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An analogy between maxillary anterior teeth dimensions measured using facial proportions and Chu proportion gauge: an *in vivo* study

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Abstract

Background: A fine balancing of geometric concepts and artistic abilities is required while designing smiles. One of the key elements that makes up the smile frame is tooth size. The maxillary front teeth are the most noticeable in the smile arch, therefore choosing the right tooth size and positioning it in the maxilla improves both aesthetics and treatment outcomes.
Aim: This study aimed to compare the dimensions of maxillary anterior teeth measured with vernier callipers and CHU proportion gauge with facial proportions such as intercanthal distance, interalar width and bizygomatic width.
Materials and Methods: On a sample of 100, Facial proportions, mesiodistal width, and height of maxillary anterior teeth were recorded using digital callipers and a Chu proportion gauge. The recorded data were subjected to statistical analysis. Mean comparisons of each width were done using a t-test, ANOVA and Tukey's Post-hoc test considering a p-value less than 0.05 to be statistically significant.
Results: Mean values of the combined width of anteriors calculated using Chu gauge was 45.08, and that calculated using Vernier Callipers was 45.85. Multiplying the factor 1.47 to Inner canthal width and 1.42 to Interalar width results in the combined width of the maxillary anterior teeth. A mean difference of 0.02620 ± 0.91777 and 0.4988 ± 0.91777 exists between Inner canthal and Combined Chu's width with a 0.04% and 0.34% error in younger and elder age populations, respectively. A mean difference of -11.4775 ± 0.91777 and -11.6039 ± 0.91777 exists between Combined mesiodistal width obtained by using Chu's width and bizygomatic width with a 0.01% error in younger and elder age populations, respectively.
Conclusions: This study reported a negligible 0.7 difference in the means of the combined width of anteriors calculated using Chu gauge and Vernier Callipers. Hence, these two methods can be used as alternatives to calculate the width of anterior teeth.
Keywords: Bizygomatic width, Innercanthal width, Interalar width, Maxillary anterior teeth width, Proportion gauge, Tooth proportions, Vernier.

1. Introduction

"No human inquiry can be called science unless it pursues its path through mathematical exposition and demonstration" - Leonardo da Vinci [1].

In today's dentistry, esthetics is a big concern. Natural esthetics, on the other hand, is not a subject of choice but rather a necessity [2]. The distinction between a pleasing and non-pleasing smile is a subjective process. As a result, dental professionals dealing with patients' esthetic needs must rely on esthetic concepts that have been proven to be effective in clinical settings [3]. Smile designing is a precise balance of geometric concepts and artistic abilities [4]. One of the key building pieces of the smile frame is tooth size. As the maxillary front teeth are the most prominent in the smile arch, choosing the right tooth size allows you to arrange your teeth in the maxilla to improve both esthetics and treatment outcomes [5].

According to Levin, the "golden proportion" produces the most harmonious tooth ratios, however, Preston has found that natural tooth ratios rarely fit that concept [1, 6]. A web-based study that looked at dentists' preferences for anterior teeth showed no link between attractive smiles and the "golden proportion." Instead, the authors proposed the concept of a "recurring esthetic dental proportion," indicating that practitioners might set the proportion according to their preferences as long as it remained consistent [7]. Several anatomic landmarks such as bizygomatic width (BZW), intercanthal distance (ICD), and interalar width (IAW), have been proposed to aid in detecting the correct size of the anterior teeth. Berry discovered a 1:16 relationship between the width of the maxillary central incisor and the bizygomatic width [8]. House and Loop stated that the bizygomatic width may not be a valid reference for determining the width of central incisors, as they discovered a range of ratios between 1:13 and 1:19 [9]. Scandrett *et al.* determined in a later study that bizygomatic measures may not be a valid method of determining the width of maxillary central incisors [10]. The intercanthal distance has been previously linked to the mean width of two central incisors, the combined width of the central incisors, the combined width of the four incisors, and the total width of the six maxillary anterior teeth, by Al Wazzan [11]. Abdullah discovered that the intercanthal distance was in "golden proportion" to the maxillary central incisor's combined width [12].

Krajicek correlated the interalar width to the width of the six maxillary anterior teeth, as shown by Mavroskoufis and Ritchie as well [13, 14]. Hoffman *et al.* calculated that the interalar width when multiplied by a factor of 1.31 gave the combined width of the maxillary six anterior teeth [15]. Several authors proposed that more than one measurement of the face may be needed to obtain the best decision for maxillary anterior teeth width [16, 17].

Many studies have been conducted to understand the facial proportions and their relation to the six healthy anterior maxillary teeth of the general population. Recently, Dr CHU devised an esthetic gauge based on the concept of Recurring Esthetic Dental proportion (RED) using the 78% RED proportion, which helps in evaluating the tooth size and proportion visually and objectively chair side [18]. Hence, this study was aimed to evaluate and compare the dimensions of maxillary anterior teeth with facial proportions (Inner canthal, Bizygomatic, Inter alar widths) and CHU proportion gauge in the Telangana population sample. The objectives of the present study were to determine inner canthal width, inter alar width and bizygomatic width using vernier callipers; to determine mesiodistal width and cervico-incisal height of maxillary anterior teeth using vernier callipers and CHU proportion gauge and to compare and evaluate these values obtained using statistical analyses to make conclusions.

2. Materials and methods

This prospective clinical study was conducted in the Department of Prosthodontics, Panineeya Mahavidyalaya Institute of Dental Sciences and Research Centre, Hyderabad, Telangana, India. Approval of the study protocol was obtained from the Institutional Review Board (The Ethical committee) of the institution. A non-random purposive sampling technique was employed, and 100 participants aged 18-25 years (young age group) and 45-66 years (elder age group) were recruited for the study. All the participants were asked to give a written and duly signed informed consent form to state their willingness to participate in the study. The inclusion criteria of the study were no facial or dental deformity and intact contact points between six maxillary anterior teeth, which are fully erupted. Exclusion criteria included: mal-aligned teeth, gingival recession/inflammation, history of orthodontic treatment, restorations and presence of deleterious habits. Demographic details of each participant were collected, and only those whose parents were natives of Telangana state were chosen for this study. A total of 100 participants of Telangana origin and no mixed ethnic origin were enrolled in the study.

2.1 Clinical examination

The participant was seated in an upright position with the head held steadily. To avoid interexaminer variability, all readings were carried out by a single examiner. A Digital Vernier Callipers (Aerospace 150 mm Digimatic Vernier Calliper) was used for measuring purposes. Each measurement was a mean of three readings. The following readings were noted.

Determination of Innercanthal Distance (Figure 1): Inner canthal distance was measured from one medial angle to the other of palpebral fissures.

Determination of Interalar Distance (Figure 2): Two points are marked on either side of the nose with a fine tip marking pen indicating the widest point in the outer surface of the alae of the nose.

Determination of Bizygomatic Width (Figure 3): This was the distance from the most prominent point on the zygomatic bone on both sides without applying pressure.

2.2 Dental Measurement

The height and width of maxillary anterior teeth were measured intraorally using the callipers and 'T' bar tip of Chu's esthetic proportion gauge (Figure 4). Dental casts of the participants were obtained by taking an impression with irreversible hydrocolloid impression material and poured immediately with type 1 dental stone. The mesiodistal width of maxillary anterior teeth was measured with callipers (Figure 5). The measurements were repeated three times for accuracy. A sharp-tipped digital calliper read to the nearest 0.1mm is required to gauge the widest mesiodistal width of maxillary anteriors from the labial side using the outer edges of callipers positioned between contact points of teeth. This process was done for all maxillary anterior teeth (Figures 5 and 6).

2.3 Method of evaluation using the Chu's esthetic proportion gauge

Chu's esthetic proportion gauge is a set of one handle and four colour-coded tips, the T bar tip, the inline tip, the papilla gauge and the bone sounding gauge. On its vertical bar (height measurements) and horizontal bar (width measurements), the T bar tip is 'T' shaped and contains colour-coded bands with fixed height/width ratios viz red, blue, and yellow. The dimensions of height and breadth are taken at the same time. The 1.5 mm thick bands cover 78 per cent of the Recurring Esthetic Dental Percentage (RED). The gap between these bands is 1 mm. For example, the central incisor, with a "red" width of 8.5 mm will be in proper proportion if its height is also "red" height 11 mm. All of the readings were taken with each person seated, head supported and with Frankfort's horizontal plane. For enhanced visualization and accessibility, a cheek retractor was used. On the incisal margins, a coloured marker was used to highlight the approximate midpoint of each anterior tooth. The gauge contained an incisal stop that assisted to support the gauge and position it on the tooth surface. This stop was roughly located at the tooth's long axis at the marked midpoint. Colour-coded markers (Central incisor = Red colour, Lateral incisor = Blue colour and Canine = Intermediate yellow Colour) 7 mm away from the incisal edge were used to determine the tooth's width. Simultaneously, the height of the gingival margin from the incisal edge to the zenith point was measured using the matching colour coding. Each tooth, one at a time was assessed using the same procedure. If the colour codings on the vertical and horizontal bars match, the tooth is supposed to be in proportion. The proportions obtained were then tabulated.

3. Results

The recorded data were subjected to statistical analysis using IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp. Descriptive statistics were performed on excel sheet data (Table 1). The frequencies of the population showed Normal distribution/Gaussian distribution. Hence, Parametric tests were performed for inferential analysis of factors in the study. For inferential analyses, IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp. software was used. These include mean comparisons of Inner canthal width (ICW), Inter alar width (IAW), Bizygomatic width (BZW), Combined width of anterior maxillary teeth using Vernier callipers (CW) and Chu's Proportion gauge (CWPG) using t-test (Table 1), One way ANOVA (Table 2) and Post hoc Tukey's tests (Table 3). *p* value less than 0.05 was considered statistically significant for all the comparisons. Descriptive data of the widths of anterior teeth measured using Vernier callipers and Chu's apparatus has been tabulated for comparison (Table 4).

A mean difference of 0.02620 ± 0.91777 exists between Inner canthal and Combined mesiodistal width of anteriors obtained by using callipers with a 0.04% error in the younger age population and a mean difference of 0.4988 ± 0.91777 exists between Inner canthal and Combined mesiodistal width of anteriors obtained by using callipers with a 0.34% error in elder age population.

A mean difference of -11.4775 ± 0.91777 exists between the Combined mesiodistal width of anteriors obtained by using callipers and the bizygomatic width of anteriors with a 0.01% error in the younger age population and a mean difference of -11.6039 ± 0.91777 exists between Combined mesiodistal width of anteriors obtained by using callipers and bizygomatic width of anteriors with a 0.01% error in elder age population.

4. Discussion

The present study observed that means of individual anterior tooth widths calculated using Vernier Callipers and Chu gauge have come out to be very close with a negligible difference of 0.7 between the two means (Table 4). Another important finding in the study was the calculation of the multiplying factor that estimates combined width of the maxillary anterior teeth. The existence of this calculated factor suggests that Inner canthal width and inter-alar width may be used as a tentative predictor for the estimation of the combined width of anteriors. The multiplying factor that is used in the study to estimate the combined width of the maxillary anterior teeth for Inner canthal width was 1.47 and for Inter alar width was 1.42.

Figure 1. Determination of Inner Canthal Width (ICW)

Figure 2. Determination of Inter Alar Width (IAW)

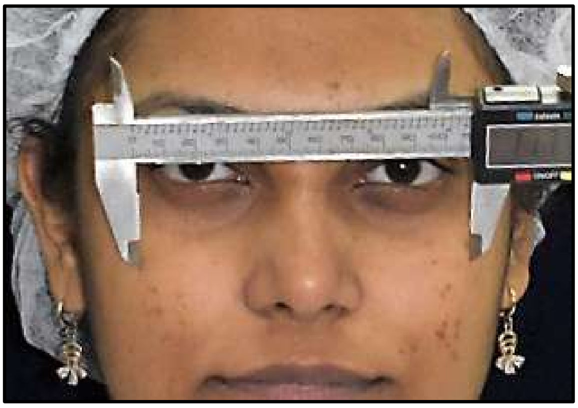

Figure 3. Determination of Bizygomatic Width

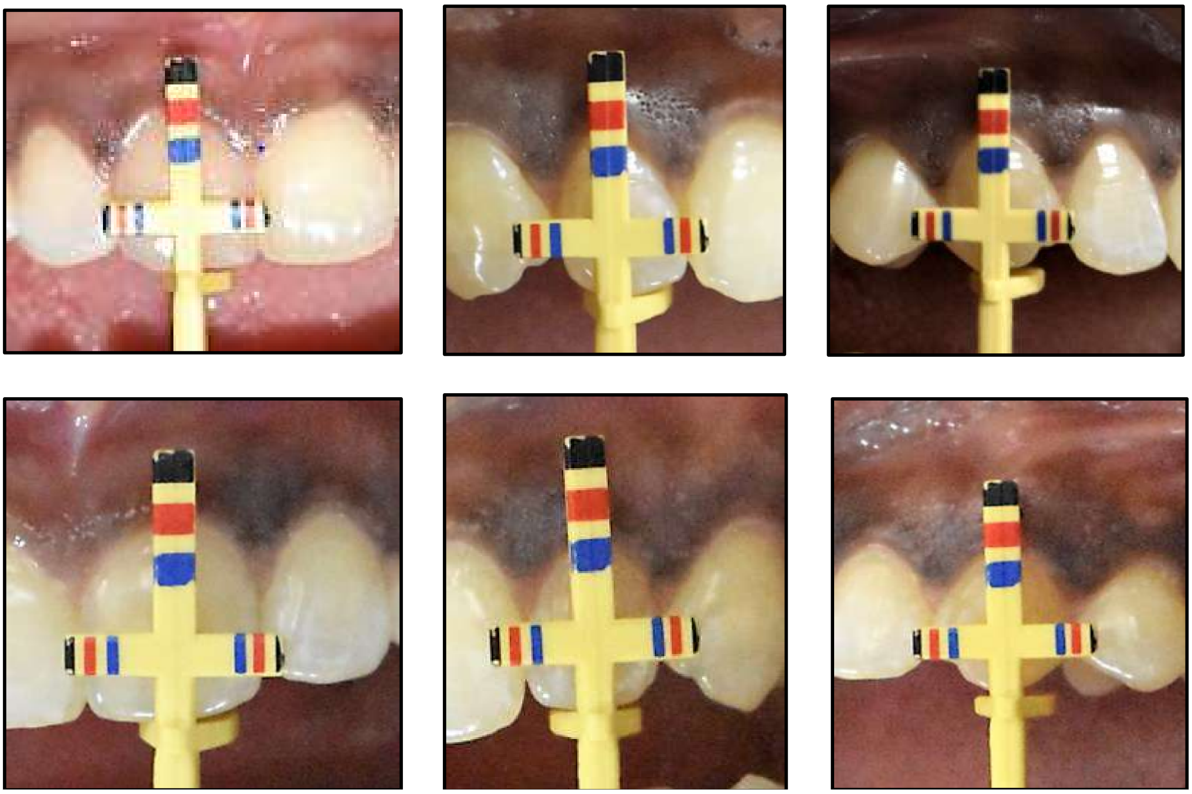

Figure 4. Determination of mesiodistal width and height of maxillary anteriors using chu proportion gauge with 't'- bar tip. 11, 12, 13 (Top row, from left to right) and 21, 22, and 23 (Bottom row from left to right).

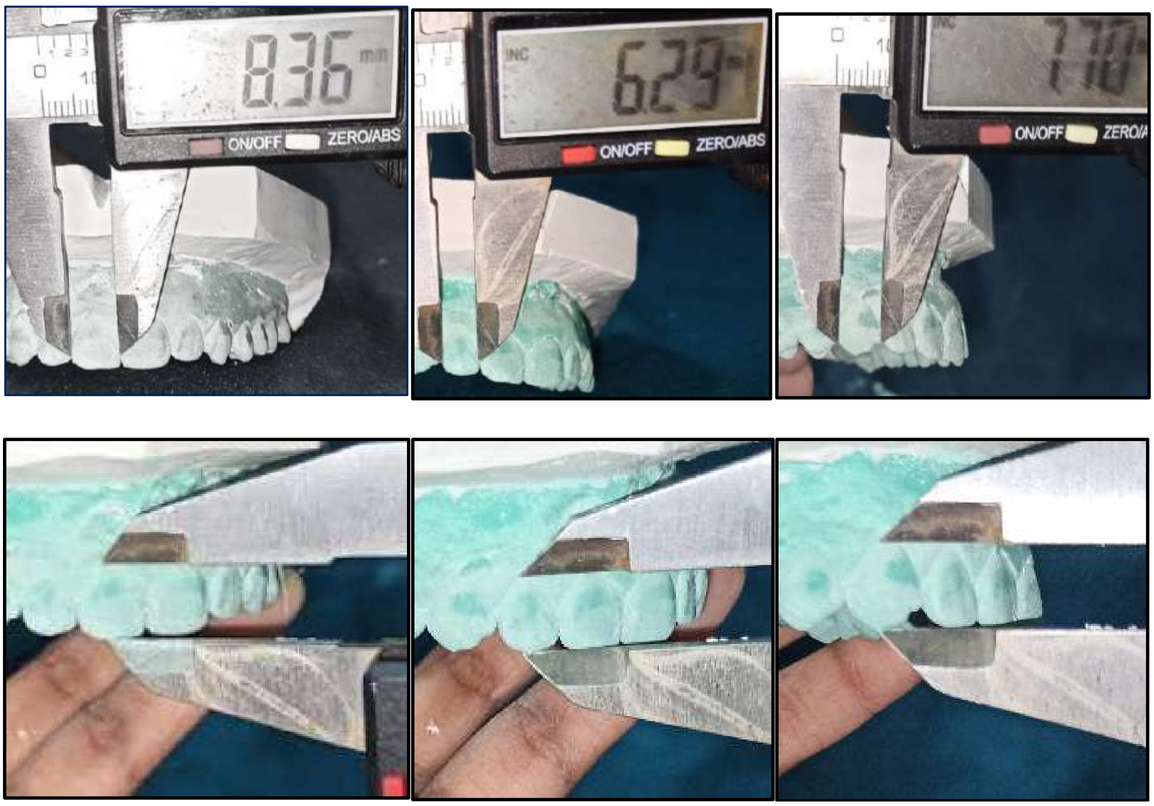

Figure 5. Determination of width (mesio-distal) and the height of 11, 12 and 13 respectively with callipers on stone casts

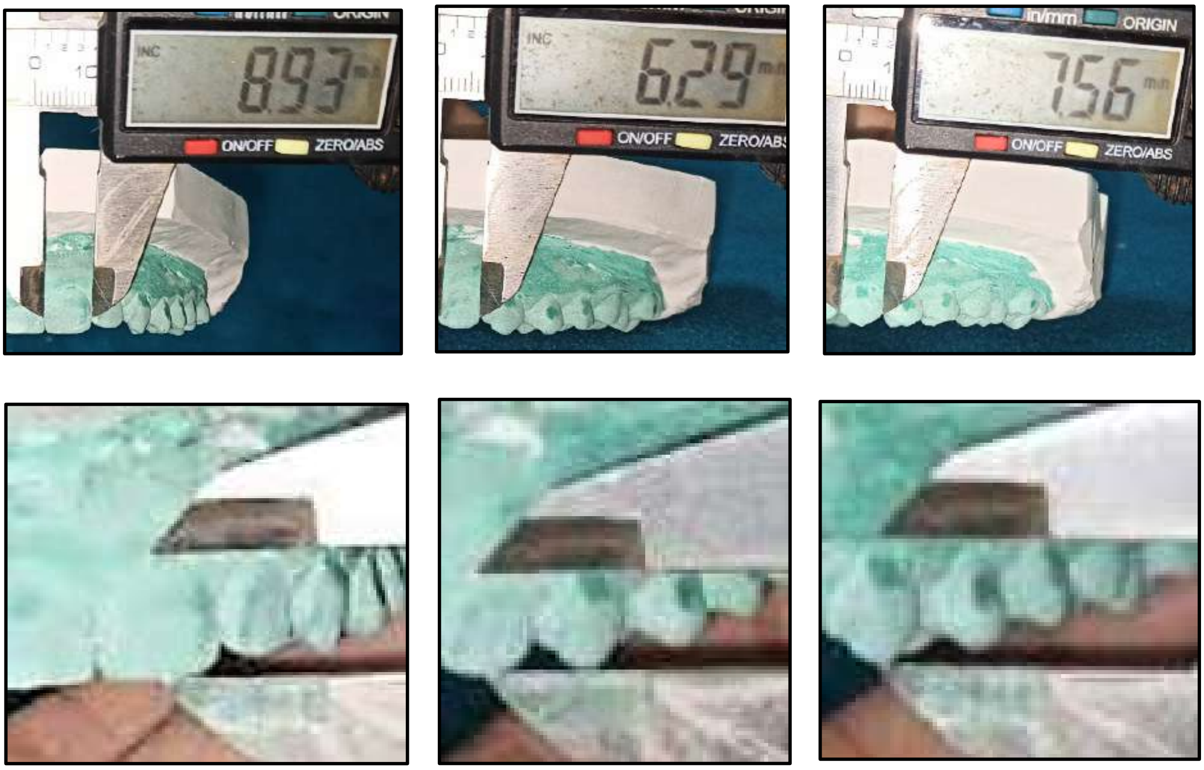

Figure 6. Determination of width (mesio-distal) and the height of 21, 22 and 23 respectively with callipers on stone casts

Table 1. Mean, standard deviation (SD) and comparison of means of various widths in younger and elder age groups using student's t-test

Age group	Variable Younger age group	Mean	SD	t- value	*p*-value
Younger age group	Age	25.46	2.56		
	Inner canthal width	45.95	3.9	83.23	**0.001****
	Inter alar width	46.86	7.56	43.81	**0.001****
	Bizygomatic width	113.68	8.4	95.81	**0.02***
	Combined mesiodistal width using vernier callipers	34.44	2.54	140.7	**0.000*****
	Combined mesiodistal width using Chu apparatus	45.92	2.3		
Elder age group	Age	42.1	7.31		
	Inner canthal width	45.51	5.76	55.811	**0.001****
	Inter alar width	44.95	4.46	71.142	**0.05***
	Bizygomatic width	113.54	8.9	89.597	**0.001****
	Combined mesiodistal width using vernier callipers	34.4	2.7	149.761	**0.04***
	Combined mesiodistal width using Chu apparatus	46	2.17		

*Significant at 5% level of significance; **Significant at 1% level of significance; ***Significant at 0.1% level of significance

Table 2. Comparison of means of inner canthal, inter alar, Bizygomatic, combined widths using vernier callipers and Chu's proportional gauge using ANOVA test in younger and elder age groups

Age group	F-value	*p*-value
Young age group	0.546	**0.03***
Elder age group	0.718	**0.05***

*Significant at 5% level of significance

Table 3. Multiple comparison of various widths between groups using Tukey's Post hoc Test

Age groups	Various widths	Mean difference	Standard Error	*p*-value
Younger age group	ICW	0.0262	0.91777	**0.04***
	IAW	0.934	0.91777	0.456
	BZW	-11.4775	0.91777	**0.01***
Elder age group	ICW	0.4988	0.80813	**0.034***
	IAW	-10528	0.80813	0.838
	BZW	-11.6039	0.80813	**0.01***

*Significant at 5% level of significance

Table 4. Descriptive values of Width of anterior teeth using Vernier callipers and Chu proportion gauge

Tooth Number	N	Vernier callipers		Chu proportion gauge	
		Mean	SD	Mean	SD
13	100	7.88	0.085	7.9	0.085
12	100	6.75	0.085	6.76	0.062
11	100	8.43	0.078	8.44	0.082
21	100	8.47	0.067	8.41	0.072
22	100	6.62	0.046	6.64	0.046
23	100	7.7	0.069	7.68	0.073
Combined	100	**45.85**	**0.267**	**45.08**	**0.279**

Hoffman *et al.* found that ICW may be estimated by increasing the IAW by 31% or multiplying it by a factor of 1.3113 [15]. Abdullah *et al.* estimated a multiplying factor of IAW as 1.26 and for ICD as 1.35 in a Saudi population [12]. Al-el-Sheikh and Al-Athel found a significant correlation between the IAW and ICW in the Arab population and recommended increasing the measured values of IAW by the statistically derived multiplying factor: 1.56 [18]. Ufuk Hasanreisoglu *et al.* stated that Bizygomatic width and interalar width may serve as references for the same, particularly in women [19]. Vanderlei Luiz Gomes et al. investigated the Brazilian population, and found that the interalar width, when increased by 31% of its value, can suggest the circumferential distance of the six maxillary anterior teeth [20]. Shibu George *et al.* stated that ICW and the golden proportion are reliable predictors for determining the width of the maxillary central incisors in the south [21]. Suryakant Chhagan *et al.* concluded that a small significant positive correlation was present between Inner canthal width and Inter alar width in the central Indian population [22]. Ewa C. Parciak *et al.* investigated individuals of Asian, African-American, and white ethnicities. Authors concluded that in Asian women, the inter commissural width correlated with the width of the central incisor, the width of 2 central incisors, the width of 4 incisors and the width of 6 maxillary anterior teeth [23]. In a systematic review, Wang et al. declared that only the recurring esthetic dental proportion (70%) with interalar distance could be an accurate method for predicting the combined width of central incisors [24]. Sukhada Arun Wagh et al., in a study of 80 participants, concluded that maxillary anterior teeth did show similarity with Chu's esthetic proportion scale [25].

However, the limitations of the study are that it was conducted in small sample size and gender wise distribution was not considered. The restricted population is a limitation which questions the applications of results to a wider range of the population. Future studies evaluating gender, ethnicity, mandibular teeth, and posterior teeth in a larger sample size are recommended.

5. Conclusion

In this study a negligible 0.7 difference was observed in the means of the combined width of anteriors calculated using Chu gauge and Vernier Callipers. Hence these two methods can be used as alternatives to calculate the width of anterior teeth. There was a positive correlation found between the width of anteriors calculated using Chu gauge and Inner canthal width and bizygomatic width. Hence, it can be concluded that the Combined width of maxillary anteriors obtained by using a Chu proportion gauge can be considered as an alternative to Inner canthal width and bizygomatic width in anterior rehabilitation cases where esthetics is of major concern.

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