Estimated of Mandible Size and Morphology Using CT for Dental Implantation

デンタルインプラントの為のCTによる下顎骨のサイズと形態の推定

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Ⅰ. Introduction

It is essential to examine bone size and morphology for pre-operative planning of implant placement[3]. The selection of implant size is dependent on available bone height, width and the location of mandibular canal. Furthermore, information of regarding bone morphology may restrict implant insertion angle. Recently, progress has been made in bone grafting techniques, and flapless implant surgery, a precise prehension of bone size and morphology results in a better surgical approach[7, 9].

A number of researchers have precisely measured the size of the mandible using radiologic technique. Lindh *et al*[5] measured the mandible height and identified the location of the mandibular canal with panoramic radiography and conventional tomography, comparatively. They have concluded that the tomography technique gave a more accurate value than panoramic radiography techniques. Bolin *et al*[2]. in 1996 compared two radiological techniques (panoramic radiography and conventional tomography) and described the correlation between them widely ranged from 0.36 to 0.91. Although clinically panoramic radiography is the most widely available and frequently used for preoperative examination[4], it is inevitable to avoid image distortions and instable magnifications that give less accurate information. On the other hand, conventional tomography is more accurate than panoramic radiography, but it is difficult to adjust the topographic objective planes, which results in a difference in actual and measurement size[6]. Tal *et al*[13] concluded that CT had the unique advantage for measuring the precise size and shape of bone when compared to panoramic radiography. Quirynen *et al*[10]. and Tepper *et al*[12] measured the size of the mandible using CT, but these measurements were limited to the only

interforaminal region.

Dental implant treatments are applied not only in the anterior regions, but more frequently in the posterior regions. Therefore, it is important to know the standard mandible size and morphology. The aim of this study is to measure the bone size in the five sections between 6 mm anterior and 18 mm posterior from the mental foramen, and determine the locations of the mandibular canal and the standard mandible morphology using available CT images.

Ⅱ. Material and Methods

Patients：Eighty Japanese patients (male/female, 52/28；age range, 10～77 years；mean age, 49 years) were included in this study. The eighty patients visited at Dental hospital of Tokyo Medical and Dental University from June 2005 to February 2006. This study aimed to estimate the standard size, morphological shape and location mandibular canal of mandible. Patients with mandible side containing either tumor or cyst were excluded from this study. In total, one hundred and thirty eight sides of mandibles were examined.

Imaging:Computed tomography (CT) examination was performed using a Somatom plus S scanner (Siemens Medical Systems, Erlangen, Germany), which operated at the 120 kV and 85-110mA with a 1mm beam thickness and a table speed of 2mm/sec. One millimeter of reconstructed axial images were obtained parallel to the inferior border of mandibles and these images were applied to Dental CT® reformatting imaging software. Two millimeter increment of cross-sectional images was obtained. These images were printed on films by a Fuji Dry imager (Fujifilm, Tokyo, Japan).

Measurement procedure：The height and width of mandible were measured at the five sections as followings. The cross-sectional image which a mental foramen was recognized was defined as the measurement section 2, and the image of 6 mm anterior to the section 2 as the measurement section 1. On the contrary, the image of 6-, 12-, and 18-mm posterior to section 2 was defined as the measurement section 3, 4, and 5, respectively as shown in Figure 1(A). In each section, the height was determined as the vertical line from the inferior border to the alveolar crest of mandible. The widths (total width, cortical and cancellous bone width) of A, B, C, and D was measured at four respective different height; 5,10,15, and 20 mm distances as horizontal line from the inferior border of the mandible toward the alveolar crest as shown in Figure 1(B). The morphological shapes of the mandibles were classified into three types using the cross-sectional images as follows；type A is round in the buccal side and concavity in the lingual side, type B concavity in the buccal and round in the lingual, and type C round shape in the both sides. To identify the location of the mandibular canal,

fig. 1 Schematic diagram of the measurement sites (a) and a cross-sectional image (b)
図1 計測部位（a）と縦断像（b）の図

table. 1 Patients Characteristics and Measurements
表１ 患者

Age（year）	Total	Sex		Sides	Mesaurements	
		Male	Female		Hights	Widths
14～19	2	0	2	3	15	60
20～29	9	7	2	13	65	260
30～39	13	10	3	21	105	420
40～49	13	7	6	21	105	420
50～59	17	12	5	34	170	680
60～69	20	10	10	37	185	740
70～79	6	6	0	9	45	180
Total	80	52	28	138	690	2760

table. 2 Mandible sizes of all patients
表２ 下顎骨のサイズ

Section		1	2	3	4	5
Hight（mm）		31.0±3.8	30.3±3.5	28.8±3.6	28.1±3.5	27.6±3.7
Width（mm）	A	11.3±1.6	10.8±1.5	10.5±1.3	10.5±1.3	11.0±1.3
	B	11.6±1.8	11.7±1.7	12.3±1.9	12.6±1.8	13.1±1.8
	C	11.5±1.6	12.1±1.6	13.6±1.8	14.8±1.8	15.8±1.9
	D	11.3±1.9	11.8±2.2	12.8±2.9	14.0±3.2	15.3±2.8

the distance from the alveolar crest to the superior border of mandibular canal were measured at the five sections described above.

Statistical Analysis：All data were represented as means and standard deviations (s. d.). The statistical difference was tested by the Student *t* test or the chi square test. *P* value less than 0.05 was considered to be significant.

Ⅲ. Results

Table 1 shows the patients distribution regarding age and gender. The age ranged from 10 to 77 years. Table 2 represents the measurement numbers of the right and the left sides of mandible, the age group, and the numbers for the heights and widths. In total, we measured 138 sides of mandibles and 690 heights and 2760 widths.

1. Size of mandible

The height and the width of mandible were shown in Table 3. The means and standard deviations of the heights ranged from 27.6±3.7 to 31.0±3.8 mm, and the widths from 10.5±1.3 to 15.8±1.9 mm. The bone height was at the greatest in section 1 and gradually decreases from section 1 to 5 (Figure 2 A). The mandibular heights and

table. 3-A Mandible sized of males
表３-A 男性の下顎骨サイズ

Section		1	2	3	4	5
Hight（mm）		31.6±3.7	30.9±3.4	29.5±3.3	28.7±3.2	28.0±3.9
Width（mm）	A	11.8±1.5	11.2±1.4	10.9±1.3	10.9±1.3	11.3±1.2
	B	12.3±1.7	12.3±1.7	12.9±1.8	13.0±1.9	13.6±1.8
	C	11.9±1.7	12.5±1.6	14.0±1.8	15.2±1.8	16.1±2.1
	D	11.7±2.1	12.1±2.3	13.4±2.9	14.5±2.9	15.6±2.8

table. 3-B Mandible sizes of females
表３-B 女性の下顎骨サイズ

Section		1	2	3	4	5
Hight（mm）		29.8±3.7	29.1±3.3	27.5±3.8	27.1±3.8	26.8±3.4
Width（mm）	A	10.3±1.1	9.9±1.3	9.7±1.1	9.9±1.1	10.5±1.4
	B	10.4±1.2	10.6±1.2	11.1±1.3	11.7±1.3	12.3±1.3
	C	10.8±1.4	11.4±1.5	12.8±1.5	14.2±1.5	15.1±1.5
	D	10.5±1.4	11.1±1.8	11.8±2.5	12.9±3.3	14.7±2.6

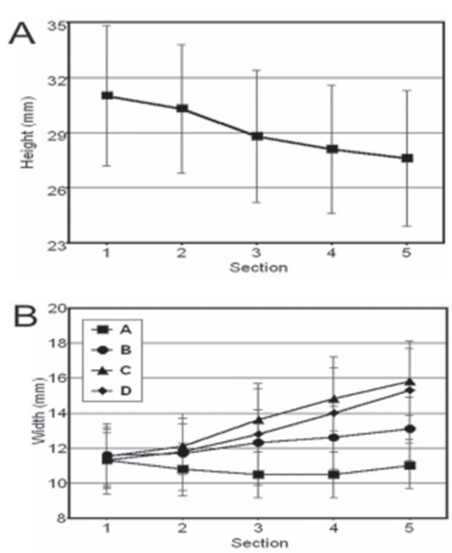

fig. 2 Mandible size of all patients : a heights and b widths
図２ 下顎骨のサイズ：高さと幅

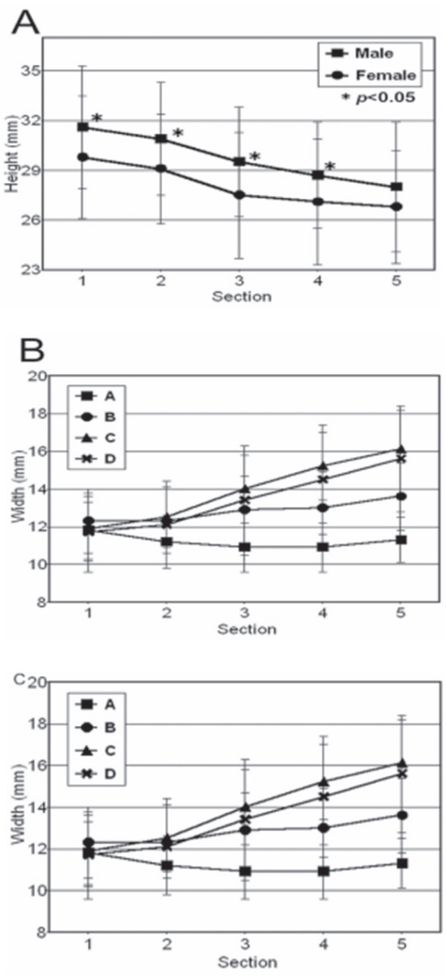

fig. 3 Mandible size by sex : a height of 52 male and 28 female patients, b widths of 52 male, c widths of 28 female patients

図３ 性別による下顎骨のサイズ： a 52人の男性と28人の女性の下顎骨の高さ、 b 52人の男性の下顎骨の幅、 c 28人の女性の下顎骨の幅

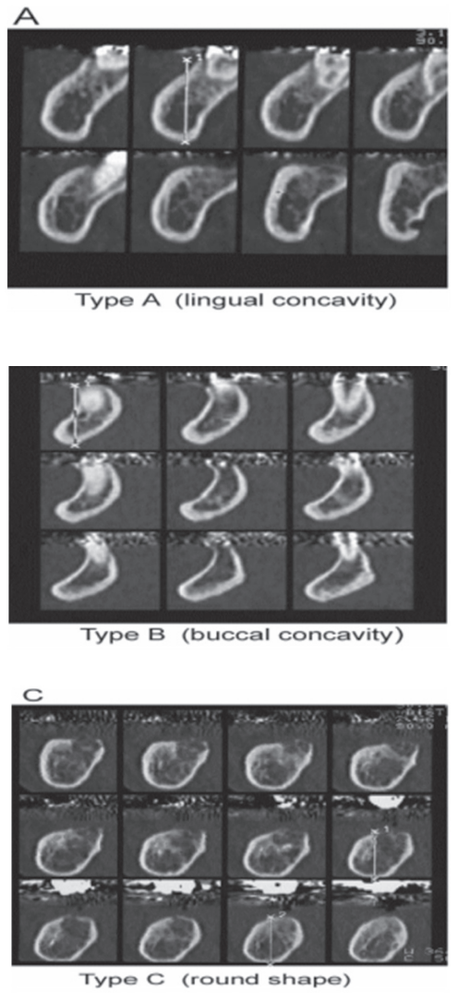

fig. 4 Cross-sectional CT images representing the mandible shapes (types A, B, C)

図４ 下顎骨の形態を示す縦断CT像（タイプA、B、C）

widths for male and female were presented in Table 3A and B, respectively. Mandibular heights for male and female ranged from 28.0±3.9 to 31.6±3.7 mm and from 26.8±3.4 to 29.8±3.7 mm, respectively. While mandibular widths ranged from 10.9±1.3 to 16.1±2.1 mm and from 9.7±1.1 to 15.1±1.5 mm, respectively. Mandibular heights for male were significantly greater than those in female except for section 5 (Figure 3 A). Mandibular widths in section 1 reveals almost the same value irrespective of the measurement heights, but there was a tendency for the width to increase depends on the heights gradually from the section 2 to 5 (Figure 2 B). Although it was not significant, the values of mandibular widths in male were greater than that those in female (Figure 3 B and C).

２. Morphological shape of mandible

The shapes of the mandible were classified into the three types shown in figure 4. Type A and type C were common in section 3, 4, and 5 in the posterior regions, and type B was popular in

table. 4 Morphological shapes of mandibles
表４ 下顎骨の形態

Section	1	2	3	4	5
TypeA	8%	5%	20%	39%	38%
TypeB	74%	58%	17%	2%	1%
TypeC	18%	37%	63%	59%	61%

section 1 and 2 in the anterior regions (Table 4). This result reveals, the morphological shapes of the mandibles were not influenced by gender or side (chi-square test, data not shown).

３. Location of mandibular canal

The distances from the alveolar crest to the mandibular canal in each section were measured. In section 2, not only the canal exists, but also the mental foramen, so both distances were measured. Figure 5 illustrates the distance from the alveolar crest to the superior border of mental foramen was 11.7±3.0 mm, and the distances to the top of canal were 15.0±3.0, 13.5±2.9, 13.6±2.9, 12.9±3.2 mm in the section 2, 3, 4, 5, respectively. The inferior alveolar canal usually extends ahead of the mental foramen as so called "anterior loop". In this study the anterior loop was present about 76 sites (55%) and the distance was 15.1±3.2 mm.

Ⅳ. Discussion

The aim of this study was to determine the standard sizes and the common morphology of mandible and location of the mandibular canal using CT. Hence we measured the various parameters on the CT images of a large sample formed by 138 mandible sides.

Ⅳ-Ⅰ. Height and width

The vertical height of the mandible was the longest in the 6 mm anterior and the shortest in the 18 mm posterior section from the mental foramen. Bolin *et al*[2] describes the bone height was the greatest in the second premolar region and the least in the second molar region using panoramic

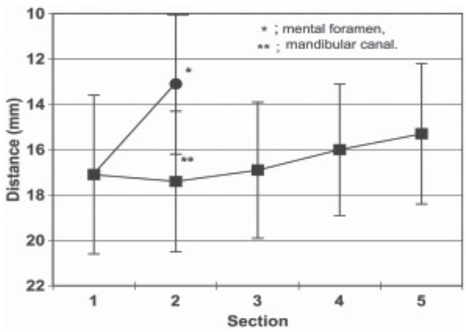

fig. 5 Distance from the superior aspect of the canal to alveolar crest (SAC). *Represents mental foramen, **mandibular canal
図５ 下顎骨の上縁から歯槽頂までの距離 *オトガイ孔 **下顎管

technique. Our data reveals similar results, but we measured the wider regions of mandible, concluding the longest height was around the canine region of section 1 and the least in the second molar region of the section 5. The heights were significantly different between genders. Our results reveal the height of males were maximally 2 mm higher than that of females. In the anterior regions, the mandible width represented almost the same value, but gradually increased depends on the heights in the posterior regions. The widths were widest in 15 mm above at level B in the anterior regions and the 10 mm above at level C in the posterior regions. Generally, the shapes of alveolar crest have a wide variation because of the atrophic changes by periodontal diseases[14] and/or teeth extraction[8]. It is worthy to note measuring widths at the levels from the alveolar crest origin should be avoided. Our method of measuring at levels from the inferior border origin produces more reproducible results. However, we could not get any statistically significant difference about the width values; this means the higher diversity of the mandible width exists than the heights

Ⅳ－Ⅱ. Morphological shape

In order to prevent the lingual or buccal strip

perforation under drilling step, the implant should be installed according to the shape of mandibles. In our study, the morphologies of mandible were classified into the three types (type A, B, and C). Quirynen *et al*[10] investigated the morphological shape of the mandible only within the interforaminal regions, and reported a round shape was the most frequently observed (69.5%), but a lingual concavity was rare only 2.4%. However we found that the round shape (type C) was relatively minor (18～37%), and the buccal concavity shape (type B) was the most popular (58～74%) in the section of 1 and 2. We cannot explain the reason of this incompatibility, but it might be due to race difference. The buccal cortical bone represents type B is higher risk of perforation, so the implant should be inserted toward the lingual angle. We extended the evaluation further to the posterior regions of mandible and found the round shape of type C (59～63%), lingual concavity of type A (20～39%), and the buccal concavity (1～17%) were common in these regions. The risk of type A is connected with a lingual cortical bone perforation. On implant insertion, it should be inserting toward the buccal angle. But, because there are some lateral bone contents in posterior regions, the risk may be lower than the anterior region. The risk of type C is considered to be lower than the other types because of the sufficient lateral bone in the posterior regions.

Ⅳ－Ⅲ. Location of mandibular canal

In the posterior regions, it is important to determine the available bone quantity to avoid intervention with the inferior alveolar nerve bundle (IANB). We tried to determine the standard location of the mandibular canal using the CT images and the result was shown in Fig. 5. The distance from the alveolar crest to the mandibular canal was the longest in the section 2 (15.0±3.0mm) and gradually decreasing toward to the section 5 (12.9±3.2mm).

Oral implants frequently perforated to the unidentified extent of the canal in the interforaminal regions. Arzouman *et al*[1] pointed out that the IANB may extend beyond the mental foramen as an "anterior loop". Solar *et al*[11] reported that a safe distance was at least 6 mm anterior to the mental foramen for implant installation. But, we detected fifty five percent of "anterior loop" in the section 1 that was 6 mm anterior from the mental foramen. The distance from the alveolar crest to the "anterior loop" was 15.1±3.2 mm, whereas that to the mental foramen was only 11.7±3.0 mm. The facts means that in the medial area of mental foramen the canal is radically ascending toward the mental foramen, therefore, implant surgeons should take into account that the interventional risk of the IANB would be high.

Ⅴ. Conclusions

Using CT cross sectional images, we estimated the precise size and the detailed morphology of mandible. We convince the information including average height, width, and shape of the mandible would be useful for dental implant surgery.

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This study aims to analyze the size and morphology of mandible and to identify the location of the mandibular canal using computed tomography (CT) scans. CT data of eighty Japanese patients (male/female, 52/28, age range, 10～77 years; mean age 49 years) were obtained and analyzed. The means and standard deviation of the height and width varied from 27.6±3.7 to 31.0±3.8 mm and from 10.5±1.3 to 15.8±1.9 mm, respectively. The means and standard deviations of cortical and cancellous bone width ranged between 4.3±1.0 mm to 5.7±1.4 and 5.3±1.3 mm to 10.7±2.8, respectively. The morphological shapes of mandible were classified into the three types. The type C (59～63%) was the most common in the posterior region followed by the type A (lingual concavity) (20～39%), whereas, the type B (buccal concavity) was the most common (58～74%) in the anterior region. The distance from the alveolar crest to the mandibular canal ranged from 12.9±3.2 to 15.0±3.0 mm. The "anterior loop" was observed about 55% of total sides. In conclusion, CT cross sectional images provided the standard sizes, the detailed morphology of mandible and the location of mandibular canal. These measurement data would be useful for treatment and planning of dental implant surgery.

●抄録● デンタルインプラントの為のCTによる下顎骨のサイズと形態の推定
／ Mohammad Abdul MOMIN

本研究は、コンピューター断層撮影（CT）を使って、下顎骨のサイズと形態を分析し、下顎管の位置を把握することを目的として行われました。

80人の日本人の患者（男女比52人対28人、年齢は10歳から77歳；平均49歳）のCTデータが分析されました。

下顎骨の高さと幅の平均値および標準偏差はそれぞれ27.6±3.7mmから31.0±3.8mm、10.5±1.3mmから15.8±1.9mmでした。皮質骨と海綿骨の幅の平均と標準偏差はそれぞれ4.3±1.0mmから5.7±1.4mm、そして5.3±1.3mmから10.7±2.8mmでした。下顎骨の形態は3タイプに分類されました。臼歯部ではタイプC（59-63%）が最も多く、続いてタイプA（舌側の陥凹）（20-39%）であった。それに対して 前歯部ではタイプB（頬側の陥凹）が最も多い（58-74%）という結果でした。歯槽頂から下顎管への距離は12.9±3.2mmから15.0±に3.0mmでした。Anterior loopは約55%に認められました。

結論として、CT像は下顎骨の標準サイズ、詳細な形態、および下顎管の位置の情報を提供しました。これらの測定データはインプラントの治療と計画に有益と考えます。

キーワード：コンピュータ断層撮影(CT)、下顎骨のサイズ、下顎骨の形態、下顎管、デンタルインプラント