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Research article

Assessment of the mandibular incisive and mental canal in dentate and edentulous mandibles using cone-beam computed tomography

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ABSTRACT

Objectives: This study evaluated the prevalence, diameter and location of the mandibular incisive canal (MIC) and the transition pattern and anterior loop length (ALL) of the mental canal and compared these values between **dentate** and **edentulous** mandibles.
Methods: A total of 187 cone-beam computed tomography (CBCT) images of mandibles, namely, 100 images of dentate mandibles and 87 images of edentulous mandibles, were obtained. CBCT data related to the incisive canal and mental canal were analyzed by one examiner.
Results: The prevalence of the MIC was 75~78 %, showing no difference based on laterality or the presence of teeth. The ALL significantly differed depending on the presence of teeth as well as sex. The presence of teeth affected the size of the MIC in the female group, and the diameter of the MIC in the edentulous group was significantly narrower than that in the dentate group. The diameter of the MIC was significantly greater in males than in females in the edentulous group. Meanwhile, the location of the MIC in the male group depended on the presence of teeth at each measuring point, and the MIC was significantly closer to the lower border of the mandible in the female group than in the male group at all measuring points except at 0 mm.
Conclusions: This study indicated that the presence of teeth significantly affects the type of transition of the mental canal, the ALL, and the diameter and location of the MIC. Additionally, sex could be a factor affecting MIC location, MIC diameter and anterior loop length.

1. Introduction

With the advent of dental implants, a traditional mandibular complete denture is not an adequate alternative to an implant-supported prosthesis, and comprehensive knowledge of the anatomy and its variations in the edentulous mandible is needed. Information on the differences in the prevalence of the mandibular incisive canal (MIC) and measurements of the incisive canal diameter (ICD) and anterior loop length (ALL) of the mental nerve according to sex, the presence of teeth, age, or laterality is clinically needed.

Abbreviations: ALL, anterior loop length; MIC, mandibular incisive canal; MF, mental foramen; ICD, incisive canal diameter; CBCT, cone-beam computed tomography.

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The discrepancies between the anatomical prevalence and radiographic visibility of the MIC and anterior loop of the mental nerve present surgical challenges in the interforaminal region, which is considered a safe zone for surgical procedures, such as bone harvesting, genioplasty, and dental implant placement [1–4].

There are considerable variations in the ALL, the prevalence of the MIC, the transition pattern of the mental nerve and the diameter of the incisive canal. Before both CBCT and multislice spiral CT (MSCT), which yield submillimeter accuracy for linear measurement, became widespread in dentistry, major studies on the anatomical assessment of bony structures were performed using cadavers [2, 5–10]. There are a few reports that the discrepancies in the numerical data between CBCT and anatomical measurements have no significant influence [1,5], and CBCT demonstrated superiority in visualizing the anatomical structures of the mandibular region over panoramic radiography, with higher MIC detection rates of 83–100 % reported for CBCT versus 15–51.2 % for panoramic radiographs [1,11,12]. The MIC extends from the mandibular canal containing branches of the inferior alveolar nerve (IAN) [2,13]. The radiological detection rate for the MIC varies from 11.2% to 100 % due to differences in imaging techniques, analysis methods, and studied ethnicity [14–16]. However, these values do not coincide with the anatomical results [2,3,5,11,16].

The MIC curves downward from the MF toward the inferior mandibular border to the buccal border rather than the lingual cortex, but it curves to the lingual side in the symphysis area [3,16]. The distance of the MIC from the lower border of the mandible varies, ranging from 9.36 to 11.5 mm near the MF area and from 7.01 to 9.4 mm near the incisor area [17–20]. Moreover, the ICD is sufficiently large to be vulnerable to neurovascular bundle damage, provoking NSD during surgery [2,21–24], especially near the MF. The ICD also varies depending on the distance from the MF: 2.09 mm at the MF, 1.25 mm at the canine area, and 0.98 mm at the incisor area [2].

The transition of the mental nerve split from the IAN is classified into 3 patterns: an anterior loop pattern, a straight pattern, and a vertical pattern innervating the skin and mucosa of the lower lip, chin, and premolar area [7,25,26]. The ALL near the MF has been investigated to establish a safety margin based on the distance from the MF, which ranges from 1.74 mm to 11 mm [5,19,26].

Mandibular morphology changes in size, ramus angle, and neck inclination with age and tooth loss [27]. It is noteworthy that the location of the mandibular canal and mental foramen are more affected by tooth loss than by age, especially for surgical procedures related to the mandibular bone [28,29]. However, information on the location and prevalence of anatomical structures in the mandibular interforaminal region based on patient-related factors such as ethnicity, sex and dental status is limited. This study aimed to investigate the prevalence of the MIC and the measurements of the ICD and ALL as well as their differences according to sex and the presence of teeth using CBCT images to provide clinical information on the safety zone anterior to the MF, thereby allowing clinicians to avoid NSD related to surgery in the interforaminal region.

2. Materials and methods

This study was approved by the Institutional Review Board (IRB) of the Yonsei University College of Dentistry (Approval No. 2-2021-0001) and was conducted from 2021 to 2022.

A total of 200 CBCT images (100 for dentate patients, 100 for edentulous patients) of the mandibles of patients who visited Yonsei University Dental Hospital, Seoul, Korea, from January 2015 to December 2020 were randomly collected from the archives for this retrospective study. CBCT images were collected from patients with at least 24 teeth and completely edentulous patients. Additionally, images of patients with a medical or dental history of osteoporosis, maxillofacial trauma, orthognathic surgery, congenital anomalies, pathology, or reconstruction were excluded. According to the exclusion criteria, 13 CBCT images from edentulous patients were excluded. In total, 187 CBCT images, including 100 CBCT images of dentate mandibles (56 males and 44 females) and 87 images of edentulous mandibles (31 males and 56 females), were included. The mean age was 37.77 ± 13.89 years for the dentate patients and 67.57 ± 10.69 years for the edentulous patients (Table 1).

2.1. 2-1. Imaging procedure

All the CBCT images were obtained with an Alphard 3030 device (Asahi Roentgen Ind., Co., Ltd., Tokyo, Japan) with the following exposure conditions: tube voltage, 80 kVp; tube current, 8 mA; exposure time, 17 s; field of view, 15.4 × 15.4 cm; and voxel resolution, 0.3 mm. The CBCT images were reconstructed as follows: contiguous 1-mm-thick axial images were reconstructed parallel to the mandibular inferior border using the bone algorithm, and cross-sectional images were created with a thickness of 1.00 mm and displayed in axial, panoramic and cross-sectional views. CBCT data were exported in Digital Imaging and Communications in Medicine (DICOM) format and processed using a CBCT viewer program (ZeTTA PACS; Batec, Seoul, Korea).

Table 1
Sex and age distribution of participants.

	Number of participants (N)	Sex (%)		Age (Mean ± SD)
		M	F	
Dentate	100	56	44	37.77 (±13.89)
Edentulous	87	31	56	67.57 (±10.69)

2.2. Measurements

All measurements were performed by an examiner who was involved in the previous study [17]. The measurements of thirty sets of both dentate and edentulous CBCT scans were repeated a second time after 1 month to evaluate the intraoperator reliability without reference to the previous recordings.

The 1-mm-thick, serially reformed panoramic sections were viewed parallel to the arch of the anterior mandible (MF to MF). The transition pattern of the mental canal was determined by the exit morphology. Regarding the loop type, the shortest straight distance between the anterior wall of the MF and the most anterior margin of the loop was measured on the panoramic CBCT scan as the ALL (Fig. 1).

The presence of the MIC was determined from panoramic scans in a yes or no binary format, and the prevalence of the MIC was calculated. To differentiate between the mandibular and incisive canals, the canal diameter and thickness were referenced since the mandibular canal is wide with a thick border [30]. The diameter of the MIC and distance from the lower border of the mandible were measured via a cross-sectional scan at 0 mm, 4 mm, and 8 mm from the MF (Fig. 2).

2.3. Statistical analysis

All the data were analyzed using SPSS 25.0 statistical software (IBM). The mean, standard deviation, and confidence interval were calculated for all the measurements. A p value less than 0.05 was considered to indicate statistical significance. The differences in the ALL, MIC diameter, and MIC distance according to the dental state and sex were analyzed using the independent sample *t*-test after assessing normality with the Shapiro–Wilk and Kolmogorov–Smirnov tests. Pearson correlation analysis was performed to assess the correlation of all the data between the right and left sides of the mandible. To compare the prevalence of MIC and the transition type of the mental canal, the chi-square test was performed for both dentate and edentulous mandibles. The intraclass correlation coefficient was calculated using Cronbach's α statistic to evaluate intraobserver reproducibility. All of the methodologies used were reviewed by an independent statistician.

3. Results

The images of 30 patients among all subjects were remeasured by the same examiner to assess intraexaminer reliability without referencing prior data after 1 month. A Cronbach's alpha coefficient of $r = 0.942–0.997$ represented high reliability of the measurements.

Assessment of the transition type of the mental nerve from the IAN revealed a significant difference between the edentulous and dentate groups ($p < 0.05$), and the loop type was the most predominant, followed by the vertical type and straight type in both groups (Table 2). However, the prevalence of the vertical and straight types was greater in the edentulous group (44 %) than in the dentate group (29 %).

The average prevalence of the MIC was 75 %–78 %. No significant differences were noted between the right and left sides or between the dentate and edentulous groups (Table 3).

The mean ALL significantly differed according to the presence of teeth (4.83 ± 1.16 mm (M): 4.24 ± 1.11 mm (F) in the dentate group and 4.32 ± 1.53 mm (M): 3.52 ± 1.32 mm (F) in the edentulous group), with a strong correlation between the right and left sides (Pearson correlation coefficient = 0.811) (Tables 4 and 5).

The means of both the diameter and distance of the MIC decreased as the canal ran toward the anterior mandible. Only in the female group did the presence of teeth affect the size of the MIC, and the diameter of the MIC in the edentulous group was significantly narrower than that in the dentate group but not in the male group. In addition, there was a sex effect on the diameter of the MIC in the edentulous group, and the diameter was significantly greater in males than in females (Table 5). Moreover, the male group significantly differed in the location of the MIC depending on the presence of teeth at each point in the measurement ($p < 0.05$), and the MIC in the female group was significantly closer to the lower border of the mandible than that in the male group at all measuring points except at 0 mm (Table 5).

The MIC diameter showed a moderate to high correlation between the right and left sides (Pearson correlation coefficient = 0.505–0.790). Similarly, the MIC distance was strongly correlated between the right and left sides (Pearson correlation coefficient = 0.763–0.806) (Table 4).

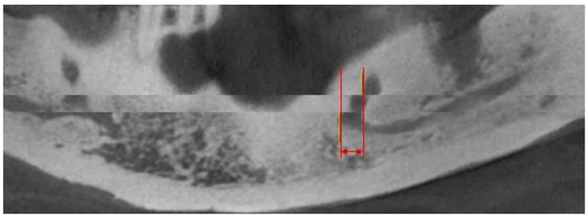

Fig. 1. Anterior loop length of mental canal.

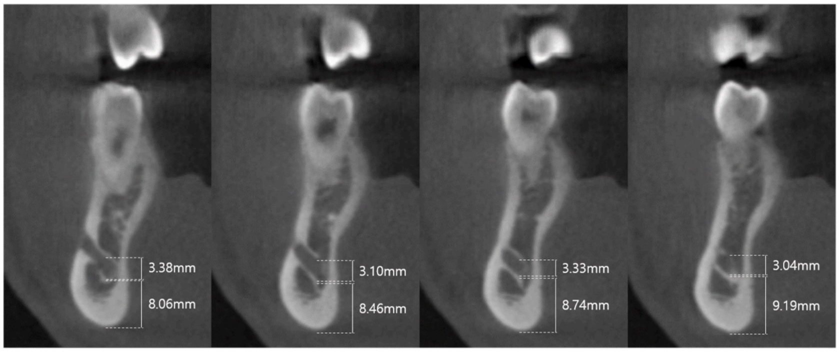

Fig. 2. Diameter and location of mandibular incisive canal.

Table 2
Transition types of mental canal.

	Dentate N (%)	Edentulous N (%)	*P*
Right			0.004[a]
Loop type	70 (70)	49 (56.3)	
Straight type	1 (1)	11 (12.6)	
Vertical type	29 (29)	27 (48.2)	
Total	100 (100)	87 (100)	
Left			0.002[a]
Loop typ	72 (72)	48 (55.2)	
Straight type	1 (1.0)	11 (12.6)	
Vertical type	27 (27)	28 (32.2)	
Total	100 (100)	87 (100)	

[a] Differences between groups were analyzed with the chi-square test.

Table 3
Prevalence of mandibular incisive canal (2N = 374).

	Rt MIC (%)	Lt MIC (%)	*p* value
Dentate (N = 100)	75 (75 %)	77 (77 %)	0.871
Edentulous (N = 87)	67 (77 %)	68 (78.2 %)	0.931
p value	0.502	0.455	

*Differences between groups were analyzed with the chi-square test ($p < 0.05$).

Table 4
Correlations between right and left sides of jaw (Pearson correlation coefficient).

			Lt.						
			ALL	Diameter of MIC			Location of MIC		
				at 0 mm from MF	at 4 mm from MF	at 8 mm from MF	at 0 mm from MF	at 4 mm from MF	at 8 mm from MF
Rt.	ALL		0.811[a]						
	Diameter of MIC	at 0 mm from MF		0.790[a]	0.595[a]	0.455[a]			
		at 4 mm from MF		0.716[a]	0.648[a]	0.516[a]			
		at 8 mm from MF		0.568[a]	0.566[a]	0.505[a]			
	Location of MIC	at 0 mm from MF					0.806[a]	0.774[a]	0.733[a]
		at 4 mm from MF					0.756[a]	0.777[a]	0.750[a]
		at 8 mm from MF					0.731[a]	0.752[a]	0.763[a]

*. The correlation is significant at the 0.05 level (bilateral).
[a] The correlation is significant at the 0.01 level (bilateral).

Table 5
Anterior loop length, mandibular incisive canal diameter, and mandibular incisive canal location.

		Dentate	Edentulous	*P*	*Interaction p value*
ALL	M	4.83 ± 1.16	4.32 ± 1.53	0.042[a]	0.5531
	F	4.24 ± 1.11	3.52 ± 1.32	0.002[a]	
	P	0.019[a]	0.043[a]		
Diameter of MIC					
at 0 mm from MF	M	2.45 ± 0.52	2.35 ± 0.63	0.328	0.146
	F	2.28 ± 0.53	1.91 ± 0.59	<0.001[a]	
	P	0.143	0.003[a]		
at 4 mm from MF	M	1.97 ± 0.42	1.80 ± 0.70	0.127	0.405
	F	1.81 ± 0.42	1.50 ± 0.49	<0.001[a]	
	P	0.070	0.028[a]		
at 8 mm from MF	M	1.66 ± 0.34	1.28 ± 0.47	<0.001[a]	0.828
	F	1.50 ± 0.35	1.09 ± 0.46	<0.001[a]	
	P	0.0321	0.047		
Location of MIC					
at 0 mm from MF	M	11.34 ± 1.42	10.38 ± 1.50	<0.001[a]	0.004
	F	9.25 ± 1.47	9.67 ± 1.32	0.123	
	P	<0.001	0.095		
at 4 mm from MF	M	10.71 ± 1.24	9.88 ± 1.48	0.001[a]	0.012
	F	8.76 ± 1.32	9.00 ± 1.52	0.330	
	P	<0.001	0.013[a]		
at 8 mm from MF	M	9.96 ± 1.26	9.16 ± 1.34	0.001[a]	0.008
	F	8.03 ± 1.57	8.36 ± 1.37	0.189	
	P	<0.001	0.015[a]		

[a] Mixed linear model.

4. Discussion

4.1. Mental nerve transition type

In this study, the anterior loop pattern of the mental canal was significantly more common in 56 % of patients in the edentulous group and in 71 % of patients in the dentate group. The prevalence rate of the loop type in previous in vivo studies largely varied from 9.7 % to 94 % due to inconsistent assessment methods and differences in ethnicity [4,31]. Notably, the prevalence of the loop type was significantly greater in the dentate group than in the edentulous group, while the prevalence of straight or vertical patterns was significantly greater in the edentulous group. It can be inferred that the end portion of the loop degenerated, altering from the loop type to the straight type when teeth were extracted and innervation was no longer useful.

4.2. Anterior loop length

Both sex and dental status influenced the ALL, given that the value in the male group was significantly greater than that in the female group, and the value in the dentate group was greater than that in the edentulous group. The mean ALL in this study, regardless of dental status, was consistent with those of two previous studies using Korean cadavers; the mean ALL ranged from 3.05 ± 1.15 mm to 5.0 ± 1.8 mm [8,32]. One meta-analysis presented various mean values with a wide range of 1.17 ± 0.8 mm to 6.13 ± 3.41 mm (range: 0 mm–19.0 mm), which was due to laterality, age, and sex. However, it is generally accepted that the ALL is significantly longer in males than in females [33,34], but the effect of the presence of teeth is unclear. A previous study of 97 dentulous and 43 edentulous mandibles showed no significant differences between the dentate group and the edentulous group [5].

The longest ALL has been reported to range from 5.0 to 19.0 mm [1,5,8,32,33,35], but two previous studies have suggested that a much longer anterior loop should be classified as an abnormality rather than a common structure [31,34]. In this study, the longest ALL was 10.02 mm in the edentulous group.

4.3. Prevalence of the MIC

This study, the first clinical-based study of Korean subjects, showed a prevalence of 75~78 %, regardless of the dental condition and sex, which is within the range of 43.89 %–100 % reported by a few previous cadaveric or radiographic studies [1–3,5,6,14–16,30,36,37]. One study showed a slightly higher prevalence rate in females and on the left side [14]. Another study using 105 cadaveric specimens demonstrated a higher prevalence of the MIC, 92 % for dentulous mandibles and 31 % for edentulous mandibles [38], but this study showed no significant difference in the prevalence rate according to laterality and the presence of teeth.

4.4. MIC location and diameter

The presence of teeth affected the location of the MIC in the male group ($P < 0.05$). The mean distance of the MIC at 4 mm from the MF, regardless of sex or the presence of teeth, was within the range of 8.72–9.86 mm reported in previous studies [6,14,16,17,32,37].

An investigation of Dutch people showed that the mean distance was as long as 11.5 mm. Xiao et al. investigated the MIC position of Chinese subjects by measuring the distance between the teeth and the upper margin of the MIC, making it difficult to make comparisons based on ethnicity [33]. A study regarding the location of lateral antral intraosseous vascular canals of the maxilla reported no significant difference according to tooth presence [39]. In this study, the mean location of the MIC showed highly significant differences between the sexes, except at 0 mm in the edentulous group ($p < 0.05$), which could be supported by previous studies reporting that sex significantly affects the mean distance of the MIC and that the values in males were greater than those in females [14,16,33].

In this study, a significant difference in the ICD according to the presence of teeth was noted in the female group, and a significant difference based on sex was found in the edentulous group ($p < 0.05$). The mean value of the ICD at each position was similar to the 1.47 ± 0.50–2.8 ± 1.0 mm at the MF reported in previous studies [2,5,15,32,36,37]. One study revealed that the mean ICD was greater in males than in females [36], which was also observed in the edentulous group in this study. However, two other studies reported no difference in diameter based on sex or dental status [2,5].

Based on the results of this study, it can be assumed that the anterior loop of the mental nerve and mandibular incisive nerve degenerate from the end, and this degeneration is more pronounced in females. Some limitations of this study should be addressed. The mean ages of the edentulous and dentate groups in this study were significantly different. This age difference could have biased the results, as age-related factors such as bone density and osteoporosis can impact the position of the MIC and ICD. Further investigations using data from uniform sex and age distributions for more subjects are expected to reveal more accurate information on the locations of anatomical structures after mandibular teeth are extracted.

5. Conclusions

Despite these limitations, this study revealed that the presence of teeth significantly affects the type of transition of the mental canal, the ALL, and the diameter and location of the MIC. Sex also affects the MIC location, MIC diameter, and ALL. Given that sex and edentulous condition may affect the location of these anatomical structures, the ALL, MIC diameter, and MIC position should be assessed using CBCT images before attempting surgical procedures in the interforaminal area. This study can provide clinical information on the safety zone anterior to the MF, thereby allowing clinicians to avoid NSD in the interforaminal region.

CRediT authorship contribution statement

Re-Mee Doh: Writing – original draft, Investigation, Funding acquisition, Formal analysis. **Dong-Jin Choi:** Investigation, Data curation. **Kwang-Su Park:** Project administration, Formal analysis, Data curation. **Bock-Young Jung:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Ethical approval statement

This study was approved by the Institutional Review Board (IRB) of the Yonsei University College of Dentistry (Approval No 2-2021-0001).

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] R. Jacobs, N. Mraiwa, D. vanSteenberghe, F. Gijbels, M. Quirynen, Appearance, location, course, and morphology of the mandibular incisive canal: an assessment on spiral CT scan, Dentomaxillofacial Radiol. 31 (5) (2002) 322–327, https://doi.org/10.1038/sj.dmfr.4600719.

[2] O. Mardinger, G. Chaushu, B. Arensburg, S. Taicher, I. Kaffe, Anatomic and radiologic course of the mandibular incisive canal, Surg. Radiol. Anat. 22 (3–4) (2000) 157–161, https://doi.org/10.1007/s00276-000-0157-5.

[3] N. Makris, H. Stamatakis, K. Syriopoulos, K. Tsiklakis, P.F. van der Stelt, 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. 21 (7) (2010) 766–771, https://doi.org/10.1111/j.1600-0501.2009.01903.x.

[4] S.K. Mishra, R. Nahar, R. Gaddale, R. Chowdhary, Identification of anterior loop in different populations to avoid nerve injury during surgical procedures-a systematic review and meta-analysis, Oral Maxillofac. Surg. 25 (2) (2021) 159–174, https://doi.org/10.1007/s10006-020-00915-x.

[5] Y. Uchida, N. Noguchi, M. Goto, Y. Yamashita, T. Hanihara, H. Takamori, I. Sato, T. Kawai, T. Yosue, Measurement of anterior loop length for the mandibular canal and diameter of the mandibular incisive canal to avoid nerve damage when installing endosseous implants in the interforaminal region: a second attempt introducing cone beam computed tomography, J. Oral Maxillofac. Surg. 67 (4) (2009) 744–750, https://doi.org/10.1016/j.joms.2008.05.352.

[6] N. Mraiwa, R. Jacobs, D. van Steenberghe, M. Quirynen, Clinical assessment and surgical implications of anatomic challenges in the anterior mandible, Clin. Implant Dent. Relat. Res. 5 (4) (2003) 219–225, https://doi.org/10.1111/j.1708-8208.2003.tb00204.x.
[7] K.S. Hu, H.S. Yun, M.S. Hur, H.J. Kwon, S. Abe, H.J. Kim, Branching patterns and intraosseous course of the mental nerve, J. Oral Maxillofac. Surg. 65 (11) (2007) 2288–2294, https://doi.org/10.1016/j.joms.2007.06.658.
[8] K. Hwang, W.J. Lee, Y.B. Song, I.H. Chung, Vulnerability of the inferior alveolar nerve and mental nerve during genioplasty: an anatomic study, J. Craniofac. Surg. 16 (1) (2005) 10–14, https://doi.org/10.1097/00001665-200501000-00004. ; discussion 14.
[9] I.S. Kim, S.G. Kim, Y.K. Kim, J.D. Kim, Position of the mental foramen in a Korean population: a clinical and radiographic study, Implant Dent. 15 (4) (2006) 404–411, https://doi.org/10.1097/01.id.0000243319.66845.15.
[10] D. Rodricks, T. Phulambrikar, S.K. Singh, A. Gupta, Evaluation of incidence of mental nerve loop in Central India population using cone beam computed tomography, Indian J. Dent. Res. 29 (5) (2018) 627–633, https://doi.org/10.4103/ijdr.IJDR_50_17.
[11] C.A. Pires, N.F. Bissada, J.J. Becker, A. Kanawati, M.A. Landers, Mandibular incisive canal: cone beam computed tomography, Clin. Implant Dent. Relat. Res. 14 (1) (2012) 67–73, https://doi.org/10.1111/j.1708-8208.2009.00228.x.
[12] S. Murat, K. Kamburoglu, C. Kilic, T. Ozen, A. Gurbuz, Nerve damage assessment following implant placement in human cadaver jaws: an ex vivo comparative study, J. Oral Implantol. 40 (1) (2014) 76–83, https://doi.org/10.1563/AAID-JOI-D-11-00191.
[13] E. Olivier, The inferior dental canal and its nerve in the adult, Br. Dent. J. 49 (5) (1928) 356–358.
[14] R.T. Ayesha, B. Pachipulusu, P. Govindaraju, Assessment of prevalence and position of mandibular incisive canal: a cone beam computed tomography study, Ci Ji Yi Xue Za Zhi 32 (2) (2020) 205–210, https://doi.org/10.4103/tcmj.tcmj_76_19.
[15] A.S. Ramesh, K. Rijesh, A. Sharma, R. Prakash, A. Kumar, Karthik, the prevalence of mandibular incisive nerve canal and to evaluate its average location and dimension in Indian population, J. Pharm. BioAllied Sci. 7 (Suppl 2) (2015) S594–S596, https://doi.org/10.4103/0975-7406.163559.
[16] O. Al-Ani, P. Nambiar, K.O. Ha, W.C. Ngeow, Safe zone for bone harvesting from the interforaminal region of the mandible, Clin. Oral Implants Res. 24 (Suppl A100) (2013) 115–121, https://doi.org/10.1111/j.1600-0501.2011.02393.x.
[17] D.J. Choi, K.D. Kim, B.Y. Jung, Location of the mandibular incisive canal related to the placement of dental implants: a case report, J. Oral Implantol. 45 (6) (2019) 474–482, https://doi.org/10.1563/aaid-joi-D-19-00046.
[18] K.E. Polland, S. Munro, G. Reford, A. Lockhart, G. Logan, L. Brocklebank, S.W. McDonald, The mandibular canal of the edentulous jaw, Clin. Anat. 14 (6) (2001) 445–452, https://doi.org/10.1002/ca.1080.
[19] R.F. Neiva, R. Gapski, H.L. Wang, Morphometric analysis of implant-related anatomy in Caucasian skulls, J. Periodontol. 75 (8) (2004) 1061–1067, https://doi.org/10.1902/jop.2004.75.8.1061.
[20] S.G. Wadu, B. Penhall, G.C. Townsend, Morphological variability of the human inferior alveolar nerve, Clin. Anat. 10 (2) (1997) 82–87, https://doi.org/10.1002/(SICI)1098-2353(1997)10:2<82::AID-CA2>3.0.CO;2-V.
[21] J.N. Walton, Altered sensation associated with implants in the anterior mandible: a prospective study, J. Prosthet. Dent 83 (4) (2000) 443–449, https://doi.org/10.1016/s0022-3913(00)70039-4.
[22] D. Kohavi, J. Bar-Ziv, Atypical incisive nerve: clinical report, Implant Dent. 5 (4) (1996) 281–283, https://doi.org/10.1097/00008505-199600540-00007.
[23] D. Wismeijer, M.A. van Waas, J.I. Vermeeren, W. Kalk, 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. 35 (4) (1997) 254–259, https://doi.org/10.1016/s0266-4356(97)90043-7.
[24] H. Watanabe, M. Mohammad Abdul, T. Kurabayashi, H. Aoki, Mandible size and morphology determined with CT on a premise of dental implant operation, Surg. Radiol. Anat. 32 (4) (2010) 343–349, https://doi.org/10.1007/s00276-009-0570-3.
[25] G. Greenstein, D. Tarnow, The mental foramen and nerve: clinical and anatomical factors related to dental implant placement: a literature review, J. Periodontol. 77 (12) (2006) 1933–1943, https://doi.org/10.1902/jop.2006.060197.
[26] H. Sahman, Y. Sisman, Anterior loop of the inferior alveolar canal: a cone-beam computerized tomography study of 494 cases, J. Oral Implantol. 42 (4) (2016) 333–336, https://doi.org/10.1563/aaid-joi-D-15-00038.
[27] A.C. Gabriel, Some anatomical features of the mandible, J. Anat. 92 (4) (1958) 580–586.
[28] J.O. Neufeld, Changes in the trabecular pattern of the mandible following the loss of teeth, J. Prosthet. Dent 8 (4) (1958) 685–697.
[29] A. Gershenson, H. Nathan, E. Luchansky, Mental foramen and mental nerve: changes with age, Acta Anat. 126 (1) (1986) 21–28, https://doi.org/10.1159/000146181.
[30] M.B. Rosa, B.S. Sotto-Maior, C. Machado Vde, C.E. Francischone, Retrospective study of the anterior loop of the inferior alveolar nerve and the incisive canal using cone beam computed tomography, Int. J. Oral Maxillofac. Implants 28 (2) (2013) 388–392, https://doi.org/10.11607/jomi.2648.
[31] B. Benninger, D. Miller, A. Maharathi, W. Carter, Dental implant placement investigation: is the anterior loop of the mental nerve clinically relevant? J. Oral Maxillofac. Surg. 69 (1) (2011) 182–185, https://doi.org/10.1016/j.joms.2010.07.060.
[32] S.K. Yu, S. Kim, S.G. Kang, J.H. Kim, K.O. Lim, S.I. Hwang, H.J. Kim, Morphological assessment of the anterior loop of the mandibular canal in Koreans, Anat Cell Biol 48 (1) (2015) 75–80, https://doi.org/10.5115/acb.2015.48.1.75.
[33] X. Li, Z.K. Jin, H. Zhao, K. Yang, J.M. Duan, W.J. Wang, The prevalence, length and position of the anterior loop of the inferior alveolar nerve in Chinese, assessed by spiral computed tomography, Surg. Radiol. Anat. 35 (9) (2013) 823–830, https://doi.org/10.1007/s00276-013-1104-6.
[34] X. Wei, P. Gu, Y. Hao, J. Wang, Detection and characterization of anterior loop, accessory mental foramen, and lateral lingual foramen by using cone beam computed tomography, J. Prosthet. Dent 124 (3) (2020) 365–371, https://doi.org/10.1016/j.prosdent.2019.06.026.
[35] A.C. de Brito, Y. Nejaim, D.Q. de Freitas, C. de Oliveira Santos, Erratum to: panoramic radiographs underestimate extensions of the anterior loop and mandibular incisive canal, Imaging Sci Dent 46 (4) (2016) 297, https://doi.org/10.5624/isd.2016.46.4.297.
[36] H. Sahman, A.E. Sekerci, Y. Sisman, M. Payveren, Assessment of the visibility and characteristics of the mandibular incisive canal: cone beam computed tomography versus panoramic radiography, Int. J. Oral Maxillofac. Implants 29 (1) (2014) 71–78, https://doi.org/10.11607/jomi.3304.
[37] F. Parnia, E. Moslehifard, A. Hafezeqoran, F. Mahboub, H. Mojaver-Kahnamoui, Characteristics of anatomical landmarks in the mandibular interforaminal region: a cone-beam computed tomography study, Med. Oral Patol. Oral Cir. Bucal 17 (3) (2012) e420–e425, https://doi.org/10.4317/medoral.17520.
[38] O. Obradovic, L. Todorovic, V. Vitanovic, Anatomical considerations relevant to implant procedures in the mandible, Bull Group Int Rech Sci Stomatol Odontol 38 (1–2) (1995) 39–44.
[39] S.R. Shetty, S.W.A. Bayatti, H. Marei, R. Shetty, H.A. Abdelmagyd, A.M. Luke, Cone-beam computed tomography characterization of the intraosseous vascular canal in the lateral wall of the maxillary antrum, J Korean Assoc Oral Maxillofac Surg 47 (1) (2021) 34–39, https://doi.org/10.5125/jkaoms.2021.47.1.34.