

# Is there a justification for cone beam computed tomography for assessment of proximity of mandibular first and second molars to the inferior alveolar canal: A systematic review

## Abstract

### Objective

The objective of this review was to determine the distance from the apices of mandibular first and second molars to the inferior alveolar canal (IAC) using cone beam computed tomography (CBCT).

### Data sources and study selection

Articles published between the period of 1988 to 2016 were included. This review included mandibular first and second molar studies that sought to observe proximity to the IAC using 3-D imaging modalities. The authors developed specific search strategies for PubMed, Scopus and Web of Science and evaluated the methodological quality of the included studies using criteria from the PICO protocol. Articles that aimed at determining the distance of the apices of mandibular first or second molars or both from the IAC and that used CBCT as an imaging modality were included in the study.

### Results

This review identified an average mean distance of 7.3 mm (range: 0.00–14.71 mm) from the apices of mandibular first and second molars from the IAC. The mean difference (IV, fixed, 95% CI) for first molars in women was 0.29 (95% CI: 0.11, 0.48) and for second molars was 0.50 (95% CI: -0.00, 1.01) compared with 0.31 (95% CI: 0.08, 0.54) for first molars in men and 0.23 (95% CI: -0.51, 0.98) for second molars on both sides of the mandible.

### Conclusion

We can conclude that an approximate average mean distance of 7.3 mm is present between the IAC and the apices of mandibular molars.

### Keywords

Radiology, CT imaging, imaging, surgical techniques, occlusion, stomatognathic physiology.

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### How to cite this article:

Khijmatgar S, Chowdhury C, Rao K, Thankappan Swarnadhai S, Krishna N. Is there a justification for cone beam computed tomography for assessment of proximity of mandibular first and second molars to the inferior alveolar canal: A systematic review. *J Oral Science Rehabilitation*. 2017 Dec;3(4):48–56.

## Introduction

The inferior alveolar canal (IAC) runs in an S-shaped pattern in the mandible. Factors like age, race, sex and the anatomy of the mandible influence its location. The IAC contains a nerve that, along with the inferior alveolar artery and vein, innervates the posterior teeth through the IAC before splitting into incisive and mental components that innervate the mandibular anterior teeth, lower lip and gingiva. All of these factors have clinical significance with reference to the distance from the first and second molars to the IAC, more so than the distance from the third mandibular molar. These facts are well documented with regard to the proximity of the IAC to the apices of the mandibular first molars. The inferior alveolar nerve (IAN) is the most commonly injured nerve—about 64.4% of injuries occur from trauma due to implant placement.<sup>1</sup> While evaluating the benefits and outcomes of dental treatment, the dentist should be aware of the position of the IAN/IAC with respect to the apices of the mandibular molars.<sup>2</sup>

Injuries to the IAC are mostly iatrogenic.<sup>3</sup> Dental clinical procedures such as endodontics, tooth extraction, implant placement and other surgical procedures in the area of the first and second molars are the major causes of iatrogenic injury to the branches of the trigeminal nerve within the IAC.<sup>4</sup> In 40% of the cases, injury is due to dental implants,<sup>1</sup> followed by 1–10% due to endodontic procedures (**Fig. 1**). Other types of injury to the IAN occur through mechanical trauma caused by overinstrumentation, extrusion of chemical agents such as irrigants, intracanal medicaments, root filling materials, the presence of foreign material or thermal injury during endodontic procedures.<sup>1,5</sup> The consequence of injury to the nerve is postoperative paresthesia or anesthesia that may be transient or permanent. The mandibular second molar apices have been reported to be the closest to the IAN compared with the premolars and first molar<sup>1</sup> and hence more prone to injury.

In order to interpret these problems, clinicians rely on various methods of radiographic examination. Information regarding teeth and their associated anatomy, including root canal morphology, is commonly obtained from conventional imaging modalities such as intraoral radiographs, cephalograms, dental panoramic tomograms and cone beam computed tomography (CBCT). The conventional signs of proximity of the IAN to molars include root

narrowing, root deflection and bifid apices, as well as root canals that show diversion, narrowing or loss of lamina dura.<sup>4</sup> Hence, the newer method of 3-D imaging is considered to be the most reliable aid in assessing the relationship of roots to the IAN because of its accuracy, efficiency and effectiveness.<sup>5</sup>

The objective of this review was to determine the proximity of mandibular first and second molar apices to the IAC and to determine the justification of the use of CBCT of mandibular first and second molars to assess treatment outcome. The results of this review will enable clinicians to estimate the distance between the IAN/IAC and the apices of mandibular first and second molars on the basis of various published studies. The information obtained can be applied during various dental procedures to estimate the potential risk of any injury to the IAN/IAC due to varying dental procedures in the mandibular posterior areas.

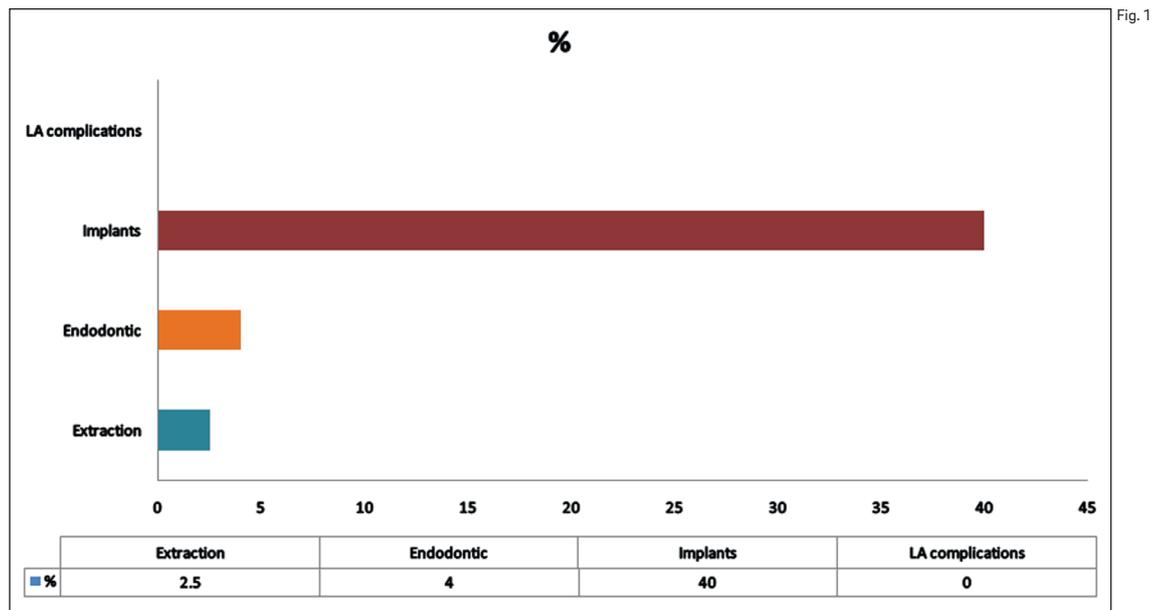
## Materials and methods

We used secondary data and included studies that considered mandibular first and second molar apices in determining proximity to the IAC using 3-D imaging. We did not include the studies for analysis from 2-D imaging, but considered them to determine the difference between 3-D and 2-D imaging in distances recorded.

### Search methods and identification and selection of studies

We carried out a search of the literature using the PubMed, Web of Science and Scopus databases. A total of three independent searches were carried out. The study used reports of CBCT scans from 1986 to 2016 that included first and second mandibular molars and their distance to the IAC in different populations and considering age, sex and various other factors. The key terms used for extracting the relevant articles were "cone beam computed tomography" or "cbct" or "CBCT dental" or "cone beam CT dental" or "cone beam dental" and "inferior alveolar canal" or "IAN canal" or "IAN" and "lower molar" or "lower first molar" or "lower second molar" or "mandibular molar". The process of article inclusion and exclusion was according to the PRISMA protocol (**Fig. 2**).

The initial search of all three databases yielded 94 articles. Later, after reviewing the



**Fig. 1**  
Prevalence of causes of inferior alveolar nerve injury.

titles and abstracts, 74 articles found to be duplicates and not to meet the criteria were eliminated. Ten articles were included for full-text reading and one study was eliminated. The 3-D studies Hiremath et al.,<sup>6</sup> Kawashima et al.,<sup>1</sup> Chong et al.,<sup>2</sup> Bürklein et al.,<sup>7</sup> Adigüzel et al.<sup>8</sup> and Simonton et al.<sup>9</sup> were included for further data analysis. The 2-D studies Tilotta-Yasukawa et al.<sup>10</sup> and Littner et al.<sup>11</sup> were included for the sake of comparison. A summary of the included articles found in the search of the databases is provided in **Table 1**.

#### Data collection and analysis

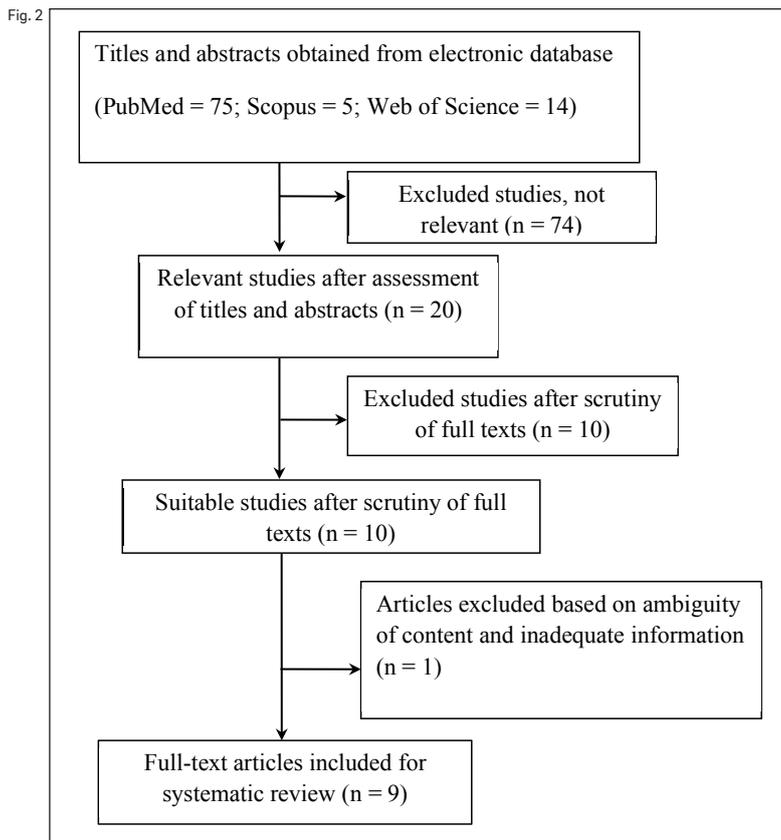
The data were the year of publication, author, country of study, type of imaging modality, model of CBCT machine, technical specifications and the distances in millimeters measured from the apices of mandibular first and second molars to the IAC. Meta-analyses were planned only when sufficient similarities were found among the included studies with regard to the side of mandible, that is, right or left; mesial or distal root; first or second molar; male or female. Sub-group analyses were conducted for different quadrants of the mandible, sex and tooth. Mean differences and standard deviations were used to summarize the data in the studies with continuous outcomes. Heterogeneity was assessed using the  $I^2$  statistic. A forest plot was constructed using Review Manager (Version 5.3, Nordic Cochrane Centre, Cochrane Collaboration, Copenhagen, Denmark).

#### Assessment of risk of bias in included studies

Based on the design and content of the selected studies, their quality was evaluated independently by two reviewers (SK and STS). The risk of bias assessment was not possible owing to nonavailability of clinical trials and the nature of the study. It was only possible to extract data from secondary data.

## Results

Among 94 articles, the authors selected 9 articles, including 7 studies that used a 3-D imaging modality, for further analysis. Since the review made use of secondary data, it was not possible to comment on risk of bias. The sample size ranged from 216 to 999 adults. This review identified an average mean distance of 7.3 mm (range: 0.00–14.71 mm) from the apices of mandibular first and second molars to the IAC. The mean difference (IV, fixed, 95% CI) on both sides of the mandible for first molars in women was 0.29 (95% CI: 0.11, 0.48) and for second molars was 0.50 (95% CI: -0.00, 1.01) compared with 0.31 (95% CI: 0.08, 0.54) for first molars in men and 0.23 (95% CI: -0.51, 0.98) for second molars. The proportion of women to men whose first or second molars were closely located to the IAC was 3 to 1. According to some studies, the distance was smaller in young individuals. The meta-analysis of the articles that had



**Fig. 2**  
Schematic representation of  
the article selection process.

similar characteristics and data is illustrated in **Figures 3 to 11**.

## Discussion

According to the studies in **Table 1**, the distance of the IAN from the apices of first and second molars ranged from 0.00 to 14.71 mm. The average mean distance was found to be 7.3 mm. These findings were from both 2-D and 3-D imaging techniques (**Fig. 12**). The distance varied according to factors such as sex, age and race (**Table 2**).

### Sex

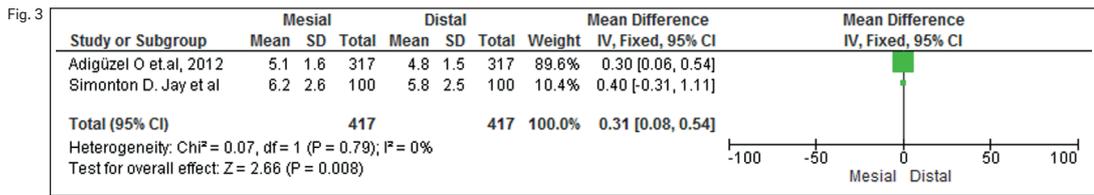
Recent studies Hiremath et al. and Adigüzel et al. considered sex as one of the factors in their studies that may influence proximity of the IAN to the apices of first and second molars.<sup>6,8</sup> These studies found that the distance from the IAN to the apices of first and second molars was smaller in women than in men.<sup>6,7</sup> Studying an Indian population, Hiremath et al. found that the distance of the mesial apices of first molars from the IAN was 1.46–13.2 mm in men and 0.93–8.03 mm in women, and for second molar,

the average distance was 1.31–14.71 mm in men and 0.00–6.90 mm in women.<sup>6</sup> A study by Adigüzel et al. on a Turkish population found that the distance from the IAN to first molars in men was 5.1 mm mesially and 4.8 mm distally and for women was 4.4 mm mesially and approximately 4.1 mm distally.<sup>8</sup> The difference in distance between men and women may be due to men generally having a larger bone structure and consequently a greater distance between apices and first and second molars.<sup>7</sup> Hence, clinically, there will be a greater possibility of iatrogenic nerve damage in women compared with men.<sup>1</sup>

### Age

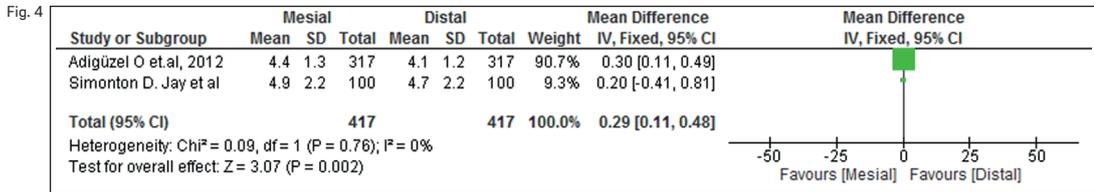
Bürklein et al. and Adigüzel et al. considered age also as a factor in their studies to determine proximity of the IAN to the apices of first, second and third molars.<sup>7,8</sup> In a study conducted on a German population, Bürklein et al. sought to determine the proximity of the IAN to the apices of mandibular first and second molars.<sup>7</sup> They found that the distance from the IAN to the mandibular first, second and third molars was smaller in patients younger than 35 years when compared with older age groups. Adigüzel et al.

No.	Author	Country	Imaging modality	Method	Result (distance in mm)
1	Hiremath et al. <sup>6</sup>	India	3-D (CS 9300, Kodak CBCT)	CBCT scans of 40 men and 40 women	Distance from IAN to mesial apex of 1 <sup>st</sup> molar: 1.46–3.23 mm (men); 0.93–8.03 mm (women) Average distance for 2 <sup>nd</sup> molar: 1.31–14.7 mm (men); 0.00–6.91 mm (women)
2	Kawashima et al. <sup>1</sup>	U.S.	3-D (i-CAT, Imaging Sciences International) at 120 kVp and 4–7 mA with 14-bit gray scale resolution and voxel size of 0.125–0.300 mm	68 men, 87 women aged 20 years and older	See <b>Table 1</b> in study
3	Chong et al. <sup>2</sup>	U.K.	3-D (PaX-Reve3D, VATECH, Ewoo Technology) operating at 3.5 mA and 85 kV; field of view for mandibular molar region was 5 × 9 × 5 cm and voxel size was 0.08 mm.	272 mandibular 2 <sup>nd</sup> molar roots evaluated from 134 CBCT scans	Distance between anatomical apex and IAN was < 3 mm
4	Bürklein et al. <sup>7</sup>	Germany	3-D (Planmeca ProMax 3D, Planmeca)	627 CBCT scans of a German population (58.2% women, 41.8% men); mean age of 51 years	Distance from IAN/IAC to 1 <sup>st</sup> molar was 4.9 mm, to 2 <sup>nd</sup> molar was 3.1 mm and to 3 <sup>rd</sup> molar was 2.6 mm
5	Tilotta-Yasukawa et al. <sup>10</sup>	France	2-D	2-D radiographic study of 35 out of 40 cases	Distance of 2 <sup>nd</sup> and 3 <sup>rd</sup> molars from mandibular canal was < 1 mm
6	Al-Jandan et al. <sup>14</sup>	Saudi Arabia	3-D	CBCT scans of hemimandibles	Horizontal distance at level of apex and IAC area at 2 <sup>nd</sup> molar: 4 mm; greater than that of 1 <sup>st</sup> molar
7	Adigüzel et al. <sup>8</sup>	Turkey	3-D (i-CAT Next Generation, Imaging Sciences International)	CBCT scans of 100 male and female patients aged 15–65 years	Distance from IAN to 1 <sup>st</sup> molar: men: 5.1 mm (mesial), 4.8 mm (distal); women: 4.4 mm (mesial), approx. 4.1 mm (distal)
8	Simonton et al. <sup>9</sup>	U.S.	3-D (Accuitomo 3DX Morita CBCT, J. Morita)	200 patients (1) Known age: 30–69 years; (2) Known sex: 25 men and 25 women were collected for each 10-year age bin (3) CBCT scans covered mandibular 1 <sup>st</sup> molar and IAN	See <b>Table 1</b> in study
9	Littner et al. <sup>11</sup>	Israel	2-D	2-D radiographic study of 46 dry mandibles	Mandibular canal was located 3.5–5.4 mm below apices of both 1 <sup>st</sup> and 2 <sup>nd</sup> molars
10	Chrcanovic et al. <sup>13</sup>	Sweden	3-D	CBCT scans of 118 subjects	1 <sup>st</sup> and 2 <sup>nd</sup> molar distance was < 6 mm



**Table 1**

Summary of the articles that were included in the review.

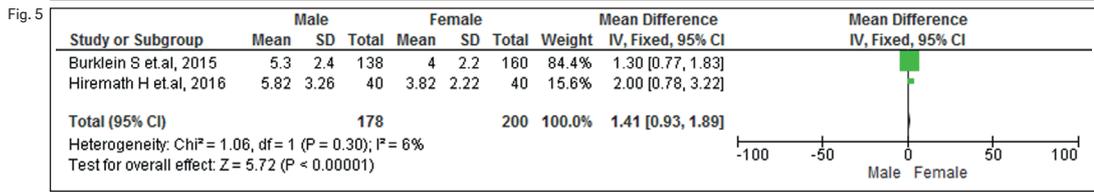


**Fig. 3**

Forest plot for the comparison of the distance of the inferior alveolar canal from the apices of first molars in men.

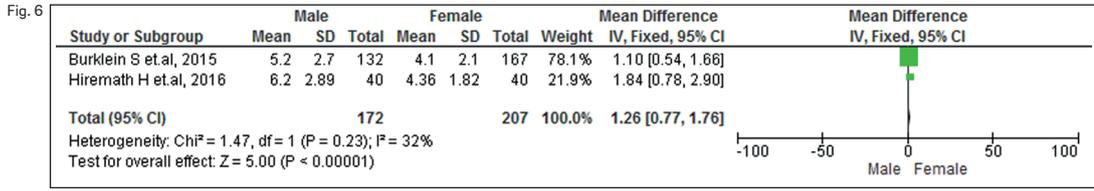
**Fig. 4**

Forest plot for the comparison of the distance of the inferior alveolar canal from the apices of first molars in women.



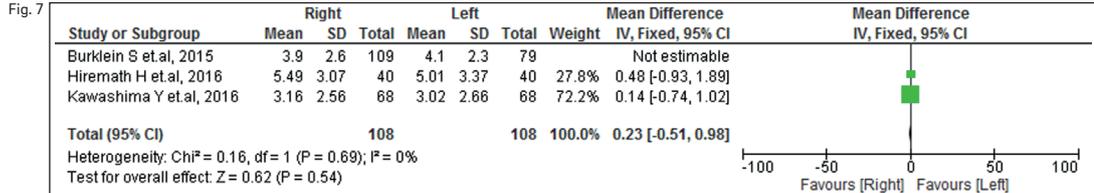
**Fig. 5**

Forest plot for the comparison of the distance of the inferior alveolar canal from the apices of left first molars in men and women.



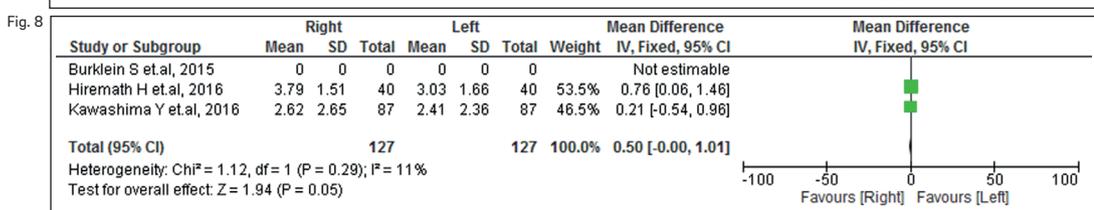
**Fig. 6**

Forest plot for the comparison of the distance of the inferior alveolar canal from the apices of right first molars in men and women.



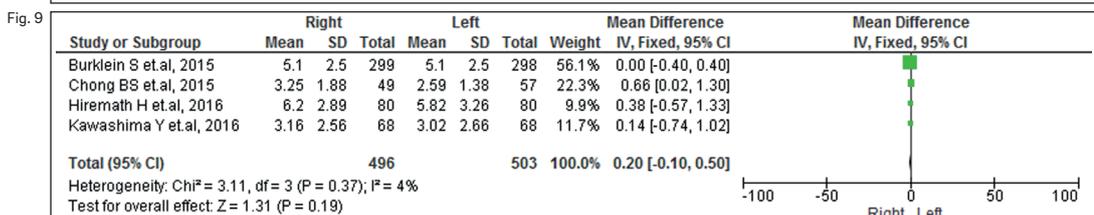
**Fig. 7**

Forest plot for the comparison of the distance of the inferior alveolar canal from the apices of second molars in men.



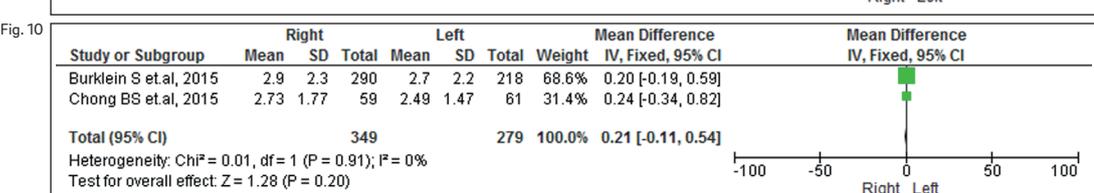
**Fig. 8**

Forest plot for the comparison of the distance of the inferior alveolar canal from the apices of second molars in women.



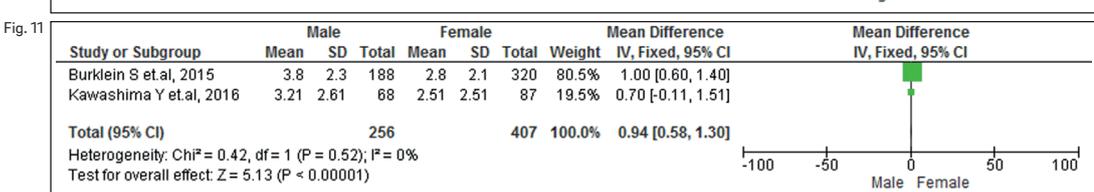
**Fig. 9**

Forest plot for right and left side.



**Fig. 10**

Forest plot for second molar distal root.



**Fig. 11**

Forest plot for comparison of differences in the distance of the inferior alveolar canal from second molars in relation to sex.

**Fig. 12**

Schematic representation of differences in distance estimated with the respective 2-D and 3-D imaging modality.

**Table 2**

Overview of the distance between the apices of mandibular first and second molars (data considered for meta-analysis).

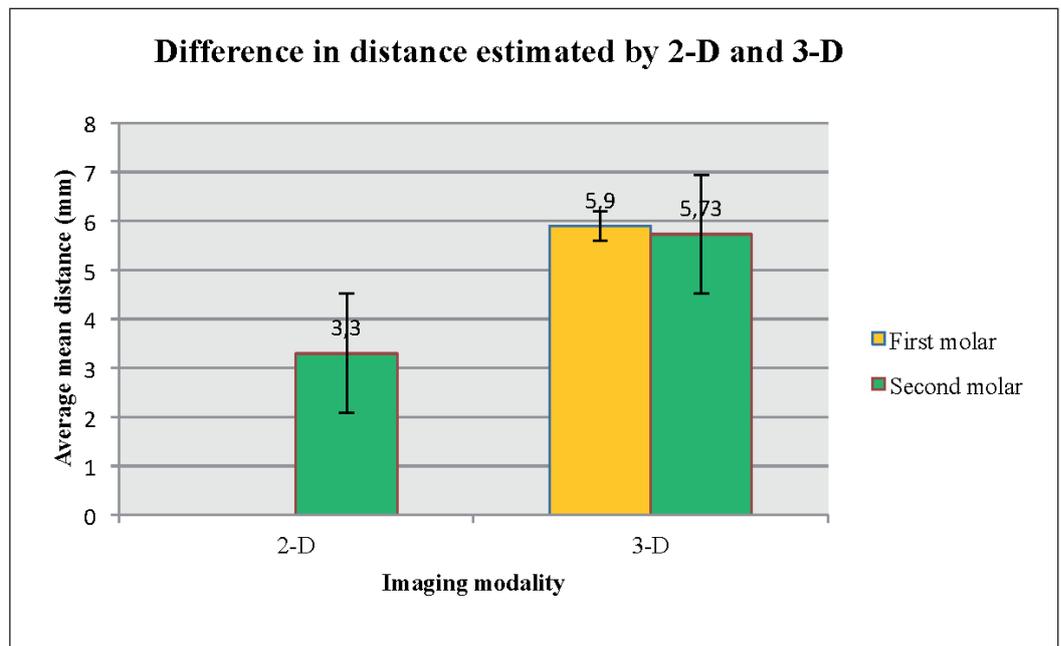


Fig. 12

concluded that the distance was smaller in the groups aged 16–25 years and 56–65 years compared with other age groups.<sup>8</sup> Previous studies have confirmed that the distance between the apices and the mandibular canal increased with eruption of mandibular teeth.<sup>11</sup> Kawashima et al. showed that there was increased bone growth after eruption of teeth and/or inferior migration of the IAC with age in both sexes.<sup>1</sup>

#### Race

Levine studied an American population and found that white patients on average had a lower distance between the buccal aspect of the canal and the outer buccal and superior cortical plates of the mandible.<sup>12</sup> They concluded that, in order to minimize the risk of IAN injury, these variables should be considered when planning mandibular osteotomies or using monocortical plates.

Hiremath et al. found that the distance from the IAN to the apices of first and second molars ranged from 0.00 to 14.71 mm in general,<sup>6</sup> and Adigüzel et al. found it to be 4.1–5.1 mm.<sup>8</sup> Chrcanovic found the distance from the IAN to first and second molars to be less than 6 mm.<sup>13</sup> Bürklein et al. showed that the distance from the IAN to first molars to be 4.9 mm, to second molars to be 3.1 mm and to third molars to be 2.6 mm.<sup>7</sup> Chong et al. demonstrated that the distance between the anatomical apex and the IAN was less than 3 mm.<sup>2</sup> Al-Jandan et al.

showed that the horizontal distance at the level of the apex and the IAC area at the second molar was 4 mm greater than at the first molar.<sup>14</sup> Alves et al. found that the distance of second and third molars from the mandibular canal was less than 1 mm.<sup>15</sup> Littner et al. suggested that the mandibular canal was located 3.5–5.4 mm.<sup>11</sup> Denio et al.'s study of dry mandibles concluded that the distance from second molars to the IAN was 3.7 mm and from first molars was 6.9 mm on 2-D radiographs.<sup>8, 16–18</sup>

Basically, there are three important processes that influence the development of the craniofacial bones: size increase, remodeling and displacement. The first two processes occur simultaneously by a combination of bone resorption and displacement. The last one results in the displacement of all the bones away from each other to undergo a size increase. The remodeling and displacement processes change and vary according to age, sex and race. These changes will have impact on the location of the IAC/IAN with respect to the apices of mandibular first and second molars.

#### Quality of evidence

The data in the first instance were derived from secondary data and the studies used varying methodologies to estimate the distance from the apices of the mandibular first and second molars to the IAC. Hence, the results obtained should be interpreted with caution.

Table 2

Type of tooth	Study	Variables	Sample size (n)	Mean ± SD	
First molar	Bürklein et al. <sup>7</sup>	Left side	Mesial	298	5.1 ± 2.5
			Male	138	5.8 ± 2.4
			Female	160	4.5 ± 2.4
		Right side	Mesial	299	5.1 ± 2.5
			Male	132	5.7 ± 2.7
			Female	167	4.6 ± 2.2
		Left side	Distal	298	4.6 ± 2.4
			Male	138	5.3 ± 2.4
			Female	160	4.0 ± 2.2
		Right side	Distal	299	4.6 ± 2.4
			Male	132	5.2 ± 2.7
			Female	167	4.1 ± 2.1
		Male	-	270	5.6 ± 2.4
		Female	-	327	4.3 ± 2.3
	-	Male	138	5.3 ± 2.4	
		Female	160	4.0 ± 2.2	
	Right side	Male	132	5.2 ± 2.7	
		Female	167	4.1 ± 2.1	
	-	-	597	4.85 ± 2.5	
	Hiremath et al. <sup>6</sup>	Left side	Male	40	5.82 ± 3.26
			Female	40	3.82 ± 2.22
Right side		Male	40	6.20 ± 2.89	
		Female	40	4.36 ± 1.82	
Adigüzel et al. <sup>8</sup>	Mesial	Male	317	5.1 ± 1.6	
		Female	317	4.4 ± 1.3	
	Distal	Male	317	4. ± 1.5	
		Female	317	4.1 ± 1.2	
Simonton et al. <sup>9</sup>	Male	Mesial	100	6.2 ± 2.6	
		Distal	100	5.8 ± 2.5	
	Female	Mesial	100	4.9 ± 2.2	
		Distal	100	4.7 ± 2.2	
Second molar	Bürklein et al. <sup>7</sup>	Left side	Mesial	218	3.5 ± 2.3
			Male	79	4.1 ± 2.3
		Mesial	Female	139	3.1 ± 2.3
			Mesial	290	3.4 ± 2.3
		Male	Female	109	3.9 ± 2.6
			Female	181	2.9 ± 2.0
		Left side	Distal	218	2.7 ± 2.2
			Male	79	3.7 ± 2.2
		Distal	Female	139	2.7 ± 2.2
			Distal	290	2.9 ± 2.3
		Right side	Male	109	3.5 ± 2.6
			Female	181	2.5 ± 1.9
		Mesial	-	508	3.4 ± 2.3
			Male	188	4.0 ± 2.4
		Female	Female	320	3.0 ± 2.2
			-	508	2.8 ± 2.3
		Distal	Male	188	3.6 ± 2.4
			Female	320	2.6 ± 2.1
	Total	-	508	3.13 ± 2.3	
	Male	-	188	3.8 ± 2.3	
	Female	-	320	2.8 ± 2.1	
	Kawashima et al. <sup>1</sup>	Male	-	68	3.21 ± 2.61
			-	87	2.51 ± 2.51
		Female	Right side	68	3.16 ± 2.56
			Left side	68	3.02 ± 2.66
		Male	Right side	87	2.62 ± 2.65
			Left side	87	2.41 ± 2.36
	Chong et al. <sup>2</sup>	Mesial	Right side	49	3.25 ± 1.88
			Left side	57	2.59 ± 1.38
		Distal	Right side	59	2.73 ± 1.77
			Left side	61	2.49 ± 1.47
	Hiremath et al. <sup>6</sup>	Male	Left side	40	5.01 ± 3.37
Right side			40	5.49 ± 3.07	
Female		Left side	40	3.03 ± 1.66	
		Right side	40	3.7 ± 1.51	

### Agreements and disagreements between studies included in the review

Adigüzel et al. and Simonton et al. used a similar methodology in determining the distance between the apices of mandibular first and second molars and the IAC.<sup>8,9</sup> These two studies used sagittal scans and intervariability tests and considered various factors that influence IAC location with respect to first and second molars. Bürklein et al. stated the inclusion and exclusion criteria.<sup>7</sup> The above-mentioned studies lack a scientific approach in determining the distance and hence, this might be a source of potential bias. Chong et al. tried to follow the principle of the Pythagoras theorem to determine the distance, which is the scientific method of determining the distance between two points.<sup>2</sup> The investigators should have considered an inter-observer reliability between two dental radiologists. The study should also have considered sex and age as factors in determining the distance.

### Conclusion

We can conclude that the average mean distance between the IAC and the apices of mandibular molars is approximately 7.3 mm. In addition to this, certain factors, such as age, sex, race, position of tooth and bone thickness, play a key role in determining the distance between the IAC and the apex. The values found are mean values and the clinical decision should be made on a case-by-case basis and the type of imaging modality used. There is significant application of CBCT in clinical outcome while treatment planning in the first and second mandibular molar region.

### Acknowledgment

We would like to thank Drs. Namitha Thomas, Natasha Shetty and Neethu for their initial participation in the review.

### Competing interests

The authors declare that they have no conflict of interest regarding the materials used in the present study. No funding was given to conduct this review.

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