endodontic therapy. Overinstrumentation of the canal or extrusion of gutta percha and/or canal sealer from the apex during mandibular endodontic treatment could cause injury to the IAN. Pogrel evaluated 61 patients with clinical and radiographic evidence of endodontic sealer in the mandibular canal.[15] Of those patients with radiographic evidence of sealer in the mandibular canal, 42 (68.9%) reported some altered sensation, 13 of whom exhibited dysesthesia.

A potential reason for extruded canal sealer to cause altered sensations is neurotoxicity. Tuğ Kılkış et al examined the neurotoxic effect of 4 commonly used canal sealers on the sciatic nerves of rats.[16] Their results confirmed via histologic examination that the chemical compositions of endodontic canal sealers exhibit some degree of neurotoxicity. Serper et al also suggested that neurotoxic effects of extruded endodontic materials can be caused by an inflammatory reaction or allergic reaction.[17]

As stated previously, the present study revealed that the average distance from a bifid IAN to the apex of a tooth was 3.45 mm on the left side of the mandible and 4.85 mm on the right side. When treatment planning for endodontic therapy, the practitioner should consider the possibility that a bifid IAN is present. Bürklein et al examined 627 CBCT scans and mapped the mean distance between the IAN and the apices of the mandibular second premolar, first molar, second molar, and third molar.[18] The mean distances to these teeth were 4.2 mm, 4.9 mm, 3.1 mm, and 2.6 mm, respectively. If a bifid IAN is suspected, the practitioner should take precautions, as the reduced distance to the apex could lead to extrusion of endodontic sealer material into the canal space.

When mandibular third molar extraction is considered, the IAN is of utmost importance due to its potential proximity to the site of surgery. Nerve damage, although rare, can occur. After third molar extraction where there was panoramic evidence to suggest that the root apex was in close proximity to the IAN, a higher incidence of injury has been found.[19,20] A possible explanation for injury to the IAN during third molar surgery could be the presence of a bifurcated IAN. A type 2 bifid IAN canal has a short superior branch terminating in the area of the second or third molar.[2] In the present study, 53.3% of bifid IANs were judged to be type 2. CBCT could be used in these high-risk cases to reduce the risk of altered sensations by giving the surgeon a more accurate representation of nerve proximity to the third molar.[21]

Conclusion

Before surgical procedures such as implant placement, endodontic treatment, and third molar extraction involving the posterior mandible, it is crucial to consider the possibility of a bifurcated IAN. The results of this study indicated that the overall incidence of bifurcated IANs is 13.4%, and the distance between IAN bifurcations and the apices of teeth can be less than 5 mm. Successful identification of bifid IANs and avoidance of the nerve can prevent postoperative complications such as paresthesia and dysesthesia. Because of their increased accuracy and lack of distortion, CBCT images are the preferred radiologic method to identify IAN bifurcations.

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Disclaimer

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