Review Article

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Detection of Mandibular Incisive Canal Using CBCT and its Anatomical Relationships in Different Nationalities: A Review Study

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Abstract

Background: The Mandibular Incisive Canal (MIC) is the mesial extension of the inferior alveolar nerve, frequently encountered during surgical procedures such as implant placement and bone graft harvesting. Thorough radiographic evaluation, particularly using three-dimensional imaging modalities like Cone-Beam Computed Tomography (CBCT), is crucial to prevent nerve injury and related complications. This review summarizes studies that investigated MIC detection using CBCT.

Methods: Following the PRISMA guidelines, an electronic search was performed in PubMed/MEDLINE and Scopus, identifying 45 studies, of which 35 met the inclusion criteria. An electronic search was conducted in August 2023 using PubMed/MEDLINE and Scopus with MeSH terms and keywords: “mandibular incisive canal,” “incisive canal,” “computed tomography, cone beam,” “CBCT,” “inferior alveolar nerve,” and “mental foramen.” Relevant studies published in English up to August 28, 2023, were included.

Results: MIC was detected in 87.11% of the cases examined by CBCT. The canal was more prevalent in females (F:M =1.12:1), with a mean patient age of 45.11 years (range 10-88). The average MIC length and width were 11.30 *mm* and 1.72 *mm*, respectively. The mean distances from the MIC to the buccal cortex, lingual cortex, inferior mandibular border, and alveolar crest were 3.71, 4.98, 9.37, and 15.76 *mm*, respectively. The longest and widest MICs were observed in the Chinese population, whereas the smallest dimensions were found in the Brazilian population. MIC prevalence was highest among Malays (100%) and lowest among Indians (86.22%).

Conclusion: CBCT is a valuable tool for detecting the MIC. Careful assessment of the MIC and interforaminal region is recommended to prevent nerve injury and associated complications such as sensory disturbances and hemorrhage.

Keywords: Brazil, China, Imaging, Mandibular nerve, Mental foramen, Malaysia, Spiral Cone-Beam Computed Tomography

Introduction

The Mandibular Incisive Canal (MIC) is the mesial extension of the Inferior Alveolar Canal (IAC), housing the incisive nerve and blood vessels responsible for innervating the lower anterior teeth. The MIC is typically less corticated and smaller in diameter compared to the IAC (1-3). Some researchers propose that the incisive nerve passes through intramedullary spaces rather than a defined bony canal, making it difficult to detect using conventional imaging (4). In certain cases, the MIC is not radiographically evident due to its plexiform nature (5).

Olivier first described the anterior course of the inferior alveolar nerve within the IAC until its division at the mental foramen, where the mental nerve exits and the incisive nerve continues mesially within the MIC, parallel to the anterior teeth roots (6,7).

The interforaminal area is commonly used for procedures like implant placement and bone graft harvesting (8,9). Although traditionally considered a safe zone devoid of major anatomical structures, complications such as hemorrhage and neurosensory disturbances have been reported (10,11). Implant placement in this region may risk MIC perforation, leading to epineurium edema, sensory disturbances, paresthesia, and potential osseointegration failure (12,13).

To avoid such complications, careful evaluation of the MIC and anterior loop is essential (14,15). The anterior loop describes the mandibular canal's curvature before it opens at the mental foramen (16). While conventional radiography is widely used, its limitations in detecting the MIC and anterior loop are well-known. Cross-sectional imaging, particularly CBCT, allows precise identification of these structures (17,18). Although ultrasound may provide information on the mental foramen, it lacks the diagnostic accuracy of CBCT (19,20).

This review investigates the MIC's anatomical characteristics and its clinical significance, emphasizing variations across populations to aid in preventing surgical complications.

Materials and Methods

An electronic search was conducted in August 2023 using PubMed/MEDLINE and Scopus with MeSH terms and keywords: "mandibular incisive canal," "incisive canal," "computed tomography, cone beam," "CBCT," "inferior alveolar nerve," and "mental foramen." Relevant studies published in English up to August 28, 2023, were included. Manual cross-referencing supplemented the search. After screening 361 studies, 249 were shortlisted based on titles and abstracts. Studies focusing solely on panoramic imaging or cadaveric assessments were excluded (1,7,21). After full-text review, 35 studies met the inclusion criteria (Figure 1).

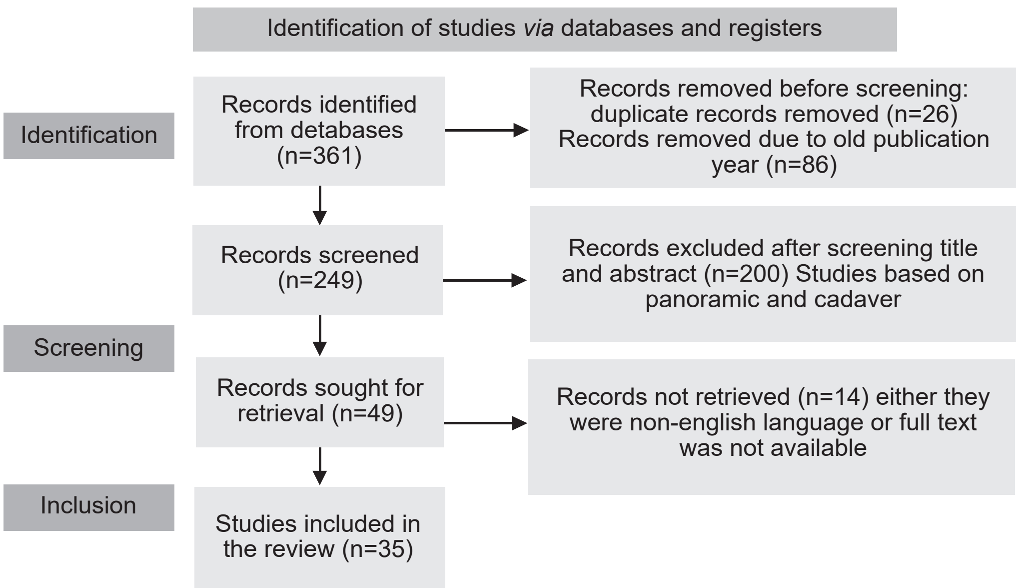

Figure 1. Flowchart showing the step-by-step identification of the studies *via* databases.

Data collected included

- Study authors and year
- Sample size
- Patient demographics (sex and age)
- MIC prevalence
- CBCT device, software, and slice thickness used
- Patient ethnicity
- MIC mean length and width
- Distances from MIC to anatomical landmarks

Statistical analysis used means for continuous variables and percentages for categorical data. Quality assessment was independently conducted by two reviewers, with a third resolving disagreements.

Results

Study selection

Thirty-five studies assessing the MIC *via* CBCT (published between 2009 and 2023) were included. Study characteristics are detailed in tables 1 and 2.

Demographics

MIC was observed in both sexes, with a higher prevalence among females (F:M=1.12:1). The mean age was 45.11 years (range 10–88) and sample sizes ranged from 50 to 1008.

CBCT examination details

Twelve CBCT units (*e.g.*, *i-CAT*, *NewTom*) and 14 software platforms were employed, with slice thicknesses varying from 0.01 *mm* to 1 *mm* (mean 0.5 *mm*). Imaging parameters like *kVp* (60-120) and *mA* (1-36) varied across studies.

Ethnic variations

MIC prevalence differed across ethnicities, ranging from 83.1% (Americans) to 100% (Malays). Chinese subjects had the longest (12.96 *mm*) and widest (2.5 *mm*) canals, while Brazilian populations had the smallest measurements.

Table 1. Reported articles of MIC presence and its characteristics in various ethnicities in the literature up until August 2023

Paper	Year	Patients	Age (yrs)	Incisive canal presence in BCT	CBCT and Applied *kVp*	Software	Slice thickness	Race	CBCT recommendation	Canal location	Mean length of MIC
Makris *et al* 22	2009	100 M=48 F=52	10-80 Mean =54.9	83.5%	NewTom -	Newtom software	-	-	✓	Buccal	15.13
Pires *et al* 23	2009	89 F=51 M=38	-	83.1%	i-CAT 120 *kVp*	-	-	American	-	-	7±3.8
Parnia *et al* 24	2012	96 M>F	20-77 M= 46.60	83%	Planmeca Promax -	Romexis	1 *mm*	-	-	-	-
Al-Ani *et al* 25	2012	60	18-80	100%	i-CAT 120 *kVp*	SimPlant	-	Malay Indian Chinese	✓	Buccal	-
Dalili *et al* 14	2012	84 M=41 F=43	13-77 Mean =49	92.3% M=F R=L	NewTom	-	*1 mm*	Iranian	-	Buccal	-
Orhan *et al* 12	2013	356 F=190 M=166	25-83 Mean =47.6	91%	NewTom 120 *kVp*	NNT	*0.3 mm*	Turkish	-	Buccal	12.4 M>F
Yovchev *et al* 26	2013	140 F=70 M=70	18-79 Mean =46.6	92.9% Unilateral =24.2 Bilateral =68.6	ILUMA	Kodak dental imaging	-	-	-	-	-
Rosa *et al* 27	2013	352 M=129 F=197	-	97%	i-CAT	i-CAT Vision	*0.5 mm*	Brazilian	✓	lingual	9.11 ±3.0

Contd. table 1.

Sahman *et al* 28	2014	243 F=131 M=113	-	94.4%	NewTom	NNT	-	Turkish	✓	-	-
Raitz *et al* 29	2014	150 M=75 F=75	-	90% R>L	i-CAT	-	*0.25 mm*	-	✓	-	-
Pereira-Maciel 30	2015	100 F=63 M=37	20-80 Mean =50.2	100%	i-CAT 120 *kVp*	iCAT software	-	Brazilian	✓	Buccal	9.8 ±3.8 L=R M=F
Ramesh *et al* 31	2015	120	30-50	71.66% Unilateral =23.33 Bilateral =48.33	Planmeca 90 *kVp*	Planmeca romexis	-	Indian	-	-	10.17 ±4.68
Panjnoush *et al* 10	2015	200 F=110 M=90	48.78± 13.65	97.5%	Planmeca	Planmeca romexis	*0.1 mm*	Iranian	✓	Buccal	R=10.4 8±4.53 L=10.40 ±4.52 M= 10.44
De brito *et al* 32	2016	90 M=56, F=34	15-76 Mean =26.3	24.4 % M=F R>L	i-CAT	i-CAT vsion	0.25 *mm*	-	✓	-	-
Kong *et al* 33	2016	50 M=25 F=25	18-42 Mean =29.82 ±7.0	100%	Newtom	-	-	Han chinese	-	Buccal	L=17.84 R=17.73 M=17.78
Kabak *et al* 16	2016	100 M=53 F=47	15-72 Mean= 38.3± 14	92%	Galileos GAX5	-	-	Belarusian	✓	-	-
Sakhdari *et al* 15	2016	200 M=100 F=100	21-68 Mean =47	87.5%	NewTom	NNT	1 *mm*	Iranian	✓	-	-
Haghanifar *et al* 34	2017	207 M=97 F=110	45.7± 13.83		Cranex 3D	On demand	1 *mm*	Iranian	✓	-	-
Isik *et al* 17	2017	430 M=185 F=245	15-86 Mean =47.14	89.1%	J.Morita	I-Dixel	-	Turkish	✓	-	-
Sener *et al* 35	2017	70		74.3%	Kodak 9000 3D	Kodak	-	Turkish	-	-	-
Gomes *et al* 8	2018	100 M=50 F=50	27-73	78% F>M	i-CAT	Dental slice	0.01 *mm*	-	✓	Buccal	19.9 ±0.4 M>F
Lim *et al* 1	2018	100 M=47 F=53	18-80	-	KaVo	eXam vision	-	Chinese malay indian	✓	Buccal at start, lingual at end	11.31 ±2.65 Malays> chinese> indians
Valizadeh *et al* 19	2018	256 M=123 F=133	>18	100%	NewTom	-	-	-	-	-	7.15
Xie *et al* 36	2019	1008 F=487 M=521	>18 M=41.1 ±14.81	87% ?	Newtom VG 110 *kVp*	NNT viewer	-	Chinese	-	-	9.46

Contd. table 1.

Zhang *et al* 11	2019	535 F=308 M=227	17-88 Mean =36	92.8% M>F	Newtom	NNT	0.5 *mm*	Chinese	-	-	13.4 ±3.3
Malusare *et al* 9	2019	150	-	87%	Kodak CS	CS software	-	Indian	✓	-	R=13.4 L=12.4 M=12.9
Gilis *et al* 37	2019	50	20-83 Mean =48	99%	Planmeca promax	Romexis	0.2 *mm*	-	✓	-	6.65 ±4.1
Ghonche *et al* 38	2019	103 M=39 F=64	20-80 Mean =53.18 ±14.4	90% Bilateral =68% Unilateral =22%	Newtom	NNT	-	Iranian	✓	Buccal (at the initiation point)	7.3 *mm* R>L
Ayesha *et al* 39	2019	80 M=F	20-60 (18-80)?	43.89% L>R	Scanora 3D	On Demand3D scanora3D	-	-	-	-	-
Ferreira barbosa *et al* 40	2020	847 Bilateral =493 Unilateral =153	18-69	76.3% F>M Mainly 4th to 6th decades	CS9000 3D gendex CB500 i-CAT next i-CAT classic	Carestream 3D	-	-	✓	-	7.7 *mm* M>F L=R
Ramaswamy *et al* 4	2020	100 F=54 M=46	20-70	-	Carestream	-	-	Indian	✓	Buccal	F=13.43 ±3.03 M=13.93 ±4.18 Mean =13.68
Alshamrani *et al* 41	2021	93	18-50	96.8% L>R	Planmeca promax	Romexis	-	Saudi arabian	✓	-	-
Martins *et al* 42	2022	50 F=33 M=17	14-74 Mean =38?	100% ?	i-CAT 120 *kVp*	Blue Sky plan	-	North brazilians		-	-
Nikkerdae *et al* 3	2022	378 M=185 F=193	14-75 Mean =47.08 ±12.6	97.62% R=L	Newtom	NNT	0.5 *mm*	Iranian	✓	Buccal	R=12 ±3.29 L=12.21 ±3.38 M=12.1
Nasher *et al* 5	2023	180 M=74 F=106	16-80	95.6% F>M R=L	Vatech	Ez3D	0.5 *mm*	Yemeni	✓	Buccal	12.74 ±4.4

Table 1. Reported articles of MIC presence and its characteristics in various ethnicities in the literature up until August 2023

Width of MIC (diameter)	Distance A*	Distance B	Distance C	Distance D	Distance E	Distance F	Distance G	Distance H	Distance I	Distance J	Distance K	Distance L
	M =3.59 ±1.03	M =5.65 ±1.7	M =11.15 ±1.76	-	M=4.8 ±1.7	M=5.6 ±1.6	M=9.4 ±1.7	-	-	-	11.5	-
	2.2 ±1.1		10.4 ±2.3	-	3.3 ±1.7	5.2±2	10.1 ±2.5	-	2.4	-	10.2 ±2.4	-

Contd. table 1.

1.47 ±0.50	-	-	-	-	-	-	-	-	3.48 ±1.17	4.46 ±1.40	8.72 ±1.43	-
-	-	-	-	-	-	-	-	-	3.15 ±1.28	4.78 ±2	9.86 ±2.51	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	10.5	-
-	-	-	-	-	-	-	-	-	-	-	-	-
1.48 ±0.66	-	-	-	-	-	-	-	-	-	-	-	-
R=1.9 ±0.45 L=1.9 ±0.41 M=1.92	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	4.62 ±1.41	6.25 ±2.03	7.06 ±2.95	10.25 ±2.27
2.57 ±0.40	1.48 ±0.22	4.46 ±0.26	9.42 ±0.77	-	4.47 ±0.35	5.56 ±0.69	9.09 ±0.65	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	M =2.97 ±0.83	M=5.25 ±1.52	M=9.92 ±1.64	M=17.86 ±2.60	M=4.21 ±1.22	M=5.96 ±1.66	M=11.50 ±3.92	M=17.72 ±4.17	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
2.04 ±1.1	-	-	-	-	-	-	-	-	-	-	-	-
R=1.12 ±0.31 L=1.06 ±0.28 M=1.09	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-		-	-	-	-
1.4 ±0.1 M=F	-	-	-	-	-	-	-	-	4	6.2	10	-
-	M =3.76 ±1.11	M=6.63 ±1.51	-	-	M=5.89 ±1.70	M=4.72 ±1.61	-	-	5.06	5.47	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-
2.5 ±0.5	-	-	-	-	-	-	-	-	3.7 ±0.9	5.1 ±1.6	8.9 ±1.7	19.5 ±3.8
-	-	-	-	-	-	-	-	-	-	-	-	-
-	2.16 ±1.21	5.56 ±1.98	10.33 ±1.98	16.14 ±5.76	-	-	-	-	-	-	-	-
R=1.19 ± 0.48 L=1.29 ±0.93 M=1.24	-	-	-	-	-	-	-	-	-	-	-	-

Contd. table 1.

-	-	-	-	-	-	-	-	-	4.33 ±1.47	4.34 ±1.53	9.41 ±1.83	-
-	M =2.6 ±1.27	M=5.13 ±1.7	M=9.32 ±1.92	M=16.37 ±5.90	M=3.96 ±1.43	M=4.61 ±1.65	M=8.76 ±2.07	M=18.60 ±3.51	-	-	-	16.63 ±7.98
F=1.74 ±0.40 M=1.94 ±0.58 Mean =1.84	-	-	-	-	-	-	-	-	F=3.56 ±1.01 M=4.01 ±1.13 Mean =3.78	F=4.01 ±1.13 M=4.33 ±1.51 Mean =4.17	F=6.94 ±1.65 M=8.53 ±1.55 Mean =7.7	-
-	-	-	-	-	-	-	-	-	4.88	5.54	9.94	-
1.29 ?	3.15 ±1.27	5.41 ±1.80	8.95 ±2.41	-	-	-	-	-	-	-	-	-
R=1.89 ±0.46 L=1.94 ±0.45 M=1.91	-	-	-	-	-	-	-	-	R=2.08 ±0.94 L=2.15 ±1.02 M=2.11	R=4.18 ±1.52 L=4.14 ±1.54 M=4.16	R= 9.68 ±1.95 L= 9.37 ±1.65 M=9.52	-
1.66 ±0.44	-	-	-	-	-	-	-	-	3.12 ±1.09	4.35 ±1.5	8.61 ±1.9 *mm*	16.77 ±4.06

*Distance A: Distance of the initial portion of the Mandibular Incisive Canal (MIC) to the buccal table.
Distance B: Distance of the initial portion of the Mandibular Incisive Canal (MIC) to the lingual table.
Distance C: Distance of the initial portion of the Mandibular Incisive Canal (MIC) to the inferior mandibular border.
Distance D: Distance of the initial portion of the Mandibular Incisive Canal (MIC) to the alveolar canal.
Distance E: Distance of the final portion of the Mandibular Incisive Canal (MIC) to the buccal table.
Distance F: Distance of the final portion of the Mandibular Incisive Canal (MIC) to the lingual table.
Distance G: Distance of the final portion of the Mandibular Incisive Canal (MIC) to the inferior mandibular border.
Distance H: Distance of the final portion of the Mandibular Incisive Canal (MIC) to the alveolar canal.
Distance I: Distance of the Mandibular Incisive Canal (MIC) to the buccal table.
Distance J: Distance of the Mandibular Incisive Canal (MIC) to the lingual table.
Distance K: Distance of the Mandibular Incisive Canal (MIC) to the inferior mandibular border.
Distance L: Distance of the Mandibular Incisive Canal (MIC) to the alveolar canal.

Table 2. Demographic characteristics and variables of the articles

Variables	Outcome		
Sex	F>M F=53% (3064) M=47% (2692) F/M:1.12		
Age	10-88 years Mean:45.11		
MIC presence in CBCT	87.11% (24.4-100)		
Mean length of MIC (*mm*)	11.30(6.65-19.9)		
Mean width of MIC (*mm*)	1.72(1.09-2.50)		
Distance of the MIC to buccal cortex (*mm*)	3.71(2.11-5.06)	Initial portion	2.73
		Final portion	4.43
Distance of the MIC to lingual cortex (*mm*)	4.98(4.16-6.25)	Initial portion	5.34
		Final portion	5.27
Distance of the MIC to inferior mandibular border (*mm*)	9.37(7.06-11.5)	Initial portion	9.92
		Final portion	9.77
Distance of the MIC to alveolar crest (*mm*)	15.76(10.2-19.5)	Initial portion	16.79
		Final portion	18.16

Mandibular Incisive Canal (MIC).

Table 3. Ethnic characteristics and variables of the studies

	America	Belarus	Brazil	Chinese	Indian	Iranian	Malaysia	Saudi arabia	Turkish	Yemen
MIC presence (%)	83.1	92	99 (97-100)	93.26 (87-100)	86.22 (71.66-100)	92.98 (87.5-97.62)	100	96.80	87.2 (74.3-94.4)	95.6
MIC length (*mm*)	7	-	9.45	12.96	12.01	9.94	11.31	-	12.40	12.74
MIC width (*mm*)	-	-	1.38	2.50	2.20	1.57	-	-	1.92	1.66
MIC to buccal (*mm*)	2.40	-	4.62	3.97	3.99	2.10	4.10	4.88	-	3.12
MIC to lingual (*mm*)	-	-	6.25	5.11	4.80	4.16	5.12	5.54	-	4.35
MIC to inferior alveolar (*mm*)	10.20	-	7.06	9.38	8.78	9.52	9.86	9.94	10.5	8.61
MIC to alveolar (*mm*)	-	-	10.25	19.5	-	-	-	-	-	16.70

Mandibular Incisive Canal (MIC).

MIC prevalence

The average MIC prevalence was 87.11% (range 24.4-100%). CBCT was consistently recommended for preoperative assessment. Buccal canal positioning was most common, with a single study reporting a lingual position.

Anatomical variations

The average MIC length was 11.30 *mm* and the diameter 1.72 *mm*. Mean distances from the canal to anatomical landmarks were:

- Buccal cortex: 3.71 *mm*
- Lingual cortex: 4.98 *mm*
- Inferior mandibular border: 9.37 *mm*
- Alveolar crest: 15.76 *mm*

Measurements varied between the initial and terminal portions of the MIC.

Discussion

The MIC is a critical anatomical structure extending from the IAC, housing neurovascular elements supplying the anterior mandible. First documented in 1928 (6), its presence was later corroborated by anatomical and radiographic studies (1,43). CBCT has significantly improved MIC visualization (8). Anatomical assessments on cadavers have detected MIC in up to 90% of the cases (5,7).

Typically, the MIC courses inferiorly and lingually from the mental foramen, become indistinct near the central incisors as it merges into a neurovascular plexus (29,40). This plexus facilitates midline cross-innervation. The incisive nerve is now considered a prominent structure rather than a mere anatomical variation (22).

Detection rates vary due to ethnic differences, imaging methods, and examiner expertise (32). Prevalence ranged from 24.4 to 100% (19), with Malays showing the highest and Indians the lowest detection rates (2,4,9,25,31). Visibility is influenced by factors like canal cortication, age-related bone changes, and skeletal development (40,44).

While some studies reported no sex-based difference in MIC prevalence (14,15,22,26,29,39), others noted a higher prevalence in females or males, particularly among Chinese cohorts (36). Laterality also varied, with some studies showing right-side dominance (29,32), others left-side (39,41), and some reporting bilateral symmetry (3,5,14). Bilateral presentation was generally more common (26,31,38).

Most studies identified a buccal canal position, although a Brazilian study noted lingual placement (27). Implant placement should account for MIC location to prevent complications (3,33). Ethnic, age, and sex differences underline the need for preoperative CBCT (40).

Accurate measurements of MIC dimensions and positions are vital for safe surgical planning. Direct trauma may cause sensory disturbances; indirect trauma (*e.g.*, hematoma) may exert pressure on the nerve (1). Implants near the MIC can cause neurosensory damage, edema, and osseointegration failure. Arterial injury within the MIC can result in severe bleeding during surgery (12).

A MIC diameter exceeding 2 *mm* may impair implant stability and increase complication risks (14,23). The average MIC diameter in studies was 1.72 *mm*, with larger diameters noted in Chinese and Indian populations.

Panoramic radiography underestimates MIC detection due to inherent limitations like distortion (46). CBCT, with superior cross-sectional imaging, provides reliable preoperative assessment (33). High-resolution MRI has been proposed for detailed analysis but remains impractical due to cost and availability (33). CBCT remains the recommended tool for identifying the MIC.

Conclusion

Given its high prevalence, clinicians should recognize the MIC's anatomical significance to prevent nerve injury, sensory disturbances, and intraoperative bleeding. With an 87.11% detection rate, CBCT is invaluable for mapping the MIC, anterior loop, and mental foramen. The variability among populations underscores the necessity of individualized CBCT assessment before interforaminal surgical interventions. Further research is essential to better understand anatomical variations and optimize patient outcomes.

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Conflict of Interest

There was no conflict of interest in this manuscript.

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