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Comparison of Three-Dimensional and Two-Dimensional Computed Tomography Scans for Cephalometric Mandibular Measurements in Thailand: A Retrospective Study

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ABSTRACT

Objective: To evaluate whether 2D computerized tomography (CT) cephalometric measurements are comparable to 3D CT measurements of the mandible bone.

Material and Methods: In this retrospective study, we collected data from patients who visited the emergency room of Songklanagarind Hospital between 2017 and 2020. A single operator identified 11 landmarks for cephalometric measurements in all images. Each image underwent three separate tracings, and subsequent repeated measurements were employed for further statistical analyses.

Results: This study included 135 patients (87 males and 48 females). The mean age of the patients was 40.48±15 years. Nine of the eleven parameters showed a significant difference between the 2D and 3D cephalometric measurements (p-value<0.05). Male patients had a longer mandible than female patients, and there was a statistically significant size difference between the sexes (p-value<0.05), except for the mental foramen size (pair t-test >0.05). Length measurements displayed a statistically significant positive correlation with height and BSA (p-value<0.05), while no correlation was observed with body mass index (BMI) (p-value>0.05). Angle measurements did not exhibit any correlation with height, BSA, or BMI.

Conclusion: In this study, 2D cephalometric measurements were significantly different from 3D CT measurements in each individual. Based on these findings, we recommend that surgeons should consider using 3D CT cephalometric measurements.

Keywords: age; cephalometric measurement; mandibles; maxillofacial bone

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INTRODUCTION

The mandible, the largest and strongest facial bone, takes the form of a "U-shaped" structure and articulates with the cranial base through the temporomandibular joint (TMJ)[1]. It plays a pivotal role in dental occlusion, forming a functional interface with the maxilla. Various anatomical regions of the mandible include the symphysis, parasymphysis, body, angle, subcondylar and condylar regions, and alveolar ridge. The condyle can be further divided into condylar (intracapsular) and subcondylar regions (extracapsular). The mental foramen represents the anterior loop of the mental nerve (MN), holding significant importance as the surgical landmark, particularly in osteotomy procedures. Awareness of potential variations is crucial for enhanced clinical practice and to prevent unnecessary complications[2] (Table 1).

In cases of oromandibular reconstruction resulting from benign tumors, cancer, osteomyelitis, osteoradionecrosis, or trauma, surgical interventions on the jawbone are essential for both functional and aesthetic purposes. The goals of mandibular reconstruction include restoration of deglutition, speech, airway support, oral sphincter competence, and cosmetic propose[3,4]. The extent of bone resection significantly impacts the postoperative quality of life, thus necessitating thorough consideration in the surgical planning[5]. Mandibular measurements, including length, width, and angular measurements such as mandibular angle reduction, corticectomy, and genioplasty are important in facial contour surgery.

The mandible exhibits variations within the human population influenced by factors such as age, gender, and dental status, and these variations persist throughout life. A 2011 study conducted in Nigeria revealed that a normal-sized mandible typically measures within or above the range of 17.22–19.33 cm in males and 16.44–18.67 cm in females. Additionally, this study highlighted significant gender differences in mandibular width (p-value<0.05, 95% confidence interval (CI))[6]. A retrospective radiographic analysis of mandibular studies in 2016 showed significant gender -based differences in mandibular components, including ramus height, coronoid height, bigonial angle, and width. The mean values for these dimensions were higher in males than in females[7].

Computed tomography (CT) is widely regarded as the gold standard for bone measurements. A 2009 study demonstrated that there are no clinically relevant differences between angular and linear measurements obtained from conventional cephalometric radiographs and those from three-dimensional (3D) skull models. However, conventional two-dimensional (2D) cephalometry measurement was different from 3D models use measurement[8]. The 3D cephalometric analysis using cone-beam computed tomography (CBCT) has emerged in the field of dental and maxillofacial imaging[9]. All 3D imaging procedures yielded nearly similar results when used to measure the condylar process and ramus height. Therefore, 3D imaging methods are necessary to obtain conclusive information on the condylar growth[10]. Moreover, the foramen may not be visible on conventional radiographs. CT scans are more accurate than conventional radiographs for detecting the mental foramen[11].

In Thailand, few studies have been conducted on digital and imaging mandibular measurements. A study conducted during the 2009 carnival season, focusing on mandible length, unveiled that 85% of osteometric parameters in males were significantly higher compared to those in females. Therefore, they can assess gender -based differences in the mandibles[12].

In this study, we aimed to compare 2D and 3D cephalometric measurements of the mandible bone. We included patients with trauma who underwent maxillofacial CT in the emergency room (ER), because most traumatic injuries to the jaw do not result in segmental defects. Mandibular fractures for 20% of facial fractures in patients with trauma[1]. We expect that this study will provide average mandibular length and angle measurements for the Thai population to establish a standard for determining surgical patient groups and outcome evaluations in the field of mandibular contour surgery.

Table 1 The anatomy landmark

Term	Definition
Bilateral landmarks	
Gonion (go)	The midway point between the lowermost point on the posterior border of the ramus and the most posterior point on the lower border of the mandible
Mental foramen	A small foramen on the anterior surface of the mandible, typically adjacent to the root of the mandibular second premolar tooth. Normal variants have the foramen located anywhere between the canine and 1st molar.
Mental nerve	A terminal branch of inferior alveolar nerve and the mental artery leave the mandibular canal through it.
Midline landmarks	
Gnathion (gn)	The middle point on the lower border of the mandible in the sagittal plane
Infradentale (id)	The mid-point of a line tangent to the outer margins of the cavities of the two mandibular central incisor teeth
Pogonion (pg)	The most projecting point of the chin in the standard sagittal line
Menton (Me)	The lowermost point on the symphysis menti on the midsagittal plane

MATERIAL AND METHODS

Study population

Patients who visited the ER of Songklanagarind Hospital between 2017 and 2020 and underwent facial CT for trauma were included. Data were collected by our research team using electronic medical records.

Methods

This retrospective study was approved by institutional ethics committee REC.63-488-10-4. We used the criteria for filtering out all unrelated cases and cases that met the exclusion criteria, and for data retrieval from electronic medical records. Sample cases of CT reports were reviewed (by a radiologist, plastic surgery doctor, and surgery resident) and cephalometric analysis identified 18 bone landmarks. Imaging data were categorized as clearly placed landmarks, and measurements were obtained. All the CT images were used to perform measurements in each dimension. The same operator performed three measurements. The data were collated using Microsoft Excel (Microsoft, Redmond, WA).

Statistical analysis

Demographic data are presented as proportions, mean (with standard deviation), or median (with interquartile range), as appropriate. Comparisons of proportions were assessed using Pearson's chi-square or Fisher's exact test, and a P-value of less than 0.05 was considered statistically significant. R version 4.0.3; R Foundation for Statistical Computing) was used for all statistical analyses.

RESULTS

The study included 135 patients (87 males and 48 females). Among them, 126 identified as Buddhists and nine as Muslims. The mean age of the patients was 40.48±15.61 years. The mean height was 164.51±9.13 cm; the mean body mass index (BMI) was 24±4.35 kg/m^2; and the mean Body surface area (BSA) was 1.69±0.18 m^2. Almost all patients were the class I occlusal relationship (92.6%). One patient had a history of facial surgery of the lateral wall orbit. Two patients had a history of upper facial fractures (Table 2).

Comparison of length and angle measurements between 2D and 3D CT

The length measurements obtained from 3D CT were consistently greater than those acquired through 2D CT. However, the angle measurement from 2D CT exceeded that from 3D CT. It is noteworthy that when comparing 2D and 3D CT measurements, all length and angle parameters

exhibited statistically significant differences (p-values<0.05), with the exception of maximum ramus height and minimum ramus breadth, for which the differences were not statistically significant (p-values=0.49 and 0.09, respectively) (Table 3).

Comparison of measurements according to gender

Males exhibited a greater mandibular length compared to that in females, with statistically significant differences between both genders (p-values<0.05), except for the size of the mental foramen (pair t-test p-value>0.05) (Table 4). Additionally, females displayed larger mandibular body curves and mental angles, while males had larger gonial angles. Interestingly, there were no statistically significant differences between both genders (paired t-test p-values>0.05). (Table 4)

Comparison of measurements between individuals of different religions

The length and angle measurements did not exhibit statistically significant differences between individuals of different religions (Table 5).

Correlation between mandibular measurements and height, BSA, and BMI

Length measurements demonstrated statistically significant positive correlations with both height and BSA (p-value<0.05) according to Pearson's correlation coefficient analysis. However, no correlation with BMI was observed (p-value>0.05). The maximum correlation of height was seen with body length (Go-Gn) and maximum ramus height (Pearson's correlation coefficient=0.54 and 0.51, respectively), indicating a moderate correlation. In contrast, the maximum correlation of BSA was seen with body length (Go-Gn) and maximum ramus height (Pearson's correlation coefficient=0.4 and 0.36, respectively), indicating a low correlation (Table 6).

Angle measurement showed no statistically significant correlation with height, BSA, or BMI (p-value>0.05) (Table 6).

Table 2 Patient characterisitics

Variable	Amount (percent)
Gender	
Male	87 (64.3)
Female	48 (35.7)
Religion (Amount, percent)	
Buddhism	126 (93.6)
Islam	9 (6.4)
Age (mean, S.D.)	40.48 (15.61)
Body weight (mean, S.D.)	64.92 (12.28)
Height (mean, S.D.)	164.51 (9.13)
BMI	24 (4.35)
BSA	1.69 (0.18)
Underlying disease (Amount, percent)	
None	92 (67.9)
Diabetes mullitus	13 (9.4)
Hypertension	21 (15.7)
Dystlipid	14 (10.1)
other	22 (16.3)
Mechanism of trauma (Amount, percent)	
MCA	87 (64.2)
Fall from ground	15 (11)
Other (Car accident, Body assault, etc	20 (14)
History of Maxillofacial surgery (Amount, percent)	1 (0.7)
History of Maxillofacial problem (Amount, percent)	2 (1.5)

S.D.=standard deviation; BSA=body surface area; BMI=body mass index; MCA=motorcycle accident

Correlation between length measurement parameters

Chin height exhibited a statistically significant positive correlation with both right and left foramen height (p-value<0.01) (Pearson's correlation coefficient=0.51 and 0.55, respectively) (Figure 1). These findings indicate a moderate level of correlation. In contrast, positive, yet relatively lower, correlations were found between body length, maximum ramus height, and chin height (p-value<0.01) (Pearson's correlation coefficient=0.21 and 0.31, respectively).

Maximum ramus height on each side had a statistically significant positive correlation with body length (p-value<0.01) (Pearson's correlation coefficient=0.45 and 0.48, respectively), indicating a moderate correlation.

Table 3 Comparison of length and angle measurements between 2D and 3D CT analyses

Cephalometric measurement (S.D.) (mm/degree)	2D CT		3D CT		Mean difference		p-value	
	Right	Left	Right	Left	Right	Left	Right	Left
Mandibular width	86.11 (6.41)		96.69 (18.03)		−10.58 (17.51)		<0.01	
Maximum mandibular length	129.22 (28.7)	125.72 (35.4)	131.19 (32.9)	129.94 (32.33)	−3.76 (14.65)	−3.18 (14.24)	0.02	0.01
Body length (Go–Gn)	75.53 (5.99)	75.56 (5.7)	78.84 (10.86)	77.91 (10.14)	−5.23 (12.35)	−2.35 (11.48)	<0.01	0.02
Maximum ramus height	59.32 (4.8)	59.33 (5.88)	59.03 (5.8)	58.68 (5.74)	0.28 (4.8)	0.65 (5.21)	0.49	0.38
Minimum ramus breadth	30.93 (3.77)	31.02 (3.66)	32.41 (3.88)	31.92 (4.77)	−1.52 (2.77)	−0.91 (3.95)	0.09	0.08
Chin height	21.18 (4.44)		27.77 (5.51)		−6.76 (5.89)		<0.01	
Mental foramen size	3.02 (0.55)	3.05 (0.58)	2.56 (0.62)	2.63 (0.63)	0.4 (0.75)	0.41 (0.74)	<0.01	<0.01
Mental foramen height	12.58 (1.726)	12.52 (1.82)	13.0.46 (2.42)	12.99 (2.36)	−0.47 (2.3)	−0.47 (2.2)	<0.01	0.01
Angle								
Menton angle	88.48 (12.93)		82.68 (6.48)		5.8 (14.48)		<0.01	
Mandibular body curve angle	153.29 (6.02)	153.36 (6.05)	132.23 (6.4)	134.43 (6.5)	19.05 (7.99)	18.91 (8.1)	<0.01	<0.01
Gonial angle	119.29 (8.33)	119.10 (8.74)	117.97 (6.39)	116.84 (6.14)	1.27 (7.987)	1.45 (8.2)	0.04	0.03

CT=computer tomography; S.D.=standard deviation

Table 4 Comparison of measurements between sexes

Cephalometric measurement	Total (N=135)		Male (N=87)		Female (N=48)		p-value	
	Right	left	Right	Left	Right	Left	Right	Left
Maximum ramus height	59.18 (5.74)	59.21 (5.87)	61.5 (5.3)	61.2 (4.2)	55.2 (4.1)	55.45 (5.25)	<0.01	<0.01
Body length (Go–Gn)	75.4 (5.87)	75.41 (5.62)	77.5 (5.7)	77.6 (5.3)	71.8 (4.5)	71.8 (4.6)	<0.01	<0.01
Maximum mandibular length	133.61 (14.95)	133.65 (15.1)	138.32 (9.82)	137.98 (10.12)	126.36 (4.87)	126.35 (6.37)	<0.01	<0.01
Mandibular width	86.12 (6.48)		88.1 (5.9)		82.4 (5.6)		<0.01	
Minimum ramus breadth	30.93 (3.77)	30.98 (3.69)	32 (3.7)	32 (3.6)	29 (3.3)	29.2 (3.2)	<0.01	<0.01
Chin height	21.02 (4.5)		21.18 (3.82)		18.65 (3.22)		<0.01	
Mental foramen height	12.53 (1.84)	12.47 (1.91)	12.94 (1.27)	13.07 (1.05)	11.59 (1.27)	11.42 (1.5)	<0.01	<0.01
Mental foramen size	3 (0.61)	3.44 (3.2)	3.1 (0.6)	3.07 (0.6)	2.9 (0.5)	2.96 (0.52)	0.117	0.322
Angle								
Gonial angle	119.26 (8.33)	119.05 (8.74)	119.5 (9.1)	119.5 (9.2)	119 (6.8)	118.3 (7.8)	0.738	0.432
Mental angle	88.79 (13.04)		88.3 (13.8)		88.7 (11.3)		0.87	
Mandibular body curve angle	153.4 (5.93)	153.6 (6.17)	152.65 (5.25)	152.5 (6)	153.42 (4.9)	153.9 (5.8)	0.07	0.09

Table 5 Comparison of measurements between individuals of different religions

Cephalometric measurement	Buddhism (N=126)		Islam (N=9)		p-value	
	Right	Left	Right	Left	Right	Left
Maximum ramus height	59.4 (5.6)	59.4 (5.9)	57.8 (7.6)	59 (6.5)	0.395	0.859
Body length (Go-Gn)	75.4 (6)	75.5 (5.8)	76.8 (5.8)	75.7 (5.1)	0.497	0.921
Maximum mandibular length	133.46 (11.17)	133.17 (11.47)	134.98 (7.27)	134.92 (7.19)	0.776	0.628
Mandibular Width	86.1 (6.4)		86.8 (7.3)		0.731	
Minimum ramus breadth	31 (3.8)	31.1 (3.6)	30.5 (3.8)	29.5 (3.8)	0.691	0.166
Chin height	20.39 (3.52)		21.2 (7.57)		0.974	
Mental foramen height	12.6 (1.7)	12.59 (1.27)	12.8 (1.5)	13.18 (1.27)	0.63	0.118
Mental foramen size	3 (0.6)	3.07 (0.6)	2.9 (0.5)	2.83 (0.39)	0.755	0.524
Gonial angle	119.4 (8.3)	119.1 (8.6)	118 (8.7)	119 (10.5)	0.614	0.972
Mental angle	88.3 (13)		91.4 (12.9)		0.461	
Mandibular body curve angle	153.65 (5.25)	153.6 (6)	150.77 (4.35)	149.4 (4.7)	0.082	0.032

Table 6 Correlation between measurements and height, BSA, and BMI

Cephalometric measurement (S.D.)	Pearson's correlation coefficient								
	Body height			BSA			BMI		
	Right	Left	p-value	Right	Left	p-value	Right	Left	p-value
Mandibular width	0.31		<0.01	0.36		<0.01	0.02		0.4
Maximum mandibular length	0.19	0.16	0.04	0.19	0.16	<0.01	0.01	0.05	0.7
Body length (Go-Gn)	0.54	0.54	<0.01	0.37	0.40	<0.01	0.09	0.07	0.3
Maximum ramus height	0.51	0.47	<0.01	0.36	0.33	<0.01	0.11	0.12	0.2
Minimum ramus breadth	0.35	0.37	<0.01	0.35	0.33	<0.01	0.06	0.05	0.6
Chin height	0.24		<0.01	0.22		<0.01	0.06		0.5
Mental foramen size	0.24	0.21	<0.01	0.10	0.09	0.5	0.09	0.1	0.2
Mental foramen height	0.32	0.31	<0.01	0.22	0.27	<0.01	0.09	0.07	0.5
Angle									
Menton angle	0.09		0.27	0.03		0.77	0.04		0.6
Mandibular body curve angle	0.12	0.14	0.12	0.01	0.02	0.8	0.11	0.08	0.3
Gonial angle	0.09	0.14	0.17	0.06	0.03	0.55	0.05	0.08	0.5

BSA=body surface area; BMI=body mass index; S.D.=standard deviation

Further, the maximum ramus height on each side had a statistically significant positive correlation with minimum ramus breadth (p-value<0.01) (Pearson's correlation coefficient=0.46 and 0.44, respectively), indicating a moderate correlation. In addition, a low positive correlation was observed between the mandibular width and maximum mandibular length (p-value<0.01) (Pearson's correlation coefficient=0.34, 0.32, respectively).

Correlation between angle measurement parameters

Angle measurements exhibited no statistically significant correlation with length (p-value>0.05), except for the mental and mandibular body curve angles. A very low positive correlation was observed between the mental angle and mandibular body curve angle (p-value<0.01) (Pearson's correlation coefficient=0.17, 0.19, respectively) (Figure 2).

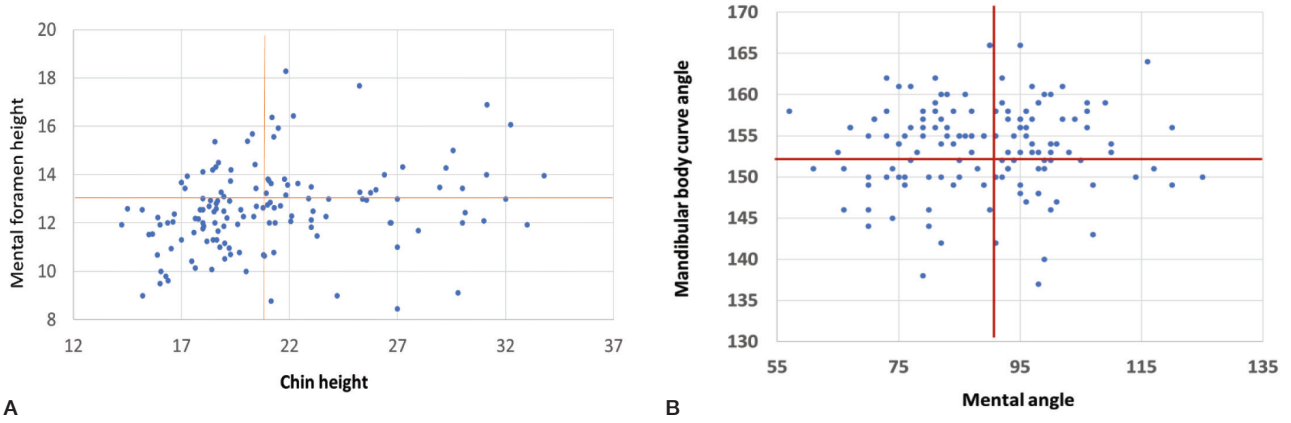


Figure 1 (A) Correlation between chin height and mental foramen height (B) Correlation between the mental angle mandibular body curve angle

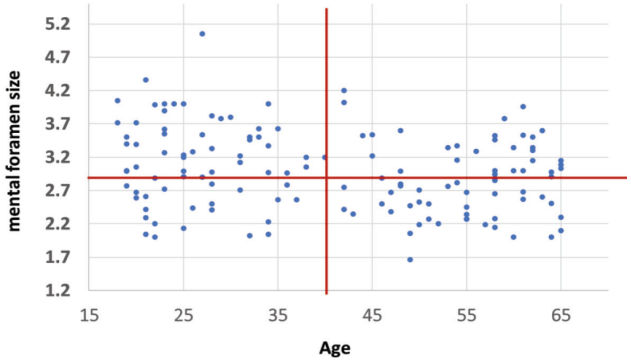


Figure 2 Correlation between the mental foramen size and age

Correlation between measurement and age

The mental foramen size had a statistically significant negative correlation with age (p-value<0.01) (Pearson's correlation coefficient=-0.23, low correlation) (Figure 2). Other measurements showed no statistically significant positive correlation with age (p-value>0.05).

DISCUSSION

Aesthetic facial reconstruction is a complex and artistic technique that heavily relies on meticulous planning to achieve favorable outcomes. In mandibular reconstruction, preserving the structural support for the anterior oral cavity and neck structures, facilitating mastication, and establishing a foundation for dental rehabilitation are pivotal considerations[13]. Analyzing mandibular defects requires great precision, with a particular emphasis on restoring the exact mandibular contour to prevent malocclusion in dentulous patients and ensure proper function.

Discrepancies were noted in both length and angle cephalometric measurements between 3D and 2DCT imaging techniques. 3D measurements were acquired from distinct spatial planes, not corresponding to the projected planes used in 2D imaging. This discrepancy in measurement methods can lead to variations in results[14].

The absence of reference data for 3D measurements, with the exception of maximum ramus height (mean difference right=0.28 (4.8), left=0.65 (5.21), p-value=0.49, 0.38, respectively), can be attributed to the limited availability of 2D images suitable for generating 3D reconstructions, as reported by Bholsithi et al.[14].

Within the Thai population, differences in mandibular length parameters were evident between the sexes. Seven out of the 11 parameters exhibited statistically significant disparities. According to Ongkana[12], female mandibles tend to be smaller than those of males due to the differential

development of the musculoskeletal system, particularly the masticatory muscles that attach to the mandible. These distinctions arise from varying rates of growth and developmental stages. Females typically reach puberty earlier than males, resulting in the earlier cessation or deceleration of mandibular and cranial growth.

Statistical analyses highlighted variations in mandibular length parameters, particularly in height and body surface area (BSA), between the sexes. A positive correlation was observed among length measurements, particularly body length (Go-Gn), and maximum ramus height (MRH), stemming from distinct bone growth rates.

For most measurements in this study, statistically significant positive correlations were found between mandibular length and various angles. The study's significance lies in presenting the average mandibular angular measurements within the Thai population.

Limitations

This was a retrospective study conducted at a single center. Therefore, the sample size was small, which may not represent the general population, potentially reducing the study's statistical power, the results provided are conclusive for the hypothesis tested. Additionally, a significant limitation is the presence of numerous missing data due to the absence of 3D CT images. Medical record data should be completed and corrected to improve the next study.

CONCLUSION

The mandible shows variations in the human population depending on sex, age, height, and BSA. In this study, 2D cephalometric measurements exhibited notable disparities when compared to the corresponding 3D-CT measurements within each patient. As a recommendation, the authors suggest that surgeons take into account the advantages of utilizing 3D-CT cephalometric measurements.

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