Prevalence and Morphology of Mandibular Incisive Canal: Comparison among Healthy, Periodontitis and Edentulous Mandibles in a Population of the Beijing Area Using Cone-beam Computed Tomography

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Objective: *To evaluate and quantify the prevalence and morphology of the mandibular incisive canal (MIC) comparatively among healthy, periodontitis and edentulous mandibles using cone-beam computed tomography (CBCT).*

Methods: *CBCT images of 1,070 hemimandibles from 535 consecutive patients, including 448 with healthy dentition, 42 with severe periodontitis mandibles and 45 with edentulous mandibles, were retrospectively analysed. MICs were identified, and linear measurements were performed. Statistical analyses were conducted to investigate differences in the prevalence and morphology of MICs relative to gender, laterality, age group and dental status.*

Results: *The MIC was observed in 92.8% of 1,070 hemimandibles. No significant differences of MIC prevalence were found between left and right sides, or between healthy and periodontitis mandibles. However, males had a higher prevalence of MIC than females, and patients with dentate mandibles had a higher prevalence of MIC than those with edentulous mandibles. For dentate mandibles, MICs started most commonly below the first premolar (51.9%) and ended around the canine (58.5%). The mean diameter of MIC was 2.5 ± 0.5 mm at origin, and 20.6% of MICs began with a diameter of ≥ 3 mm. The mean length of MIC was 13.4 ± 3.3 mm. The mean distances from the MIC to the labial cortex, lingual cortex, alveolar ridge and inferior border of mandible were 3.7 ± 0.9, 5.1 ± 1.6, 19.5 ± 3.8 and 8.9 ± 1.7 mm, respectively. Moreover, significant differences of measurements were found relative to gender, age group, and dental status.*

Conclusion: *Due to the large variations in size and course of MICs, special caution should be exercised in any individual surgery affecting the anterior mandible.*

Key words: *mandibular incisive canal, dentate mandible, edentulous mandible, cone-beam computed tomography*

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The mandibular incisive canal (MIC) is described as the terminal branch of the mandibular canal, which continues its intraosseous pathway into the mandibular anterior region, and plays an important role in the sensation and nutrition of the mandibular anterior teeth[1,2]. In the past, the mandibular interforaminal region was recognised as a safe area for performing oral surgical procedures. However, more and more case reports showed various postsurgical complications in this area[3-5]. Injury of the neurovascular bundles was the most common complication of surgical procedures such as intraosseous implant placement, genioplasty in orthognathic surgery and bone grafting from chin and trauma surgery. Damage of neurovascular bundles can cause haemorrhage,

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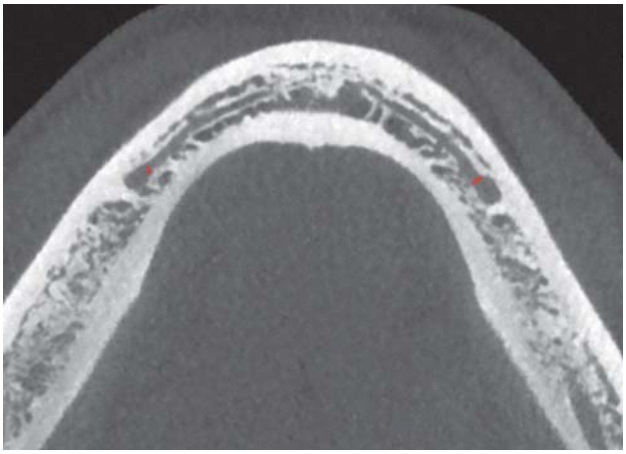

Fig 1 The origins of the mandibular incisive canal (MIC) are marked with red bars. Note the sudden reduction of the width of the mandibular canal on the axial view.

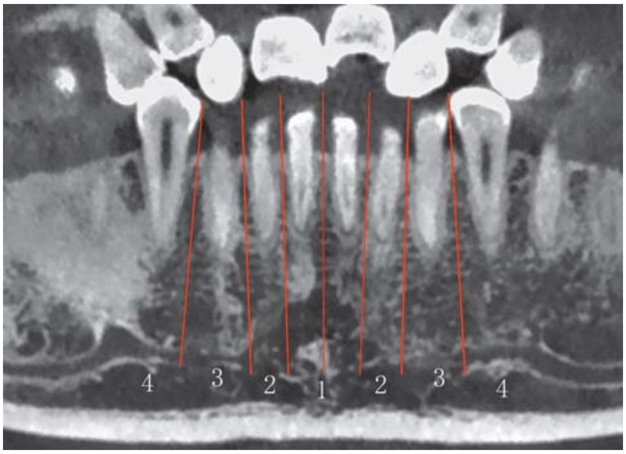

Fig 2 The terminus sites are recorded as premolar (4), canine (3), lateral incisor (2), and central incisor (1) according to the corresponding tooth position and its mesial and distal interdental bone space. In this case, the mandibular incisive canal (MIC) ended at the lateral incisor on right side.

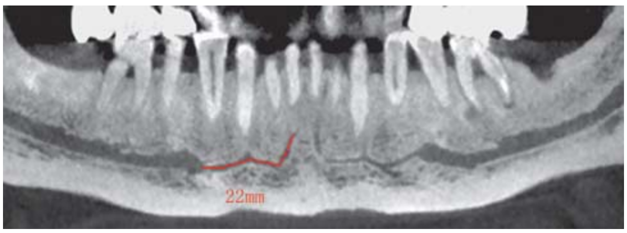

Fig 3 Panoramic view of the mandibular incisive canal (MIC) in a periodontitis mandible. The bilateral MICs symmetrically originated from the first premolar region and ended at the inferoapical region of the central incisor. The right MIC was traced with a red line of 22 mm length.

tingling sensation or paraesthesia, resulting in surgical failure[6]. Therefore, an accurate determination of the mandibular incisive canal is paramount to all concerned clinicians. Cone-beam computed tomography (CBCT) has advantages over conventional radiographs in displaying these tiny mandibular structures[7], facilitating an accurate measurement of MICs. According to a previous CBCT study[8], the prevalence of MIC ranged distinctly from 71% to 100%, the diameter of MIC from 0.45 to 4.12 mm, and the length of MIC from 6.6 to 40.3 mm. Large variations in data from previous studies may be explained by differences in ethnic backgrounds, sampling sizes, image resolutions, and specifications of anatomic structures. In China, the prevalence of MIC has been reported in the population of southeastern China[9,10]. Nevertheless, no studies with a large sample size and high-resolution scans have been conducted so far with regard to the characteristics of MIC in the population of the Beijing area, which represents a large and densely populated region of northern China. Furthermore, reports concerning MIC morphology among patients with severe periodontitis, as well as those with edentulous mandibles, are scarce in the literature. The purpose of this large sample sized study was to assess the size, length and spatial path of MIC comparatively among healthy, periodontitis and edentulous mandibles in vivo.

Materials and methods

Subjects

CBCT images of patients who presented at our imaging centre, at the Peking University School and Hospital of Stomatology, from July 2017 to July 2018, were retrospectively collected and evaluated. Patients fulfilling the following criteria were enrolled:

Inclusion criteria

- Age ≥ 16 years;
- Cases with complete and healthy dentition (the third molar as an exclusion) for the healthy group, and cases without a tooth left for the edentulous group and cases with ≥ 50% bone loss of the bone height of the anterior mandibular teeth for the periodontitis group;
- Scans with a field of view of at least 12 × 8 cm;
- High-quality images without motion artefacts.

Exclusion criteria

- Presence of orthodontic or surgical intervention in the interforaminal region;
- Presence of tumoral lesions, cleft lip and palate, or systemic diseases that might have affected the skeletal structures of maxillofacial region.

In total, CBCT images of 535 patients with 1,070 hemi-mandibles were collected. There were 227 males and 308 females (mean age 36 years, range from 17 to 88 years). They consisted of 448 patients with healthy dentition, 42 with severe periodontitis mandibles and 45 with edentulous mandibles. The 448 patients with healthy dentition were divided into six age groups: ≤ 20; 21-30; 31-40; 41-50; 51-60; and ≥ 61 years.

Evaluation of the origin and terminus of MIC at the anterior mandible using CBCT images

The CBCT images were obtained using NewTom VGi (QR s.r.l, Verona, Italy) with the following exposure settings: 110 kV, automatic mA, and 5.5 s pulsed exposure. A voxel size of 200 µm was applied. The NNT software (version 4.00.1, Verona, Italy) was used for data analysis according to the manufacturer's instructions. All images were displayed on an 18.7-inch monitor with screen resolution set at 1546 × 2048 pixels (Dome E3; NDS Surgical Imaging, San Jose, CA, USA). For visualisation of the origin and terminus of the MIC, all CBCT images were separately assessed by two oral radiologists. Both of them had more than 5 years' experience with CBCT imaging and were initially calibrated by examination of 10% of the cases. The two observers recorded their responses on a dichotomous scale (with/without MIC). Four weeks after independent evaluation, both observers compared their findings through discussion, until a consensus was reached. At this stage, the *k* coefficient was calculated to determine the reliability of image evaluations by the two observers.

The origin and course of mandibular incisive canals were carefully observed under free angulation of three-dimensional (3D) slices on multiplanar reconstruction images, together with 0.5 mm thickness and distance of multiplanar panoramic reconstructed views. Axial images were reoriented to make the axial slices parallel to the occlusal plane and to ensure symmetry prior to secondary reconstruction of each subject. The origin of the MIC was an anterior extension of the mandibular canal before it turned upward and backward to form the mental foramen (often as the anterior loop), which displayed a sudden reduction of the width (Fig 1). Moreover, only the presence of a continuous rounded radiolucent canal defined by intensive thin cortical lines was recorded as an existence of MIC. For each patient, the entire course of MIC was carefully traced in 3D CBCT slices, and the origin and terminus site were labelled according to the corresponding teeth. The origin sites were classified as: second premolar, between first and second premolar, first premolar, and between first premolar and canine. The terminus sites were recorded as premolar, canine, lateral incisor, and central incisor, each representing the corresponding tooth position and its mesial and distal interdental bone space (Fig 2).

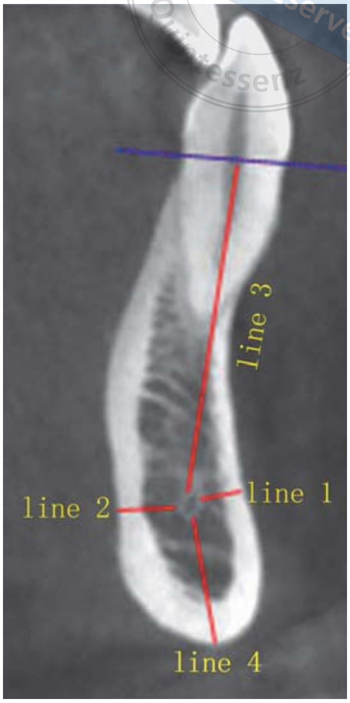

Fig 4 Spatial distances of the mandibular incisive canal (MIC). The horizontal distances from the MIC to the labial and lingual cortex were measured via line 1 and line 2, respectively. Line 3 and line 4 were used for the measurements of the vertical distances from the MIC to alveolar ridge and the inferior border of the mandible.

Measurements of the diameter, length and sagittal position of MIC

The diameters of the MIC at origin and terminal sites were measured by the mean value of the vertical and horizontal diameter in the cross-sectional slices. Meanwhile, lengths were calculated on the reconstructed panoramic views from its origin to disappearance of the corticated canal (Fig 3). For the dentate mandibles, horizontal distances from the MIC to the labial and lingual cortical borders of the mandible, and the vertical distances from the MIC to alveolar ridge and the inferior border of the mandible were measured at the terminal site, as well as at the canine, lateral incisor and central incisor respectively (Fig 4). For the edentulous mandibles, these distances were calculated at terminal site. All measurements were recorded twice by the same observer and mean of these values were used for analysis.

All measurements of the MIC were recorded relative to gender, laterality, age group and dental status.

Table 1 Mandibular incisive canal (MIC) prevalence by sex, laterality and dental status.

Factors		Visible	Invisible	*P*
Sex	Male	430 (94.7%)	24 (5.3%)	0.038
	Female	563 (91.4%)	53 (8.6%)	
laterality	Right	496 (92.7%)	39 (7.3%)	0.906
	Left	497 (92.9%)	38 (7.1%)	
Periodontal status	Healthy	839 (93.6%)	57 (6.4%)	0.780
	Periodontitis	78 (92.9%)	6 (7.1%)	
Dental status	Dentate	917 (93.6%)	63 (6.4%)	0.001
	Edentulous	76 (84.4%)	14 (15.6%)	

Statistical analysis

Statistical analyses were conducted using SPSS (version 22.0, SPSS, Chicago, USA). Chi-square tests were used to investigate the incidence, as well as the start and end point of the MIC relative to gender, laterality, dental status, and age groups. The student *t* test was used to compare the differences in measurements of diameters, lengths, and distances to mandibular borders relative to laterality, gender, dental status. The one-way ANOVA was conducted to compare the differences of these values among age groups when it came to be Gaussian distribution, otherwise, the Kruskal-Wallis H test was used. When there were significant differences, post-hoc multiple comparisons tests were conducted. The correlation between the beginning diameter and length was conducted using the Pearson's correlation. Differences were considered significant for P values < 0.05.

Results

Prevalence

The MICs were clearly visualised in 92.8% of 1,070 hemimandibles. No significant differences were found between left and right side ($P = 0.906$), or between healthy and periodontitis mandibles ($P = 0.780$). However, males had a higher incidence of MIC than females ($P = 0.038$), and dentate mandibles had a higher incidence of MIC than edentulous mandibles ($P = 0.001$) (Table 1). With respect to dichotomous evaluations, the *k* coefficient between the two observers was 0.82.

The origin and terminus site of the MIC in dentate mandibles

As for the dentate mandibles, the origin and terminus sites of the MIC relative to adjacent teeth are shown

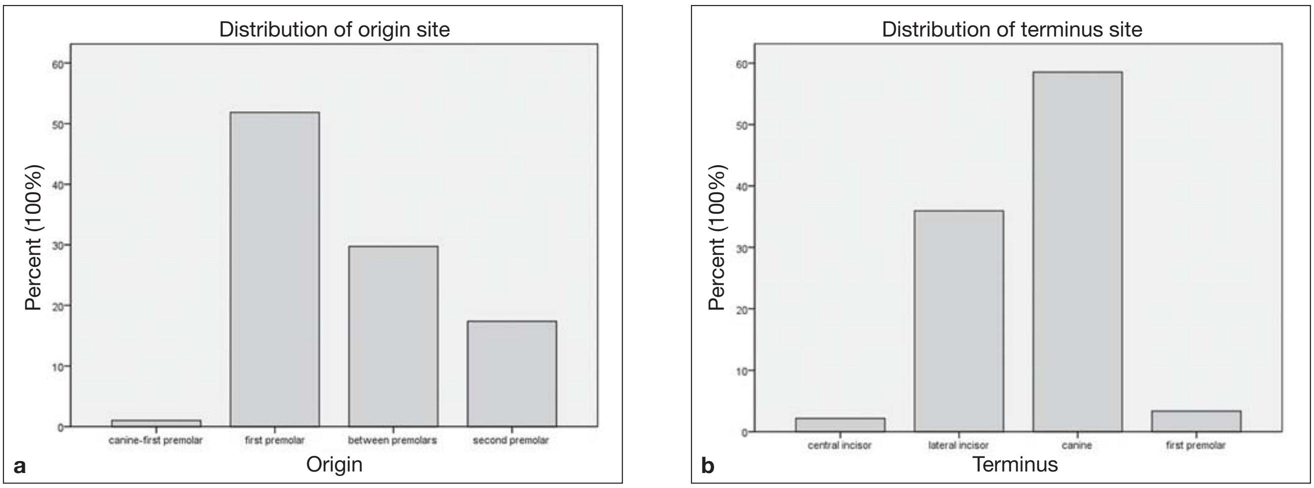

Fig 5 The distribution of the origin and terminus site of the mandibular incisive canal (MIC) relative to adjacent teeth (%). **(a)** Origin. **(b)** Terminus.

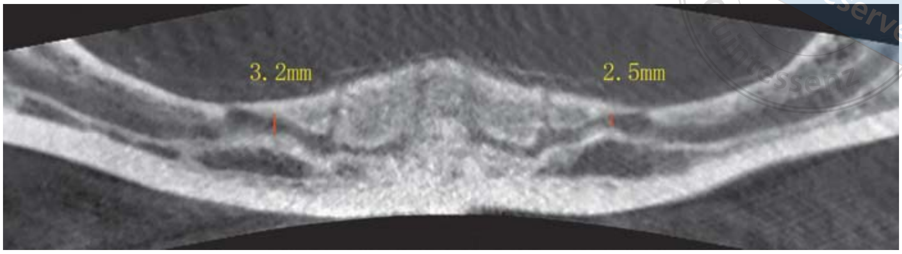

Fig 6 Panoramic view of the mandibular incisive canal (MIC) in an edentulous mandible. Note the impressively beginning diameter of the MICs (3.2 mm on the right side and 2.5 mm on the left side, red bars), and four median-sized branch canals running till the alveolar crest.

in Figure 5. 51.9% of the MICs originated below the first premolar root, followed by between the first and second premolar (29.7%), second premolar (17.4%) and between first premolar and canine (1%). 58.5% of the MICs ended around the canine root, followed by the lateral incisor (36.0%), first premolar (3.3%) and central incisor (2.2%) (Fig 3). Only in one case, the MIC was found to pass through the symphysis area.

No significant differences of distributions of the origin and terminus site were found relative to laterality ($P = 0.595$) and gender ($P = 0.405$). Between healthy and periodontitis mandibles, no significant difference was found in the distribution of the origin site ($P = 0.341$), but significant differences were detected in the distribution of the terminus site ($P = 0.025$). In periodontitis mandibles, the MIC ended more frequently around the lateral incisor (51.3%, 40/78), while it ended more commonly around the canine in healthy mandibles (59.7%, 482/839). Moreover, there were significant differences in the distribution of the start point ($P = 0.000$) and end point ($P = 0.037$), among age groups.

Measurements of the diameter, length and sagittal position of the MIC

As for the 993 hemimandibles, the mean diameter of the MIC was 2.5 ± 0.5 mm at the origin, and 0.8 ± 0.2 mm at the terminus, with a mean length of 13.4 ± 3.3 mm. 20.6% (205/993) of the MICs began with a diameter ≥ 3 mm (Fig 6), 69.6% (691/993) began with a diameter of 2 to 3 mm, and 9.8% (97/993) with a diameter < 2 mm. The mean horizontal distances from the MIC to the labial and lingual cortex at terminal sites were 3.7 ± 0.9 mm and 5.1 ± 1.4 mm, respectively, and the mean vertical distances from the MIC to the alveolar crest and inferior border at terminal sites were 19.5 ± 3.8 mm and 8.9 ± 1.7 mm, respectively (Table 2). No significant differences were found between right and left sides in the above values ($P > 0.05$). The mean diameter at origin and length of the MIC, as well as the distances to mandibular cortexes, were larger in males than those in females, however, no significant differences of the mean diameter at endpoint were found between males and females.

Table 2 Mandibular incisive canal (MICs) measurements among 535 patients (mm).

Measurements	Minimum	Maximum	Mean	SD	P_1	P_2
Origin diameter	0.9	4.5	2.5	0.5	0.142	0.000
Terminus diameter	0.4	1.3	0.8	0.2	0.174	0.829
Length	3.6	25.2	13.4	3.3	0.108	0.000
Labial	1.0	8.0	3.7	0.9	0.204	0.000
Lingual	0.8	10.3	5.1	1.6	0.562	0.000
Alveolar	4.5	30.2	19.5	3.8	0.570	0.011
Inferior	4.2	14.9	8.9	1.7	0.728	0.000

P_1, the P value between left and right side in prevalence of MIC;
P_2, the P value between gender in prevalence of MIC;
Labial, Lingual, Alveolar and Inferior border: distances to the mandibular cortexes at terminal sites.

Table 3 Mandibular incisive canal (MIC) measurements by age group and dental status (mm).

Patients (N)		Origin diameter	Terminus diameter	Length	Distance to labial cortex	Distance to lingual cortex	Distance to alveolar edge	Distance to inferior border
Age groups	≤ 20 (152)	2.8 ± 0.5	0.8 ± 0.2	13.1 ± 3.4	3.8 ± 1.0	5.0 ± 1.5	20.5 ± 3.2	8.4 ± 1.7
	21-30 (104)	2.4 ± 0.4	0.8 ± 0.2	12.4 ± 3.3	3.7 ± 0.9	4.8 ± 1.3	21.2 ± 3.1	8.7 ± 1.6
	31-40 (69)	2.4 ± 0.4	0.7 ± 0.1	13.0 ± 3.2	3.5 ± 1.0	4.9 ± 1.2	19.0 ± 2.7	8.9 ± 1.5
	41-50 (50)	2.4 ± 0.4	0.8 ± 0.1	14.1 ± 3.1	3.6 ± 1.0	5.3 ± 1.4	19.5 ± 2.7	9.3 ± 1.7
	51-60 (45)	2.6 ± 0.4	0.7 ± 0.2	14.2 ± 3.6	3.5 ± 0.7	5.3 ± 1.1	19.8 ± 2.5	9.1 ± 2.0
	≥ 61 (28)	2.5 ± 0.5	0.7 ± 0.1	14.1 ± 3.1	3.9 ± 1.0	5.2 ± 1.1	20.3 ± 3.2	9.6 ± 1.8
	P	.000	.000	.000	.094	.012	.000	.000
Dental status	Healthy (448)	2.5 ± 0.5	0.8 ± 0.2	13.3 ± 3.4	3.7 ± 0.9	5.0 ± 1.3	20.2 ± 3.1	8.8 ± 1.7
	Edentulous (42)	2.3 ± 0.5	0.8 ± 0.2	13.4 ± 2.8	3.6 ± 0.9	5.1 ± 1.2	12.4 ± 4.1	8.7 ± 1.3
	P	.000	.580	.676	.537	.605	.000	.587
Periodontal status	Healthy (448)	2.5 ± 0.5	0.8 ± 0.2	13.3 ± 3.4	3.7 ± 0.9	5.0 ± 1.3	20.2 ± 3.1	8.8 ± 1.7
	Periodontitis (45)	2.6 ± 0.6	0.7 ± 0.2	14.3 ± 3.3	3.9 ± 1.0	5.4 ± 1.6	18.7 ± 3.4	9.5 ± 1.9
	P	.192	.000	.009	.109	.097	.000	.000

As for the different age groups, dental status, and periodontal status, the measurements are listed in Table 3. Differences in the MIC were found among age groups in the beginning diameter, terminal diameter, length, and vertical distances of MIC to the alveolar crest and inferior border of the anterior mandibles. Moreover, significant differences in MIC were detected between dentate and edentulous groups in the beginning diameter and vertical distance to the alveolar crest. Also, significant differences of MIC were found between the healthy and the periodontitis group in the terminal diameter, length, and vertical distances to the alveolar crest and inferior border of the anterior mandibles. Post-hoc testing differences among age groups showed that the diameters at the origin in the ≤ 20 years group were significantly larger than in other older age groups, except for the ≥ 61 age group.

Moreover, the Pearson's correlation analysis showed a mild correlation between the beginning diameters and lengths of the 993 visible MICs ($P = 0.046$, $r = 0.063$).

Relative to the canine, lateral incisor and central incisor, the distances to mandibular cortexes in healthy group were calculated (Table 4). Although the MICs had different terminus sites and lengths, significant differences were not detected among different tooth positions relative to the horizontal distance to the labial cortex, and vertical distances to the alveolar crest and inferior border of the anterior mandibles.

Discussion

The mandibular symphysis was a good option for autogenous bone grafting when a moderate quantity of bone was required. However, harvesting from this region did carry some risks including haemorrhage, and injury to existing dentition and nerves. The main neurovascular bundles that should be considered included the incisive canal and mental nerves[11,12]. After evaluating 50 dentate mandibles with computed tomography (CT), Pommer et al[13] recommended safety margins as follows: 4 mm maximum depth of bone graft, 5 mm anterior to the mental foramen, 8 mm below the root apex, and leaving the inferior border intact. Vu et al[11] modified the recommended parameters after evaluating osteotomies in 19 cadavers, as follows: 9 mm below the root apex or 23 mm below the cementoenamel junction and 5 mm above the inferior border of mandible. Despite these, large anatomical variations have been reported from previous studies among different ethnic backgrounds, dental status and even among individual cases. Due to trauma and periodontitis, the anterior mandible has also been a commonly applied site for implant placement.

Table 4 Spatial distances of the mandibular incisive canal (MIC) at the canine, lateral incisor and central incisor (mean ± SD, mm) in healthy mandibles.

	Canine (n = 819)	Lateral incisor (n = 312)	Central incisor (n = 19)	*P*
Labial	3.682	3.693	3.495	0.622
Lingual	4.774	5.525	6.426	0.000
Alveolar	20.120	20.021	21.262	0.264
Inferior border	8.917	8.873	8.163	0.275

Labial, Lingual, Alveolar and Inferior border: distances to the mandibular cortexes.

Permanent sensory disturbances in the anterior region of the lower lip were detected by Wismeijer[14] in 7% of the cases where two to four implants were placed. All of them were placed in the so-called mandibular ‘safe zone’. Hence, a comprehensive knowledge of the exact location and spatial parameters of the MIC has been a requisite in reducing the risk of surgical procedures in the interforaminal region[15,16].

Previous studies showed that the prevalence of the MIC was 68.6% to 100%, via evaluating osteotomies in cadavers[11,16,17], or 75.9% to 100%, via using noninvasive CBCT imaging[1, 2,7-10,13,18-21]. Xu et al[17] reported that 80% of the MICs were formed by a layer of a very thin compact bone or partially by spongy bone, and that 20% were formed completely by spongy bone, observed via the dissection measurement of 80 semi-mandibles. In the present study, the prevalence of the MIC was 92.8%, which was comparable with previous studies, especially studies using similar population groups[9,16]. Ferreira et al[8] observed that the voxel size played an important role in the visibility of the MIC, and a higher prevalence was presented with a smaller voxel size. The images with 0.2 mm voxel size used here were accurate enough to detect the MIC. No significant differences were found between left and right sides, which was consistent with most of other studies. A higher prevalence of MICs was found here in males compared with females, which has not been mentioned previously in the literature. A significantly higher prevalence was found in dentate mandibles compared with edentulous mandibles, which was similar to Sener et al[16] findings. However, Yang et al[9] reported no difference between dental status. The radiographic visualisation of the incisive canal in edentulous patients might have been adversely affected by poor bone quality. Furthermore, a severe resorption of the residual alveolus in edentulous mandibles might have diminished the necessity of neurovascular supply of the MIC. Moreover, a higher prevalence of the MICs in healthy mandibles was found compared with that in periodontitis mandibles, despite the fact that no statistical differences were observed.

The origin of the MIC relative to adjacent tooth had never been mentioned in previous studies. In the present study, the origin was specified as an exact reduction of the cortical canal before it turned upward and backward to form the mental foramen, and the relative teeth position localised the MICs more precisely, eliminating deviations from the variations of mandible sizes. More than half (51.9%) of the MICs started below the first premolar, followed by between the first and second premolar (29.7%), and only 1% started below the canine.

Kabak et al[18] showed that the cortical plate of the MIC lost its visible integrity in the mesial direction and gradually ceased due to a decrease in the thickness of the bone substance, in its wall. Finally, blood vessels and nerves passed from the MIC to the root apices through the spaces between spongy bone trabeculae. After analysing 100 CBCT scans, Kabak et al[18] found that 21% of the MICs reached the central incisor root area, 11.5% ended below the lateral incisor region and 37.5% ended below the canine region. By studying 80 hemi-mandibles, Xu et al[17] saw that 70% of the MICs ended below the lateral incisor and 30% below the lateral and central incisor. Sahman et al[22] noted that the majority of the MIC terminated between the canine and the first premolar. Yang et al[9] reported that approximately 60% of the MIC ended around the lateral incisor and canine. In our study, the MICs ended most frequently around the root of the canine (58.5%), followed by the lateral incisors (36.0%). Overall, 38.2% of the MICs extended beyond the root of the canine and only 2.2% of the MICs extended below the central incisor. The risk of nerve injury decreased in the direction to the midline of the mandible. By using magnetic resonance imaging, it has been reported that 70% of incisive canals crossed the midline and one fourth of those were ‘plexus-like’[11,17]. Vu et al[11] noted that the incisive canals could not be found at the midline in approximately half the specimens. Mraiwa et al[23] stated that the MICs reached the midline in 18% of cases. In our study, the MIC went through the midline only in one case. The marked variations might be explained by racial differences, specifications of MIC and means of canal visualisation. In the present study, the MICs should be regarded as well-visualised, which might have led to an underestimation of the prevalence.

Consistent with other studies, the diameters of the MIC decreased in the direction to the midline of the mandible. The mean diameter measured here was 2.5 ± 0.5 mm at the start point, and 0.8 ± 0.2 mm at the end point. Approaching to the midline, MICs became so fine that the resolution of the CBCT scan was probably insufficient for MIC visualisation[7]. Though no differences were found between gender and laterality of the end point values, the diameter at the origin was significantly larger in males than in females, which coincided with the results by Yang et al[9] and Sahman et al[22]. This could be attributed to the larger mandible size in males than in females. The mean diameter at the origin was reported to be 1.9 to 2.6 mm[9,10,16,17,22]. The marked variations could be attributed to the different specifications observed between the start and end point. Kong et al[10] defined the origin positions as anterior region of the mental foramen; however, this definition was not followed by other studies. In the present study, the MIC diameter varied from 0.9 to 4.5 mm at the origin, and 20.6% of them were ≥ 3 mm. The presence of the MIC, especially one with a large diameter, has been associated with serious risks in surgical procedures, especially in implant surgery[24,25].

In our study, the diameter of the MIC at origin was larger in dentate mandibles than in edentulous mandibles, while no significant differences were reported by Yang et al[9] in a vivo study using 412 patients, or by Sener et al[16] in a study using 70 cadavers. Though no differences were detected in the MIC diameters at origin between healthy and periodontitis mandibles, the diameters of the terminus were significantly larger in healthy mandibles than in periodontitis mandibles, which has not been reported previously. The values varied greatly between different age groups, which is not according to the results by Yang et al[9]. In our study, the diameters at the origin in the ≤ 20 years group were significantly larger than in other older age groups, except for the ≥ 61 age group. Although the exact reason is still unknown, physical growth during puberty in younger people might play an important role in explaining the observed differences; i.e., adolescents might have higher neurovascular supply in this region.

The mean length of the MIC observed here was 13.4 ± 3.3 mm, which was shorter than those reported in other studies. This might have been due to the measurement method used. In the present study, the length was calculated from the beginning point which showed an exact reduction of the mandibular canal, to the most mesial point in the infra-apical region where the canal was invisible. However, in the majority of studies, the origin of the MIC has been considered to be measured from the mental foramen or close to it[11,18]. Kong et al[10] recorded the end point of the MIC at the alveolar edge, in which the mean length of the MIC was 17.84 mm. In our study, no significant differences were found between dentate and edentulous mandibles, which was similar to the findings of Pires et al[7] and Apostolakis et al[24]. However, Yang et al[9] and Sener et al[16] found longer MICs in edentulous mandibles. Moreover, the results showed longer MICs in the periodontitis mandibles than in healthy mandibles, which has been previously described.

The mean distances of the MICs were 3.7 mm, 5.1 mm, 19.5 mm and 8.9 mm to the labial cortex, lingual cortex, alveolar crest and inferior border of mandibles, respectively. Regarding the distances of the MIC to the adjacent mandible walls, the results showed no significant differences between laterality, while significant longer distances were found in males compared with females. No other studies have reported these statistical data regarding the periodontal status. In the present study, no significant differences were found in the mean labial distances of the MICs among all the items, which implied that MICs were located about 3.7 mm deep to the labial surface of the mandible in any age group or dental status. The recommended safe thickness of 4 mm by Pommer et al[13] for chin bone harvesting seemed not safe[12,14,24]. As for the lingual distance of the MIC, no significant differences were found between dental status and age groups, except for one difference between the 21-30 and in 51-60 age groups. The distance of the MIC to the alveolar crest varied greatly among different dental situations and age groups, which could be easily explained by the resorption of bone height in the edentulous and periodontitis mandibles. A distance of 8.9 ± 1.7 mm between the MIC and inferior mandibular border was comparable with previous studies[9,10]. In spite of the marked variations among these studies, the neurovascular supply of the anterior mandibles should not be overlooked. A completely safe zone in the anterior mandibles did not truly exist. Since CBCT images are routinely performed in modern dental practice, adequate evaluation of the interforaminal region is a requisite to prevent damage to the intrabony neurovascular bundles.

In summary, the MIC was observed in 92.8% of 1,070 hemimandibles, with significant differences observed between dentate and edentulous mandibles. The MICs started most commonly below the first premolar (51.9%) and ended around the canine (58.5%). The mean diameter of the MIC was 2.5 ± 0.5 mm at origin, and 20.6% of the MICs began with a diameter ≥ 3 mm. Significant differences of the linear measurements of the MIC were found relative to gender, age group and dental status. Due to the large variations of the MIC morphology, special caution should be exercised in any individual dentoalveolar surgery affecting the anterior mandible.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Ya Qiong ZHANG acquired and analysed the case data and prepared the manuscript; Drs Xue Bing YAN, Li Qi ZHANG and Xiao Yan XIE analysed the radiological data; Professor Deng Gao LIU designed the work, supervised the study and revised the manuscript; Professor Zu Yan ZHANG supervised the study.

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References

1. Makris N, Stamatakis H, Syriopoulos K, Tsiklakis K, van der Stelt PF. Evaluation of the visibility and the course of the mandibular incisive canal and the lingual foramen using cone-beam computed tomography. Clin Oral Implants Res 2010;21:766–771.
2. Pereira-Maciel P, Tavares-de-Sousa E, Oliveira-Sales MA. The mandibular incisive canal and its anatomical relationships: A cone beam computed tomography study. Med Oral Patol Oral Cir Bucal 2015;20:e723–e728.
3. Romanos GE, Greenstein G. The incisive canal. Considerations during implant placement: case report and literature review. Int J Oral Maxillofac Implants 2009;24:740–745.
4. Lee CY, Yanagihara LC, Suzuki JB. Brisk, pulsatile bleeding from the anterior mandibular incisive canal during implant surgery: a case report and use of an active hemostatic matrix to terminate acute bleeding. Implant Dent 2012;21:368–373.
5. de Souza Tolentino E, Silva PA, Pagin O, Centurion BS, Molin SK, de Souza Tolentino L. Uncommon trajectory variations of the mandibular canal and of the mandibular incisive canal: case report. Surg Radiol Anat 2013;35:857–861.
6. Goller Bulut D, Köse E. Available bone morphology and status of neural structures in the mandibular interforaminal region: three-dimensional analysis of anatomical structures. Surg Radiol Anat 2018;40:1243–1252.
7. Pires CA, Bissada NF, Becker JJ, Kanawati A, Landers MA. Mandibular incisive canal: cone beam computed tomography. Clin Implant Dent Relat Res 2012;14:67–73.
8. Ferreira Barbosa DA, Barros ID, Teixeira RC, et al. Imaging aspects of the mandibular incisive canal: a PROSPERO-registered systematic review and meta-analysis of cone beam computed tomography studies. Int J Oral Maxillofac Implants 2019;34:423–433.
9. Yang XW, Zhang FF, Li YH, Wei B, Gong Y. Characteristics of intrabony nerve canals in mandibular interforaminal region by using cone-beam computed tomography and a recommendation of safe zone for implant and bone harvesting. Clin Implant Dent Relat Res 2017;19:530–538.
10. Kong N, Hui M, Miao F, Yuan H, Du Y, Chen N. Mandibular incisive canal in Han Chinese using cone beam computed tomography. Int J Oral Maxillofac Surg 2016;45:1142–1146.
11. Vu DD, Brockhoff HC 2nd, Yates DM, Finn R, Phillips C. Course of the mandibular incisive canal and its impact on harvesting symphysis bone grafts. J Oral Maxillofac Surg 2015;73:258.e1–258.e12.
12. von Arx T, Häfliger J, Chappuis V. Neurosensory disturbances following bone harvesting in the symphysis: a prospective clinical study. Clin Oral Implants Res 2005;16:432–439.
13. Pommer B, Tepper G, Gahleitner A, Zechner W, Watzek G. New safety margins for chin bone harvesting based on the course of the mandibular incisive canal in CT. Clin Oral Implants Res 2008;19:1312–1316.
14. Wismeijer D, van Waas MA, Vermeeren JI, Kalk W. Patients' perception of sensory disturbances of the mental nerve before and after implant surgery: a prospective study of 110 patients. Br J Oral Maxillofac Surg 1997;35:254–259.
15. Yilmaz Z, Ucer C, Scher E, Suzuki J, Renton T. A survey of the opinion and experience of UK dentists: Part 1: The incidence and cause of iatrogenic trigeminal nerve injuries related to dental implant surgery. Implant Dent 2016;25:638–645.
16. Sener E, Onem E, Akar GC, et al. Anatomical landmarks of mandibular interforaminal region related to dental implant placement with 3D CBCT: comparison between edentulous and dental mandibles. Surg Radiol Anat 2018;40:615–623.
17. Xu Y, Suo N, Tian X, et al. Anatomic study on mental canal and incisive nerve canal in interforaminal region in Chinese population. Surg Radiol Anat 2015;37:585–589.
18. Kabak SL, Zhuravleva NV, Melnichenko YM, Savrasova NA. Study of the mandibular incisive canal anatomy using cone beam computed tomography. Surg Radiol Anat 2017;39:647–655.
19. do Carmo Oliveira M, Tedesco TK, Gimenez T, Allegrini S Jr. Analysis of the frequency of visualization of morphological variations in anatomical bone features in the mandibular interforaminal region through cone-beam computed tomography. Surg Radiol Anat 2018;40:1119–1131.
20. Gomes LT, de Almeida Barros Mourão CF, Braga CL, de Almeida LFD, de Mello-Machado RC, Calasans-Maia MD. Anatomic evaluation of the incisive canal with cone beam computed tomography and its relevance to surgical procedures in the mental region: a retrospective study in a Brazilian population. Oral Maxillofac Surg 2018;22:379–384.
21. Al-Ani O, Nambiar P, Ha KO, Ngeow WC. Safe zone for bone harvesting from the interforaminal region of the mandible. Clin Oral Implants Res 2013;24 Suppl A100:115–121.
22. Sahman H, Sekerci AE, Sisman Y, Payveren M. Assessment of the visibility and characteristics of the mandibular incisive canal: cone beam computed tomography versus panoramic radiography. Int J Oral Maxillofac Implants 2014;29:71–78.
23. Mraiwa N, Jacobs R, Moerman P, Lambrichts I, van Steenberghe D, Quirynen M. Presence and course of the incisive canal in the human mandibular interforaminal region: two-dimensional imaging versus anatomical observations. Surg Radiol Anat 2003;25:416–423.
24. Apostolakis D, Brown JE. The dimensions of the mandibular incisive canal and its spatial relationship to various anatomical landmarks of the mandible: a study using cone beam computed tomography. Int J Oral Maxillofac Implants 2013;28:117–124.
25. Rosenquist B. Is there an anterior loop of the inferior alveolar nerve? Int J Periodontics Restorative Dent. 1996;16:40–45.