A Radiographic Study of Mandibular Incisive Canal in Thais Using Cone-Beam Computed Tomography

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Abstract

The inferior alveolar nerve innervates the mandibular anterior teeth, whereas the mental nerve supplies sensory information to the soft tissues around the foraminal region and the integument of the chin. The incisive canal is the prolongation of the mandibular canal anterior to the mental foramen. Osteotomies frequently penetrate the incisive canal during preparation for a dental implant without any adverse reactions but some complications such as bleeding and paresthesia have been recorded. Anatomical research has revealed that the diameter of the incisive canal varied between 0.48 and 0.66 mm; unfortunately, no investigation of the Thai population has been conducted. To assess the appearance, size and course of the mandibular incisive canal (MIC) using cone-beam computed tomography (CBCT) in Thais. The samples consisted of 149 CBCT images of the mandibles, from 78 males and 71 females who fulfilled the study criteria (age ranged between 21 and 73 years). Standard-setting of the i-CAT system was used for the CBCT scan. Measurements were achieved by the digital ruler included in the viewing software. Mandibular incisive canal's diameter and length were measured. One observer carried out double measurements and observations. The MIC was visible bilaterally in 91.3% of all the images, 85.93% in males, and 97.2% in females. The mean horizontal diameter (MICD-h) was 1.74 mm (SD=0.87). In males and females, the mean MIVD-h was 1.85 mm (SD=0.56) and 1.52 mm (SD= 1.10), respectively. The mean (MICD-v) was 1.73 mm (SD=0.60) which was 1.88 mm (SD=0.64) in male and 1.57 mm (SD= 0.51) in female. The total mandibular incisive canal's length (MICL) was 7.78 mm (SD=4.05) which was 8.44 mm (SD=3.82) in males and 7.11 mm (SD=4.19) in females. All parameters showed significant differences between males and females. The findings suggested that the canal curved downwards toward the inferior mandibular border but did not reach the mandibular midline. Considering the broad variation in mandibular incisive canal anatomic data among populations, the current study may act as anatomical reference data for the Thai population that will be useful to achieve optimal preoperative implant planning.

Keywords: *Dental implant, Inferior alveolar nerve, Mandibular incisive canal*

1. Introduction

Neurosensory impairments resulting from mandibular neurological damage, particularly to the inferior alveolar nerve and its branches, are among the unintended consequences of implant surgery in the mandibular interforaminal region. These complications can arise if critical anatomical elements including the mandibular incisive canal, the length of the anterior mental loop, and the mental foramen are not correctly recognized and safeguarded. Their anatomical structures are frequently damaged from surgical treatment. Prior to implant surgery, it is critical to precisely locate these anatomical features utilizing modern 3D imaging methods such as computed tomography and cone-beam computed tomography (Stratemann et al., 2008).

The inferior alveolar nerve, one of the trigeminal nerve's mandibular divisions, runs forward and downward via the mandibular canal to the mental foramen between the mandible's lingual and buccal cortical plates, where it separates into the mental and incisive nerves. The mandibular incisive nerve is defined as a small canal that runs anterior to the mental foramen. This canal passes through the intramedullary space, and conventional radiography may not be able to identify or define the mandibular incisive canal (MIC). Evidence shows that a real mandibular incisive canal exists, placed medial to the mental foramen, having less cortical bone and a narrowing canal diameter toward the front jaw (Juodzbalys et al., 2010) discovered a well-defined mandibular incisive canal just next to the mental foramen (Mraiwa et al., 2003) investigated the position and orientation of this canal. Statistically, the mandibular incisive canal shifted inferiorly toward the symphysis. When implanting mesial to the mental foramen, it is critical to verify the configuration of the anterior looping of the mental foramen and the diameter and orientation of the mandibular incisive canal. Drilling during implant insertion may irritate the mandibular incisive nerve, resulting in inferior alveolar nerve stretching and injury.

The anterior mental loop is defined as the location of the mental neurovascular bundle anterior to the mental foramen before reversing direction to exit the mental foramen (Ngeow et al., 2009). Vital structures such as the mandibular canal, mental foramen, and incisive nerve canal anatomical data have been given in the interforaminal region via dissection and/or imaging from prior research (Kuzmanovic et al., 2003; Hu et al., 2007; Uchida et al., 2007; Kim et al., 2010; Apostolakis & Brown, 2012; Al-Ani et al., 2013). According to published reports, the properties of these structures appear to be race-related (de Freitas et al., 1979; Green, 1987; Santini & Land, 1990).

Radiographic modalities help clinicians to identify the presence of these anatomical variations. However, traditional two-dimensional radiologic approaches such as panoramic tomography and periapical radiographs are limited in their ability to reveal the mandibular incisive canal (Jacobs et al., 2002; Mraiwa et al., 2003; Ngeow et al., 2009). Hence, several studies have demonstrated that cone-beam computed tomography (CBCT) is an effective tool for pre-operative treatment planning (Jacobs et al., 2018). Numerous CBCT investigations were analyzed to determine the presence and size of the mandibular incisive canal in various populations, but none have investigated these anatomic features in the Thai population (Apostolakis & Brown, 2012; Pires et al., 2012).

2. Objectives

This research was designed to determine the prevalence and course of the mandibular incisive canal (MIC) using cone-beam computed tomography (CBCT) in the Thai population.

3. Materials and Methods

This retrospective study evaluated the CBCT scans of patients at the Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand between January 2010, and January 2020. Thai patients over the age of 20 years with all teeth in the inter-foraminal area met the inclusion criteria. Patients with pathologic disorders, a history of trauma, or a history of anterior mandibular surgery were excluded from the research. CBCT scans were excluded if the images demonstrated inadequate image quality or if the field of view did not cover the region of interest. Patients with significant crowding of the anterior mandible teeth and patients who were receiving fixed orthodontic treatment were also excluded. None of the participants had any systemic bone diseases. The Human Research and Ethics Committee at Chulalongkorn University's Faculty of Dentistry, Bangkok, Thailand, accepted the current study under the study code HREC-DCU 2020-030.

A total of 149 CBCT scans of the mandibles from 78 males and 71 females (ages ranging between 21 and 73 years old) were selected. All CBCT images were acquired using standard exposure parameters on an i-CAT® CT scanner (i-CAT® Cone Beam 3-D Imaging System, Imaging Sciences International, Hatfield, PA, USA).

I-CAT® Vision program on a screen equipped with an Intel UHD Graphics 620 (CPU @ 2.50GHz) (Microsoft Surface, Microsoft, USA) in a well-lit environment was used to analyze the CBCT radiographs. All images were evaluated by one pre-calibrated observer who is a dentist with six years of experience.

The observation was performed on both sides of the jaw to establish the MIC's existence and length. The radiographs were observed in the axial view and aligned with the mandible inferior border. Then, a reformatted panoramic view was generated. Then, perpendicular to the reformatted panoramic view, cross-sectional slices with a 0.25 mm slice interval were presented.

Cross-sectional imaging depicted the MIC as a circular or oval radiolucent canal running from the anterior border of the mental. The anterior region of the mental foramen was detected in the axial view. When the anterior loop (AL) was visible, the most anterior segment of the AL was regarded as the origin of the MIC. The mandibular incisive canal's length (MICL) was determined by the amount of successive cross-sectional slices taken from the start of the canal to the last slice that the canal was visible (figure 1).

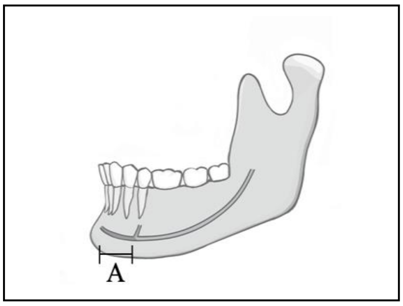

Figure 1 Drawing of the mandible indicating "A" as a length of the mandibular incisive canal (MICL)

The diameters of the mandibular incisive canal (MICD), both horizontal (MICD-h) and vertical (MICD-v) were measured at its origin (figure 2).

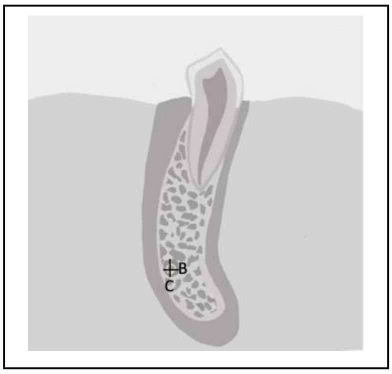

Figure 2 Drawing of the MIC at the origin. The horizontal diameter of the mandibular incisive canal (MICD-h) (B) and vertical diameter of the mandibular incisive canal (MICD-V) (C) at the origin

All data were entered into an excel sheet (Microsoft Office 2020) and evaluated by SPSS 22.0 (SPSS, Chicago, IL, USA). To compare data between males and females, the Mann-Whitney U test was utilized. The significant level was set at $p<0.05$. Twenty percent of the samples were randomly selected, and measurements were repeated after a 4-week-time interval intraobserver reliability is determined using the intraclass correlation coefficient (ICC).

4. Results and Discussion

4.1 Results

The MIC was identified bilaterally in 91.3% of all the subjects, 67 (85.93%) in males and 68 (97.2%) in females. Good intra-observer reliability was achieved with ICC presenting consistent data of the diameter and length of the canal (ICC value = 0.8).

CBCT scans of 149 subjects (298 hemimandibles), consisting of 78 (52.3%) males and 71 (47.6%) females were included in the current research. The age range was 21 to 73 years old (mean age was 47.15±14.26 years old). The distribution patterns of subjects in each age group and sex are shown in Figure 3.

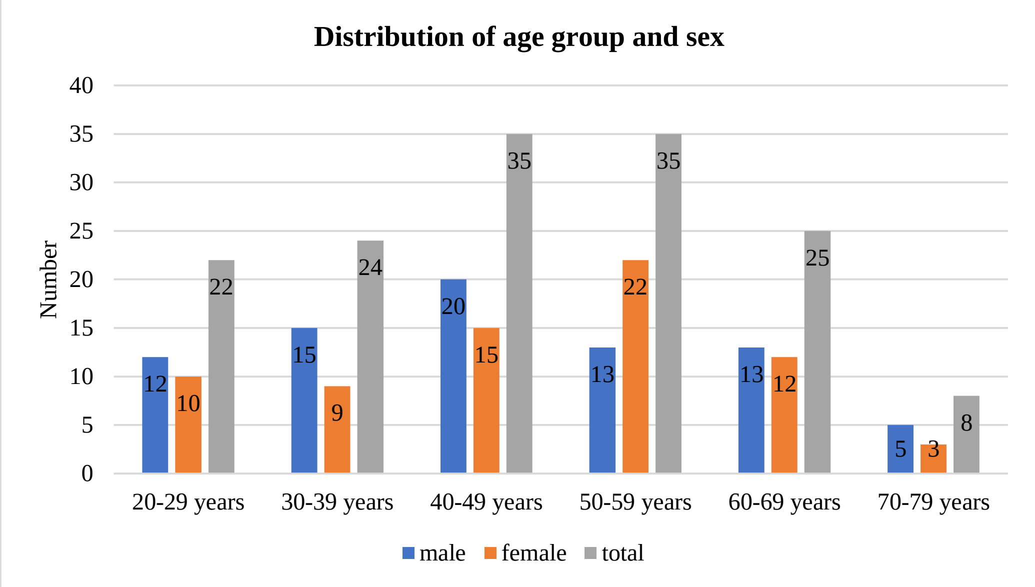

Figure 3 Distribution of subjects in each age group

Morphometric measurements of the MIC were presented in table 1. The mean MICD-h was 1.74 mm (SD=0.87). In males and females, the mean MICD-h was 1.85 mm (SD=0.56) and 1.52 mm (SD= 1.10), respectively. The mean MICD-v was 1.73 mm (SD=0.60). In male and female, mean MICD-v were 1.88 mm (SD=0.64) and 1.57 mm (SD= 0.51), respectively. The total length of the mandibular incisive canal (MICL) was 7.78 mm (SD=4.05). The length of the incisive canal in male and female were 8.44 mm (SD=3.82) and 7.11 mm (SD=4.19), respectively. Males and females demonstrated statistically significant differences in all variables (p0.05).

The course of the canal was curving downwards toward the inferior mandibular border but did not reach the mandibular midline.

Table 1 Comparison of mandibular incisive canal diameter and length according to sex

	Mean (SD)			
Variables (mm.)	**Total (n=149)**	**Male (n=78)**	**Female (n=71)**	**P-value**
Horizontal diameter	1.74 (0.87)	1.85 (0.56)	1.52 (1.10)	0.001*
Vertical diameter	1.73 (0.60)	1.88 (0.64)	1.57 (0.51)	0.005*
Length	7.78 (4.05)	8.44 (3.82)	7.11 (4.19)	0.008*

*A significant difference at P value < 0.05

4.2 Discussion

It has been demonstrated that the use of CBCT in dento-maxillofacial imaging allows for the accurate 3D analysis of anatomical structures with a relatively low radiation dose (Parnia et al., 2012). CBCT has been widely suggested to identify anatomical structures, including the MIC. The present study revealed that the MIC was identified bilaterally in 91.3% of all the subjects which was consistent with previously published studies using CBCT that the MIC could be detected ranging from 81.3%-100% of the subjects (Pires et al. 2012; Al-Ani et al. 2013; Sahman et al. 2013; Xu et al. 2015). Similar to the current findings, other studies have found that the tendency of the MIC was higher in females than males (Misch and Crawford 1990; Jacobs et al. 2002; Apostolakis and Brown 2012; Gomes et al. 2018). The differences in the prevalence of MIC could be attributed to different resolutions and image quality of CBCT machines.

Numerous investigations have been conducted to determine the length and diameter of the MIC. According to Andrade et al., the average length of the mandibular canal is 21 mm (De Andrade et al., 2001). In their previous CBCT investigations, Makris, Pires, and other researchers determined the mean length of the incisive canal to be 15.13 mm and 7 mm, respectively (Makris et al., 2010; Pires et al., 2012). Apostolakis and Brown (2012) found that the mean length of incisive canals was 8.9 mm, and the 24.6 mm was found to be the longest. In comparison to the studies by De Andrade et al. and Makris et al., the mean MICL recorded in this report was shorter, which could be due to a variety of variables (De Andrade et al. 2001, Makris et al. 2010). First, the criteria for identifying the canal here needed its practically continuous presence to avoid confusion with other canals in the region, since multiple canals have been proved to pierce the mandible's lingual cortex and run an intraosseous course (McDonnell et al., 1994; Tepper et al., 2001). On cross-sectional imaging, confusion between these canals and the mandibular incisive canal may result in an over-or underestimate of canal length. Second, this study did not include the length of the anterior loop (AL), which decreased the mean MICL which was different from any previous studies. Third, it appeared that, while a canal was discovered in most cases, a canal could not be recognized in a minor percentage of cases (8.7%). This might be because the incisive canal is composed of intertrabecular gaps that are densely packed with neurovascular bundles. Then, the length of the canal was determined to be zero in these cases and was comprised in the calculation. The last factor might be due to different ethnicities among samples as the average shape and size of the mandibles in various populations are different. In this study, all subjects were Thai. In other studies, subjects were Caucasian (Apostolakis & Brown, 2012; Sahman et al., 2014), and Chinese Mongoloid (Kong et al., 2016; Xie et al., 2019) respectively.

In this study, the mean MICD-h and MICD-v were 1.74 mm and 1.73 mm. The canal became narrower when close to the midline. This finding is consistent with the results of previous studies. Mardinger et al. 2000; Mraiwa et al. 2003; Parnia et al. 2012 found that the mean diameters were 1.1, 1.2, 1.8, and 1.47 mm, respectively, and with Obradović et al (1995), stated that a diameter range of 0.48 to 2.9 mm. Mraiwa et al (2003) identified the widest canal in these studies (3.4 mm). However, the size of the canal in this study was much smaller than the sizes reported by Uchida et al (2007) (up to 6.6 mm) and Pires et al (2012) (0.4–4.6 mm).

Some research limitations could not be avoided. Firstly, the number of samples that could be included was limited to strict inclusion criteria. More samples may help validate the results. Secondly, one observer explored all images. Another observer with more experience in viewing CBCT should be added in a future study to assess inter-observer agreement.

Placing an implant in the mandibular interforaminal region might not always be accomplished without complications as shown that practically all patients had a mandibular incisive canal. In 1996, Rosenquist postulated that an implant placement in the canal may not osseointegrate and trauma-induced epineurium edema may spread to the nerve. resulting in neurosensory impairment in the nerve's main branch (Rosenquist, 1996). According to a study, sensory abnormalities in the mental nerve area following implant placement are caused by damage to a long, wide-width incisive nerve (Kohavi & Bar-Ziv, 1996). An instance of unexpected discomfort following implant placement in a large-diameter incisive canal was recently reported (Romanos & Greenstein, 2009). Nevertheless, equipped with 3D imaging modalities like CBCT, clinicians should be able to detect the MIC prior to implant surgery, allowing dentists to optimize the treatment plan for the patients.

5. Conclusion

Considering the broad variation in mandibular incisive canal anatomic data among populations, the current study may act as anatomical reference data for Thai population that will be useful to achieve optimal preoperative implant planning.

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