International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

Check for updates

A morphometric study of Bonwill's triangle for gender differences in dry mandibles of the Indian population

Venkata Lakshmi Nagella [1,*], Damodaran.SM [1], Kavitha Sekar [2], Tamilselvi Palaniappan [1] and Indu Bharkavi SK [3]

[1] *Department of Anatomy, Sathyabama Dental College & Hospital, Chennai, Tamil Nādu, India.*
[2] *Department of Anatomy, Vinayaka Mission's Kirupanandavariyar Medical College & Hospital, Salem, Tamil Nadu, India.*
[3] *Department 0f Oral pathology and Microbiology, Sathyabama Dental College & Hospital, Chennai, Tamil Nādu, India.*

International Journal of Science and Research Archive, 2023, 10(02), 906–913

Publication history: Received on 08 November 2023; revised on 16 December 2023; accepted on 19 December 2023

Article DOI: https://doi.org/10.30574/ijsra.2023.10.2.1065

Abstract

Bonwill's triangle, an imaginary equilateral triangle of the mandible, can cause mandibular alignment issues in post-dental occlusion, complete dentures, and mandibular fractures due to incorrect measurements across genders. This study aimed to analyze Bonwill's triangle size in dry mandible bones of the Indian population, focusing on gender differences to create error awareness in dental treatments and mandibular fractures. The study involved fifty-three dry human mandibles, segregated into male and female based on metric and non-metric parameters. The study measured the distances between the center of the right condyle to the midpoint of medial mandibular incisors (X-Y), the center point of the left condyle to the midpoint of medial mandibular incisors (Y-Z), and the center point of both condyles (Z-X). The mean lengths of Bonwill's triangular measurements in males were X-Y (101.08 mm), Y-Z (100.39 mm), and Z-X (97.06 mm), while females had 100.3 mm, 99.45mm, and 93.41mm respectively. Only two sides of the triangle were in accordance with Bonwill's theory. In the Indian population, Bonwill's triangle was significantly larger in male mandibles, and the intercondylar distance (Z-X) was less than 100mm in both genders, resulting in an isosceles triangle. Bonwill's triangle serves as a basis for modern technology to find geometric parameters for fractured mandibles and dental procedures, sex identification in forensic dentistry, anthropological studies, and bone grafts.

Keywords: Bonwill's triangle; Gender variations; Isosceles; Indian Population

1. Introduction

Mandibular symmetry plays an important role in the integrity of cranio-maxillofacial components, which are pivotal for mastication, speech, and facial expression. Traumatic fractures, congenital malformations, and pathological deficiencies cause mandibular asymmetry and disturb the dental occlusion plane. In 1858, American dentist G. Bonwill proposed an equilateral triangle in the mandible to prove its symmetry. It measures 100 mm or 4 inches on three sides between the medial contact point of the incisors and the midpoint of the right and left mandibular condyles [1, 2, 3]. This triangle forms the basis for the construction of some articulators and Monson's pyramid [4]. The morphological features of the maxillo-mandibular-dental system, which include the temporomandibular joint (TMJ), masticatory muscles, jaws, bones, and teeth, are studied using Bonwill's triangle and Mason's pyramid. Variations in the size of Bonwill's triangle have major effects on dental occlusion [4], complete dentures [5], articulation [6], mandibular fractures [7], and angulation of the cusp [8]. Contradictory to Bonwill's statement, Lenhossek, Izard, and Jovanovic showed that the triangular is almost equilateral, but the length of the triangular sides may vary, especially in female mandibles measuring less than 100mm [9]. As articulators are based on Bonwill's triangle, the fact that an equilateral triangle of the same size (100 mm) on all sides may contribute to inaccuracies in the construction of articulators for different genders within an ethnic group. Many authors have also described that variations exist in different ethnic groups,

* Corresponding author: Venkata Lakshmi Nagella; E-mail :venkatalakshmink@gmail.com

genders [9], and ages [10]. Despite the fact that Bonwill's triangle theory is still debatable and numerous studies have shown varying lengths of the triangular sides in various ethnic groups (Table 1), there is still a shortage of pertinent information regarding Indian ethnicities. The present study was focused on evaluating whether Bonwill's triangle measurements are accurate in the Indian population for both genders to create error awareness while constructing mandibles post-fractures and dental procedures.

2. Material and methods

The work was carried out at the Anatomy department of Sathyabama Dental College and Hospital, Chennai. Fifty-three dry human adult mandibles with well-preserved alveolar margins were segregated into male and female based on metric and non-metric parameters. Aged, broken, and mutilated mandibles were not subjected to the study. Four non-metric parameters and six metric parameters were analyzed. Non-metric criteria were taken into consideration for segregation in the initial step. The gender categorization was done using two characteristics that strongly suggested a certain sex [11]. Non- metric parameters are considered the better determinants of sex [12] and were done by three subject experts to avoid the observer's error. Metric parameters were used in the second phase to establish the gender of the mandible and dispel any ambiguity regarding segregation. The non-metric parameters were photographed, and the metric parameters were measured in millimeters (mm) with a digital vernier caliper, recorded, and statistically analyzed.

2.1. Non-metric parameters [11,12, 25,26]

- Shape of the chin - Square or bilobed in male and round or pointed in female.
- Gonial flare - Everted in male and inverted or normal in female.
- Contour of the mandibular base - Presence of antegonial notch in male and straight in female.
- Posterior border of ramus of mandible at Occlusal plane level - Distinct angulation in male and straight in female.

2.2. Metric parameters [13]

- Bicondylar breadth: The distance between the lateral points on the two condyles.
- Bigonial breadth: The distance between the two gonia.
- Mandibular body height: The vertical distance between the alveolar process to the base of mandible at the level of mental foramen.
- Symphyseal Height: The vertical distance between the alveolar process to the inferior border of mandible at the level of symphysis menti.
- Maximum Breadth of Ramus: The distance between the most anterior point on the mandibular ramus and a line connecting the most posterior point on the condyle and the angle of mandible.
- Maximum Height of Ramus- The distance between the midpoint of mandibular notch to the angle of mandible.

2.3. Measurement of Bonwill's Triangle [14]

A digital vernier caliper was used to measure the distance from the center of the right condyle to the midpoint of medial mandibular incisors (points X–Y), the center of the left condyle to the midpoint of medial mandibular incisors (points Y–Z), and between the center points of the right and left condyles (points Z–X).

2.4. Statistical Analysis

Metric parameter values and Bonwill's triangle measurements were analyzed using SPSS software (Version 16) and subjected to a paired sample' t' test to find any significant relation between the variables, which was tabulated.

3. Results

In our study, we observed that 85% of the male bones have a square chin, an everted gonial flare, strong muscle markings, and an ante-gonial notch in the mandibular base. 80% of the female bones have a round chin, an inverted gonial flare, less prominent muscle markings, and a straight mandibular base (Figures1&2). Metric parameters show the mean values of male mandibles were greater than females (Table 2). The paired sample "t" test shows significant p values, indicating the high reliability of the data.

Based on the metric and non-metric parameters, 28 male and 25 female mandibles were identified. The photographs show Bonwill's triangle measurements between X-Y, Y-Z, and Z-X (Fig. 3). Table 3 shows the mean values and standard deviations of the triangle in male and female mandibles. The statistical analysis shows the variables X-Y and Y-Z were not significant, but Z-X was observed to be statistically significant. Table 4 displays the paired sample 't' test analysis of the distance between the three sides of Bonwill's triangle in the male and female mandibles. The comparison of Yand Z, Z and X shows significant values in both genders, indicating that the intercondylar distance is significantly low in both genders.

Table 1 Comparison of Bonwill's triangle measurements in various ethnic groups

Ethnic group (Study type) (No of Sample)	**Measurements of X-Y, Y-Z, Z-X in millimetres(mm)**	**Shape of the triangle**
Taiwanese (CT Study) (Male - 51, Female - 48)	106.1mm - 107.3mm – 108mm (M) 100mm- 100.6mm - 103.8mm (F)	Equilateral in both genders with lower values in females
Yugoslav (224 random mandibles)	Not available	Isoceles
East African (Male -284, Female -51)	109.3 mm - 109 mm - 98.3 mm (M) 105.8 mm - 105 mm -104.5mm (F)	Isoceles (M) Equilateral (F)
Greek (Male-10, Female-9)	102.4 mm - 101.72 mm -102.4 mm (M) 101.24 mm - 101.38 mm - 101.38 mm (F)	Equilateral in both genders with lower values in females
German (CBCT Images) (120 random mandibles)	a. Arm length - 103 mm (Range 90.2 mm - 117.9 mm) b. Intercondylar length - 99.6 mm (Range 85.2 mm to 112.6 mm)	Isoceles
French (149 random mandibles)	Not available	Isoceles
Turkish	Not available	Equilateral
Indian (Dry bone study) (40 random mandibles)	97.7 mm - 98.5 mm - 97.3 mm	Equilateral
Indian (Dry bone study) (100 random mandibles)	Not available	Equilateral
Indian (CBCT study) (40 male, 40 females)	104.02 mm - 105.09 mm - 106.72 mm (M) 99.50 mm - 100.10 mm - 102.59 mm (F)	Equilateral in both genders with lower values in females
Korean (CBCT study) (60 male, 60 females)	108.1 mm (Arm length) and 108.3 mm (Intercondylar length) (M) 102.3 mm (Armlength) and 103.4 mm (Intercondylar length) (F)	Equilateral in both genders with lower values in females

(Note: M, F indicates male and female respectively).

Table 2 Descriptive analysis of metric parameters of the mandible in males and females

Parameters	Male		Female		Significance (P < 0.05)
	Mean(cm)	SD	Mean(cm)	SD	
Bicondylar breadth	11.62	0.449	10.96	0.310	< 0.000
Bigonial breadth	9.66	0.513	8.94	0.410	< 0.000
Mandibular body height	2.61	0.119	2.38	0.248	< 0.002
Symphyseal Height	2.66	0.252	2.40	0.268	< 0.023
Maximum Ramus Breadth	3.79	0.212	3.53	0.206	< 0.003
Maximum Ramus Height	4.75	0.337	4.39	0.396	< 0.011

The values are expressed as Mean ± SD. SD- Standard deviation.

Table 3 The paired sample test analysis of the comparison of Bonwill's triangle measurements between male and female mandibles

Measurements	Male	Female	T-Value	Significance (P < 0.05)
	Mean ± SD	Mean ± SD		
X-Y (Distance between the center of right condyle to midpoint of medial mandibular incisors)	101.08±3.82	100.3±4.82	0.659	0.512
Y-Z (Distance between the center of left condyle to midpoint of medial mandibular incisors)	100.39±3.27	99.45±4.67	0.848	0.399
Z-X (Distance between the center point of right and left condyles)	97.06±4.05	93.41±3.31	3.561	0.000*

* Indicates significance

Table 4 The paired sample test analysis of the distance between the three coordinates of Bonwill's triangle in both male and female mandibles

Comparison	Male		Female	
	T-value	Significance (P < 0.05)	T-value	Significance (P < 0.05)
Between X & Y	0.735	0.465	0.621	0.537
Between Y & Z	3.379	0.001*	4.582	0.000*
Between Z & X	3.823	0.000*	5.775	0.000*

* Indicates significance

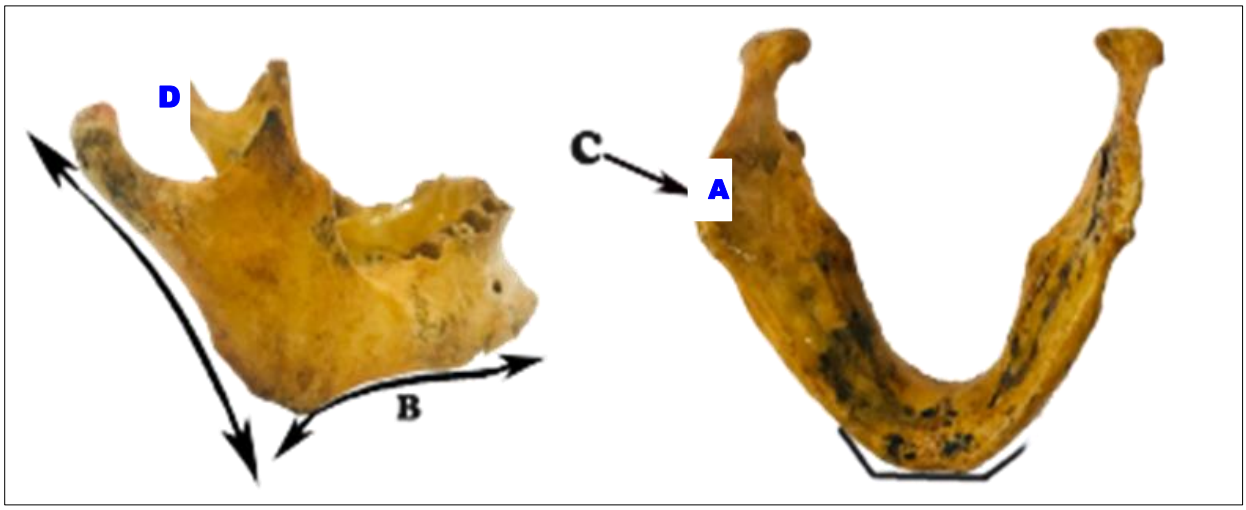

Figure 1 Non metric parameters of male mandible showing square shaped chin(A), antigonial notch at mandibular base(B), everted gonial flare(C), angulation at posterior border(D)

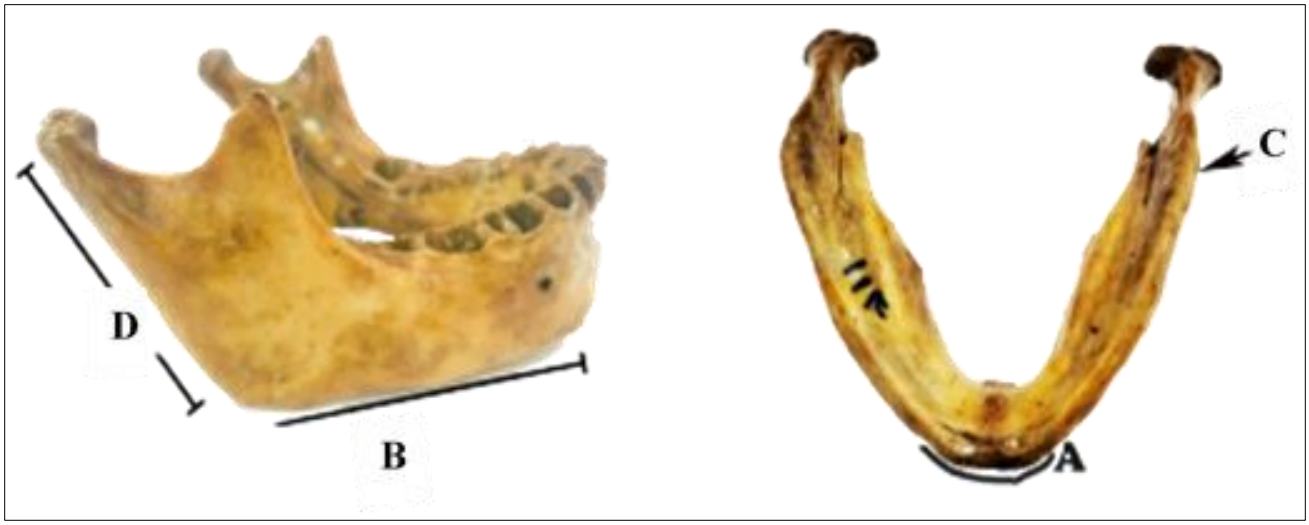

Figure 2 Non metric parameters of female mandible showing round shaped chin(A), straight mandibular base(B), normal Gonial flare(C) and straight posterior border(D)

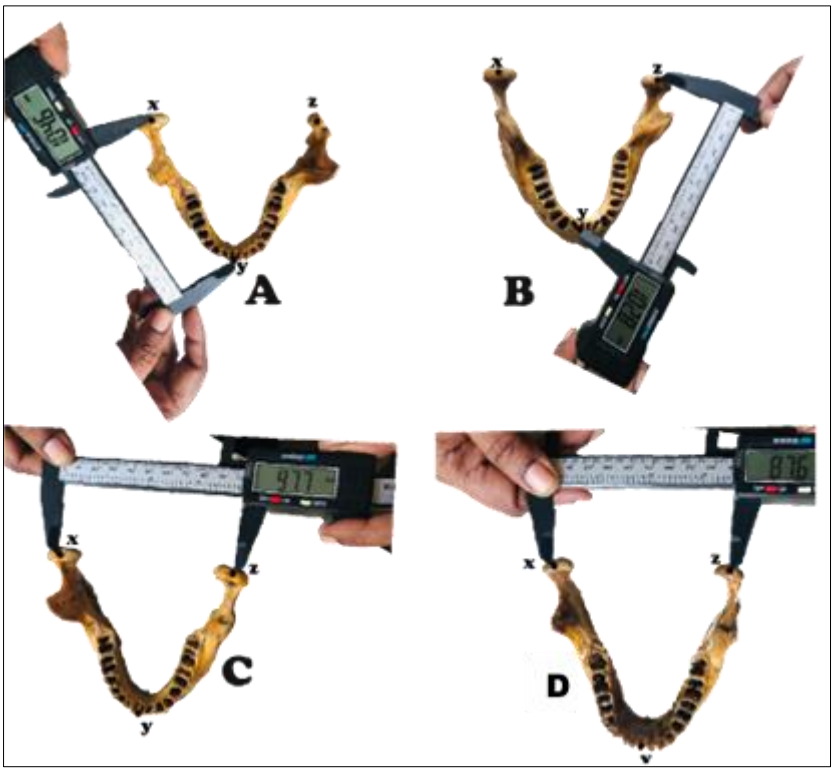

Figure 3 Bonwill's triangle measurements: A showing the distance between the center of the right condyle and the midpoint of the mandibular incisor (X-Y), B showing the distance between the center of the left condyle and the midpoint of the mandibular incisor (Y-Z), C and D showing the distance between the center points of the right and left condyles in males and females, respectively (Z-X)

4. Discussion

The conventional non-metrical method for identifying the gender of the mandible was believed to be more objective and reproducible but was dependent on the skill and experience of the expert. So, the present study used non-metric parameters backed by metric parameters that could be a useful tool for mandibular sex differentiation [15]. The accuracy of the metric parameters was highest when both bicondylar breadth and mandibular body height were considered together, as described by Aprajita Sikka *et al*.

Our study shows the mean values of the triangle sides for both genders are X-Z (101.08 ±3.82 for males, 99.59±4.82 for females), and Y-Z (100.39 ± 3.27 for males, 98.8±4.88 for females), which are almost in accordance with Bonwill's theory of 100 mm. However, female mandibles have slightly lower values, as described by various studies in Greek, Korean, Taiwanese, and Indian populations [2, 9, 10, 16, 24]. In comparison to other ethnic groups such as Greeks (101.38 vs. 102.4) and Turkish populations (115.2 mm vs. 105.4 mm), the paired t test analysis reveals that the mean values of the distance between condyles (Z-X) of male and female mandibles are considerably low (97.06 vs. 93.41) ($P < 0.05$) [18]. The study in Taiwanese reveals that the intercondylar distance increases with age until 50 and then decreases [10]. The variations in condyle distance have an impact on denture preparation and positioning of castings, making it crucial to consider the substantial low values between condyles in an ethnic group [8]. This study's results of low intercondylar distance are consistent with Yugoslavia [16], East African male [9], German [17], and French [18] population studies showing the Isosceles triangle. Other demographic studies, like those of Taiwanese [10], East African females [9], Greeks [8], and Turkish [1], show equilateral triangles, while Wilson found only 6% of mandibles align with Bonwill's theory in the European population [8].

Previous Indian studies using vernier caliper on dried mandible bones have shown an equilateral triangle with 4 inches on all sides [14, 20]. However, our findings contradict these studies due to gender-neutral random sampling of mandible bones. The study's results may also be in conflict with a gender-specific sampling of the CBCT study in an Indian population may be because of our study sample, as dry bone lose organic substances over time [21] which could account for lower readings of intercondylar distance.

Welcher's experiment showed that mandible values were greater in wet conditions and intercondylar size was 3mm less in dry mandibles [22]. Dry mandible bones consistently display lower values, ranging from 70 to 130 mm in Swiss populations, 65 to 96 mm in French populations, and 96 mm in German populations, but a radiographic examination of the Croatian population showed an average intercondylar distance of 126mm [23]. A Taiwanese population study found that mandibular measurements decrease by 1 to 2.5 mm every decade after thirty. Despite careful selection of adult mandibles, precise age determination is challenging in dry bones.

The study explores the use of Bonwill's triangle, a simple yet useful tool in dentistry, to position castings in virtual articulators and align the mandible following fractures using the average value of Bonwill's triangle, considering the values specific to various ethnic groups. Even today, if a facebow is not utilized, most dentists position castings in a software-controlled virtual articulator using the average value of Bonwill's triangle. It highlights the importance of accurate mandibular geometry in preventing complications during surgical planning and assisting surgeons in reconstructing the mandible with minimal resources [14]. This knowledge could potentially help with proper alignment of the mandible following fractures or dental malocclusions and prevent TMJ symptoms like headaches, joint discomfort, and muscle pain. The study also provides a basic notion of Bonwill's triangle values, which could be further developed through a large population study using radiograph images to draw exact values.

5. Conclusion

The Bonwill's triangular size was significantly larger in male than female mandibles. Only two sides of Bonwill's triangle coincide with the values of 100mm in the Indian population. With the available number of samples, we conclude the triangle is not equilateral but isosceles in the Indian population, with the values between intercondylar distances significantly low in both genders. Bonwill's triangle may not serve to align the fractured mandible perfectly nor the construction of articulators, but when working under limited resources, it forms the basis for all geometric parameters to support modern technology.

Compliance with ethical standards

Acknowledgments

The authors acknowledge and are thankful to Sathyabama Dental College and Hospital for providing all the research facilities to carry out this work. We express our sincere gratitude to the staff of Sathybama Dental College and Hospital, Dr. Khadijah Mohideen, Reader, Department of Oral Pathology and Microbiology; Dr.S. Tharanikumar, Reader, Department of Oral and Maxillofacial Surgery; and Dr. Preethi N., Senior Lecturer, Department of Oral Medicine and Radiology, for their valuable contribution to gender-wise segregation of the mandibles.

Disclosure of conflict of interest

The authors declare no conflict of interest and there is no financial interest to report.

Statement of ethical approval

The study is exempt from human ethical approval from the institute but received the institute's local ethical clearance to carry out the work in the department.

References

[1] Stimson G. Mertz Forensic Dentistry. CA CRC Press, London, UK. 1997; p. 4-6.

[2] Kong HJ, Oh SC. Evalution of Bonwill triangle using cone beam computerized tomography in Korean. J Dent Rehabil Appl Sci. 2018; 34:97-103.

[3] Connor JN. From Boucher's Prosthodontic Treatment for Edentulous Patients. In Vol 26. Edited by Hickey JC, Zarb GA. The C. V. Mosby Company, United States. 1981; p. 263.

[4] Adolphus Odogun Loto. Dental occlusion: A newly proposed tetrahedral theory of occlusion: Edorium J Dent. 2017; 4:26-35.

[5] Christensen FT. The effect of Bonwill's triangle on complete dentures. J Prosth Dent .1959; 9(5):791-6.

[6] Starcke EN. The history of articulators: A critical history of articulators based on geometric theories of mandibular movement. Part I. J Prosthodont. 2002; 11:134-46.

[7] Dergin G, Emes Y, Aybar B. From Evaluation and Management of Mandibular Fracture: In Trauma in dentistry. Edited by Gözler S. London: IntechOpen. 2019; p. 13.

[8] Fotoula Nikolopoulou, Anestis Xrysostomidis, Xristina Psari, Maria Piagkou, Theodoros Troupis. Bonwill's Triangle in Greek Human Mandibles. Adv Dent & Oral Health. 2019; 11(3): 555816.

[9] Zivanovic S. Bonwill's triangle and asymmetry in East African Human Mandibles. Arch Oral Biol. 1969; 14(9):1041-1044

[10] Yen-Wen Shen, Lih-Jyh Fuh. A Computed Tomographic Study of the Bonwill Triangle for the Taiwanese Population. J Prosthodont and Implantol. 2018; Volume 7, Number 3.

[11] Singh R, Mishra SR, Sushobhana, Passey J, Kumar P, Singh S. Sexual dimorphism in adult human mandible of north Indian origin. Foren Med and Anat Res. 2015; 3:82-8.

[12] Nucharin Ongkana and Paiwan Sudwan. Morphologic Indicators of Sex in Thai Mandibles. Chiang Mai Med J. 2010; 49(4):123-128.

[13] Aprajita Sikka, Anjali Jain. Sex determination of mandible: a morphological and morphometric analysis. Int J of Contemp Med Res. 2016; 3(7):1869-1872.

[14] Athul Antony Simon, Shashirekha M, Varsha Mokhasi, Aga Ammar Murthuza. "Bonwill's Triangle - The Uncharted Anatomic Geometry". Int J of Cur Res. 2020; 12, (10), 14159-14161.

[15] J Vinay G, Mangala GSR, Anbalagan. Sex Determination of Human Mandible Using Metrical Parameters. J of Clin and Diag Res. 2013; Vol-7(12): 2671-2673.

[16] Gudnara N, Zivanovic S. Asymmetry in East African Skulls. Am J Phys Anthrop.1968; 28(3): 331-337.

[17] Maggetti I, Bindl A, Mehl A. A three-dimensional morphometric study on the position of temporomandibular joints. Int. j. of comput. dent. 2015; 18(4):319-31.

[18] Choquet J. The triangle equilateral de Bonwill. L' Odontologie. 1909; 41: 307-312.

[19] Erkan Arat, Deniz Sen, Bullent Sermet. Investigation of intercondylar distance of Turkish population. Gu Dishek, Fak Derg. 1997; 14: 95-99.

[20] Arun Ganesh MK, Mohanraj KG. Morphometric analysis of Bonwill's triangle and its dental applications in dry human mandible bones. J Adv Pharm Technol Res. 2022; 13: S194-7.

[21] Symes SA, L'Abbé EN, Chapman EN. et al. From A companion to forensic anthropology. In chap 17 Interpreting trumatic injury to bone in medicolegal investigations. West Sussex (UK): Wiley-Blackwell. c 2012; p. 340–89.

[22] Welcher H. The affiliation of a mandible to a specific schidel, Arch. f. Anthrop. 1902; 27:37-106.

[23] Lazic B, Tepavcevic B, Keros J. Intercondylar distances of the human temporomandibular joints. Coll Antropol. 2006; 30(1): 37-41.

[24] Koothati RK, Khandare S, Suresh D, Sravanthi YM, Avinash K, Himapavana M. Evaluation of Bonwill's triangle parameters using cone-beam computed tomography for gender determination: A retrospective study. J Oral Maxillofac Radiol. 2023; 11:6-10.

[25] Loth SR, Henneberg M. Mandibular ramus flexure: a new morphologic indicator of sexual dimorphism in the human skeleton. Am J Phys Anthropol. 1996; 99(3):473–85.

[26] Oettle AC, Pretorius E, Steyn M. Geometric Morphometric Analysis of Mandibular Ramus Flexure. Am J Phys Anthropol. 2005; 128:623–29.