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Quantifying the Selection of Maxillary Anterior Teeth Using Intraoral and Extraoral Anatomical Landmarks

Ayman Ellakwa, Kieran McNamara, Jasdeep Sandhu, Kedall James, Amit Arora, Iven Klineberg
Ali El-Sheikh, F Elizabeth Martin

ABSTRACT

Background: One of the major hurdles in clinical prosthodontics has been the selection and replacement of maxillary anterior teeth in the absence of pre-extraction records. The aim of this study was to determine if a relationship exists between intraoral and extraoral facial measurements that could assist dental practitioners in selecting esthetically appropriate maxillary anterior teeth in the absence of pre-extraction records.

Materials and methods: A cross-sectional study design was used with a sample size of one hundred and twenty participants. A questionnaire was used to identify the selection criteria and a photograph was taken for facial measurements using digitally calibrated software. Ninety-eight participants met the selection criteria and were included in the study. Measurements of intraoral landmarks were taken from stone casts of maxillary impressions using calibrated digital calipers. Each measurement was completed by two assessors to obtain mean values. Data were statistically analyzed using SPSS version 17 software. Data were assessed by one way analysis of variance (ANOVA) followed by *post hoc* ($p < 0.05$) to find any difference between tested groups. Pearson coefficients were used to determine whether correlation exists between measurements.

Results: The mean values for intraoral maxillary landmarks were: Central incisor width = 8.39 mm, circumferential canine tip to canine tip distance = 34.89 mm, arch width = 48.24 mm, left arch length = 45.24 mm, right arch length = 45.56 mm. The mean values for extraoral landmarks were: Intercanthal distance = 33.24 mm, interpupillary distance = 60.68 mm, interalar distance = 38.27 mm, intercommissure distance = 50.61 mm. Differences existed within subgroups for all intraoral and extraoral measures. A weak positive correlation existed between intraoral ($r < 0.4$) and extraoral measurements ($r < 0.38$) that remained consistent when examined by gender.

Conclusion: This study showed that the average length and width of the maxillary arch and interalar width were the anatomical landmarks that provided the strongest predictive relationship with anterior maxillary teeth ($r = 0.38 - 0.4$). Using these dimensions an average multiplying factor can be used to calculate maxillary incisor width or canine tip to canine tip distance. As the predictive strength is not strong, the authors recommend its use as a preliminary guide for determining the width of the maxillary anterior teeth during the initial selection of artificial teeth in the absence of pre-extraction records.

Clinical Significance: The results of this study can be used to help dentists select the size of artificial maxillary anterior teeth in the absence of pre-extraction records.

Keywords: Central incisors, Size, Intraoral, Extraoral, Landmarks, Teeth, Selection and correlation.

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INTRODUCTION

One of the major hurdles in clinical prosthodontics has been the selection and replacement of maxillary anterior teeth in the absence of pre-extraction records.[1,2] The selection of anterior maxillary teeth for a prosthesis is carried to achieve pleasing esthetics.[3,4] However, issues associated with matching the anterior dental esthetics arise due to individual anatomical variations.[5] If artificial teeth are selected to resemble their predecessors, patient acceptance is greater[6] and an enhanced esthetic outcome is achieved.[1,6] Maxillary central incisors are reported to be the most important teeth to satisfy the esthetic requirements of the patient[7] with width being considered more critical than length.[8,9] Patient complaints primarily involve anterior tooth esthetics and the maxillary central incisor is usually at the center of the complaint.[10] As a result, selecting artificial teeth requires an understanding of both physical and biological factors that are directly related to individual patients features.[11]

Although it is agreed that the clinicians' choice in selecting the appropriate width of artificial anterior maxillary teeth should be based on facial or arch measurements and proportions,[12] there is little agreement between clinicians and few reliable guidelines that exist.[13]

Numerous facial and intraoral measures have been proposed to assist clinicians' selection of artificial teeth.[14] One of the first measures recommended was the Berry Biometric Ratio Method[11] which states that a biometric ratio of 1:16 can be used to describe the relationship between width of the maxillary central incisor to the bizygomatic width.[11,15] This relationship has since been shown to be based on flawed statistical procedures.[15] Although the ratio of 1:16 is sound, the magnitude of the correlation is poor (r = 0.15–0.18) resulting in this method having little predictive value in selection of maxillary central incisor teeth.[15]

More recently interalar width,[3,4,15] interpupillary distance,[16,17] intercanthal distance,[18] intercommissural width,[6] and palatal width[19] as well as the use of multiple anatomical measures[2,11] have been proposed to establish width of the maxillary anterior teeth. Despite previous attempts to quantify the selection of anterior teeth, to date no universally accepted anatomical measure has been found to reliably assist artificial tooth selection[20] and to our knowledge no attempt has been made to explore this in an Australian population.

This clinical study was conducted to determine if a relationship exists between intraoral tooth and arch measurements and extraoral facial measurements that could assist dental practitioners in selecting esthetically appropriate maxillary anterior teeth in the absence of pre-extraction records.

MATERIALS AND METHODS

All first and second year dental students (n = 120) in the graduate entry Bachelors of Dentistry program at the University of Sydney were invited to participate. Each student received a participant information statement outlining the study information, a questionnaire and a consent form. Ethical approval for the study was obtained from the University of Sydney, Human Research Ethics Committee under the protocol number 13134.

The study closely followed their curriculum and thus allowed for a high consent rate. Information in the questionnaire was used as anthropological identification for each of the student subjects and helped provide a basis of determining our selection criteria. Selection criteria included: (1) Age above 18 years ensuring dental and craniofacial development was completed[9,11] (2) No prosthetic appliances or full coverage restorations on labial or occlusal aspects of the six maxillary anterior teeth (3) Asymmetrical maxillary arch due to previously missing or extracted maxillary teeth, other than maxillary third molars.

Images with full frame Sony Alpha 900 Digital SLR camera (1-7-1 Konan, Minato-ku, Tokyo 108-0075, Japan) were taken with a steel metric ruler held parallel to the subject's face as shown in Figure 1. The images were used for extraoral assessment. If a subject wore spectacles they were asked to remove them prior to the photograph. Photographs were standardized; subjects were required to 'look straight into the camera' with 'a relaxed lip position'. Each digital picture was opened with a digital calipers software program (Bill Redirect Version 5.0X, USA) and screen calipers were calibrated to the metric ruler present within the digital image. Following calibration, the measurements obtained were: Interpupillary distance—recorded from the center of the pupil; intercanthal distance—measured between the right medial canthus and the left medial canthus; interalar distance—taken from the most lateral aspect of the alar; and the width between the labial commissures. All extraoral measurements were made by two independent examiners to obtain mean values.

Students completed maxillary impressions of each other as part of a clinical exercise. The impressions were taken in irreversible hydrocolloid material and poured using type 1 dental stone. Digital calipers (Figs 2A and B), which were calibrated before each new measurement, were used for all measurements taken of the dental casts. Intraoral cast measurements included mesiodistal (MD) width of the maxillary central incisor, arch width from canine tip of upper left canine (23) to canine tip of upper right canine (13) along arch of greatest curvature of the facial surface, arch width from mesiopalatal (MP) cusp of maxillary right second molar (17) to MP cusp of the maxillary left second molar (27) [BC distance], and arch length from the center of the incisive papilla to MP cusp of 17 and MP cusp of 27 [AB and AC distances respectively]. Each cast parameter was measured by two independent and blinded examiners to obtain mean values.

Once all information was compiled, questionnaires were reviewed to ensure selection criteria had been met while casts that had failed to record relevant intraoral landmarks

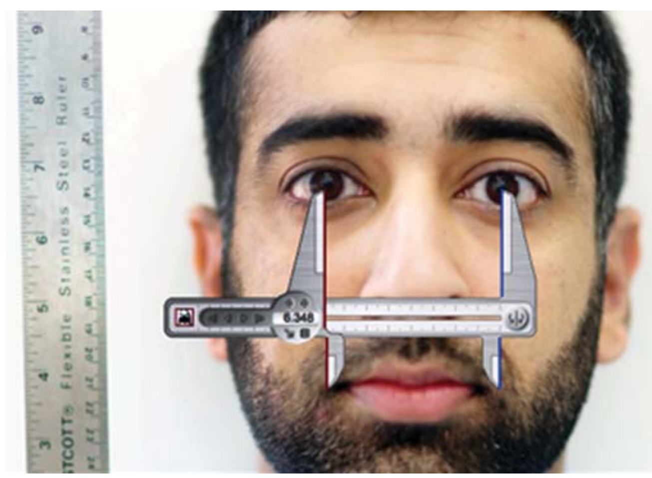
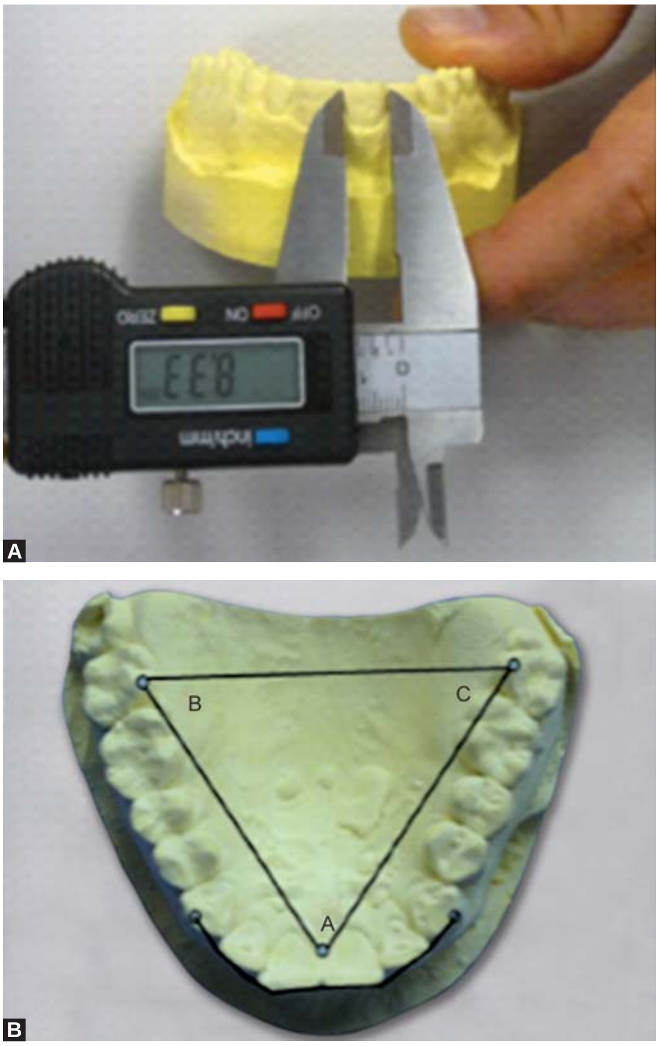


Fig. 1: Digital photograph showing the method of measurement for extraoral anatomical landmarks



Figs 2A and B: Calibrated calipers and maxillary cast used for intraoral measurements (A) Calipers and technique used to assess mesiodistal maxillary central incisor width (B) Palate width and length landmarks and circumferential canine tip to canine tip distance. BC distance = right MP7 to left MP7, AB distance = right MP7 to incisive papilla and AC distance = left MP7 to incisive papilla

were removed. Of the 120 students that were approached, 98 students (43 females, 55 males) had a complete data set and were included in the study.

Data were analyzed using SPSS version 17 software. Normality of the distribution was tested with the Kolmogorov-Smirnov test. Bland-Altman plots were used to assess interexaminer agreement for intraoral and extraoral measurements. This was achieved by calculating the mean difference between assessors and assessing the percentage of measures outside two standard deviations from the mean.

Comparison of the variability within the group was assessed using the potentially explanatory categorical variables identified in the questionnaire. The means of each measured variable was analyzed under the following sub-populations: Gender, age, previous orthodontic treatment including extraction history for orthodontic purposes and ethnic origin of both parents. As the mean distributions were normal, ANOVA followed by Tukey post hoc tests were used to test statistically significant ($p < 0.05$) difference between the groups. Pearson coefficients were used to determine whether correlation exists between intraoral and extraoral measurements.

RESULTS

The distribution of data determined by the Kolmogorov-Smirnov test was found to be normal. Bland-Altman plots showed that the agreement between examiners was high for interalar width with an average difference of only 0.03 mm and the worst agreement was for the canine to canine width with an average value difference of 0.36 mm.

Results of the mean values of the intraoral and extraoral measurements and standard deviations are presented in Table 1. There was a correlation between the width of maxillary central incisor and the width of AB, AC, BC distances and interalar distances. It was interesting to note that subtracting the interalar width from the mean of intra-oral maxillary measurement (AB+BC+AC) gave the approximate width of maxillary central incisor.

Table 2 shows weak to moderate correlation between the intraoral and extraoral measurements. Age ($p = 0.683$) was not shown to be significant with respect to mean mesio-distal maxillary incisor width (Table 3).

Statistical analysis showed a significant difference ($p < 0.05$) between gender for all intraoral and extraoral measurements except the width of the labial commissures (Tables 3 to 7).

DISCUSSION

This study assessed the value of using facial and dental arch measures to reliably predict landmarks and dimensions that could potentially assist clinicians with tooth selection in the anterior maxilla. Mean scores of the extraoral and intraoral measurements recorded in this study were consistent with results from a previous study.[7]

The limitations of the study included the relatively small sample of individuals from ethnically diverse backgrounds, as well as difficulties with reproducibility of the two outcome variables. As the authors were unable to repeatedly capture the posterior palate soft tissue landmarks that remain static despite tooth extraction,[1] the direct implications of the findings on edentulous ridges require further investigation.

The mean mesiodistal central incisor width (8.39 mm) was consistent with previous studies conducted *in vivo*[7] (8.4 mm) and on plaster casts[21] (8.59 mm). When compared with studies on extracted teeth[7] (9.00 mm), the current method showed lower mean values and a greater variation between assessors due to difficulties inserting the calipers

Table 1: Mean values for extraoral and intraoral measurements by gender (mm)

	Male		*Female*		*All subjects*		*p-value*
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	
Extraoral measurement							
Intercanthal distance	34.30	3.38	31.87	4.29	33.24	3.80	0.03
Interpupillary distance	62.01	4.18	58.91	4.08	60.68	4.30	0.00
Interalar width	39.82	3.34	36.28	3.89	38.27	3.80	0.00
Commissure of lip width	51.11	4.40	49.95	4.91	50.61	4.60	0.28
Intraoral measurement							
Width of central incisor	8.50	0.53	8.25	0.43	8.39	0.49	0.01
Canine to canine width	35.62	2.22	33.95	1.71	34.89	2.13	0.00
BC	49.74	3.42	46.32	3.40	47.24	3.70	0.01
AC	46.32	2.71	43.86	3.38	46.24	3.09	0.01
AB	46.61	2.45	44.23	3.07	46.56	2.50	0.00

Proposed central incisor widths or equation = (BC distance + AB distance + AC distance)/3 – Interalar width
Width of central incisor equation = (47.24 + 46.24 + 46.56)/3–38.27 = 8.41

Table 2: Pearson correlation matrix for intraoral and extraoral measurements

Measurement	*MICD*	*MIPD*	*MIAD*	*MICD*	*MMAW*	*MLML*	*MRML*	*MMLW*	*MMCW*
All subjects (Male and Female)									
Central incisor width	0.12	0.13	0.21*	0.08	0.29**	0.38**	0.38**	0.4**	0.55**
Combined width of 6 anterior teeth	0.15	0.15	0.38**	0.16	0.41**	0.36**	0.38**	0.4**	1
Female									
Central incisor width	0.03	0.03	–0.1	–0.18	0.11	0.32*	0.25	-	0.38**
Combined width of 6 anterior teeth	0.20	0.11	0.15	0.16	0.11	0.27	0.24	-	1
Male									
Central incisor width	0.04	0.08	0.24	0.18	0.27*	0.33*	0.39*	-	0.57**
Combined width of 6 anterior teeth	–0.09	–0.02	0.32	0.10	0.39	0.25	0.32	-	1

*correlation is significant at p = 0.05 (2-tailed)
**correlation is significant at p = 0.01 (2-tailed)
MICD: Mean intercanthal distance; MIPD: Mean interpupillary distance; MIAD: Mean interalar distance; MICD: Mean intercommissural distance; MMAW: Mean maxillary arch width (BC distance); MLML: Mean left maxillary arch length (AC distance); MRML: Mean right maxillary arch length (AB distance); MMLW: Mean maxillary length and width; MMCW: Mean maxillary canine to canine width

Table 3: Bivariate associations of the mesiodistal width of maxillary central incisor with potential explanatory variables

Potential explanatory variable		*N*	*Mean*	*SD*	*f-value*	*p-value*
Gender	Male	55	8.49	0.53	6.16	0.01
	Female	43	8.25	0.43		
Age	Less than 25 years	64	8.40	0.50	0.17	0.68
	More than 25 years	34	8.36	0.52		
Orthodontic treatment	No	64	8.40	0.52	1.70	0.19
	Yes/ With extraction	15	8.54	0.47		
	Without extraction	19	8.22	0.43		
Family origin	Asia	41	8.41	0.58	0.09	0.96
	Europe/Australia	25	8.38	0.46		
	Middle East	18	8.36	0.44		
	Indian/subcontinent	13	8.34	0.45		

into contact points and defining exact points of greatest convexity on plaster casts.[7] The results showed sexual dimorphism (male 8.49 mm, female 8.25 mm, p = 0.014), which is consistent and extensively described in the literature[21] with the permanent central maxillary teeth of males being approximately 3% larger than females.[7,8] Age (p = 0.683) was not shown to be significant with respect to mean mesiodistal incisor width. This was not consistent with previous studies that reported that age had an inverse relationship—indicating that with an increase in age there was a decrease in tooth width.[11] This has been attributed to interproximal tooth wear and loss of tooth structure at the incisal edge through attrition and abrasion.[11] As the aim was to predict central incisor width, the age of the sample was selected with the intent of measuring original tooth width at full musculoskeletal development to prevent age

Table 4: Bivariate associations of combined width of the maxillary canine to canine tip with potential explanatory variables

Potential explanatory variable		*N*	*Mean*	*SD*	*f-value*	*p-value*
Gender	Male	55	35.62	2.22	16.55	0.00
	Female	43	33.95	1.71		
Age	Less than 25 years	64	35.04	2.06	0.97	0.33
	More than 25 years	34	35.59	2.33		
Orthodontic treatment	No	64	34.71	2.05	0.94	0.04
	Yes/ With extraction	15	35.56	2.09		
	Without extraction	19	34.92	2.60		
Family origin	Asia	41	35.56	1.97	2.70	0.05
	Europe/Australia	25	34.11	1.93		
	Middle East	18	34.55	2.47		
	Indian/subcontinent	13	34.77	2.38		

Table 5: Bivariate associations of the BC distance with potential explanatory variables

Potential explanatory variable		*N*	*Mean*	*SD*	*f-value*	*p-value*
Gender	Male	55	47.74	3.42	24.31	0.00
	Female	43	46.31	3.39		
Age	Less than 25 years	64	47.63	3.69	4.90	0.03
	More than 25 years	34	49.38	3.77		
Orthodontic treatment	No	64	49.14	3.37	10.08	0.00
	Yes/ With extraction	15	44.55	3.70		
	Without extraction	19	47.99	3.67		
Family origin	Asia	41	48.70	3.92	0.40	0.75
	Europe/Australia	25	47.87	3.99		
	Middle East	18	47.69	3.72		
	Indian/subcontinent	13	48.25	3.30		

Table 6: Bivariate associations of the length of the AC distance with potential explanatory variables

Potential explanatory variable		*N*	*Mean*	*SD*	*f-value*	*p-value*
Gender	Male	55	46.60	3.06	18.03	0.00
	Female	43	44.23	2.45		
Age	Less than 25 years	64	45.04	3.05	5.95	0.02
	More than 25 years	34	46.54	2.57		
Orthodontic treatment	No	64	46.27	2.54	15.38	0.00
	Yes/With extraction	15	42.14	2.98		
	Without extraction	19	45.89	2.50		
Family origin	Asia	41	45.06	2.89	0.45	0.72
	Europe/Australia	25	45.09	3.41		
	Middle East	18	45.32	3.09		
	Indian/subcontinent	13	46.04	2.10		

Table 7: Bivariate associations of the AB distance with potential explanatory variables

Potential explanatory variable		*N*	*Mean*	*SD*	*f-value*	*p-value*
Gender	Male	55	46.60	3.06	18.03	0.00
	Female	43	45.23	2.45		
Age	Less than 25 years	64	45.04	3.05	5.95	0.02
	More than 25 years	34	46.54	2.57		
Orthodontic treatment	No	64	46.27	2.54	15.38	0.00
	Yes/ With extraction	15	42.14	2.98		
	Without extraction	19	45.89	2.50		
Family origin	Asia	41	45.08	2.89	0.45	0.70
	Europe/Australia	25	45.09	3.41		
	Middle East	18	45.32	3.09		
	Indian/subcontinent	13	45.04	2.10		

related tooth loss potentially skewing relationships with other dental arch and facial measures.

Intercanine tip width is chosen as a useful guide when setting maxillary artificial teeth.[11] Our results showed the greatest variability between assessors (average difference 0.36 mm). This was due to difficulty identifying canine tip on dentitions with variable degrees of wear and discrepancy in reproducing the arc of greatest curvature around the anterior maxilla. The result for mean circumferential distance from one maxillary canine tip to the other was 34.66 mm. Within this group the four subcategories of country of origin showed borderline significance (p = 0.049). Those results (34.36 mm) were consistent with studies of European based population[13] (34.3 mm, 34.2 mm). In addition, in the current study subjects of Asian origin had on average 1mm longer canine tip to canine tip distances (35.56 mm) which corroborated the findings from a Chinese population (35.74 mm).[6]

Palate width and length were recorded using arbitrary reproducible dental landmarks in the posterior maxilla (incisive papilla and 17/27 MP cusp tips). Due to restrictions imposed on the methods of data collection, the authors were unable to repeatedly capture the posterior palatal soft tissue landmarks (hamular notches, palatine fovea) or to identify those landmarks on stone models. Findings from this study indicate arch length and width were statistically significant by gender and orthodontic history (p = 0.00). While males displayed sexual dimorphism, individuals, who had not received previous orthodontic treatment, were found to have significantly wider and longer palates with both effects being of similar magnitude (p = 0.0001). Of those participants who had previously received orthodontic treatment and who had bilateral premolar extractions as an adjunct to treatment showed a mean shorter and narrower palate compared with those who had orthodontic treatment alone; as would be expected following premolar extraction and mesialising posterior teeth. The shortened arch from incisive papilla to second molars would result in an arch width measure closer to the arc of curvature hence resulting in a smaller value.

Intercanthal and interpupillary distances are chosen as they are important components to an individual's facial esthetics,[6] easily measured, have high interexaminer reliability and adult eye dimensions are established early and maintained throughout adult life (adult interpupillary distance was reached by the fourth year,[16] while adult intercanthal distance is established by 11 years).[22,23] Additionally, no differences related to race or age have been shown in the literature.[18] The strength of the correlation contradicts previous findings that interpupillary width[16,17] can be used as a reliable tool while selecting anterior tooth position (r = 0.15). The intercanthal correlation values are similar to those reported by Ulhas[20] but as this is a very weak association, the authors do not support its use in anterior teeth selection.

A relationship between interalar width and anterior dental arch width is supported in the literature by Lee[4] and Picard[3]. Wehner[15] first suggested extending lines parallel from the lateral surface of the ala of the nose to the labial surfaces of the maxillary occlusal wax rims as an estimation of canine tip position. Previously reported values in the literature show a large range (32.2 mm[6]-43.94 mm[16]) with the results being greater than most mean interalar widths previously reported. As the interexaminer reliability was excellent (mean difference = 0.03) and statistical difference between male and female subjects was maintained, the authors recommend that demographics of the population to be considered while interpreting these results.

The intercommissural width has previously been shown to be the highest single predictor of mesiodistal incisor width reported (r = 0.45[6], r = 0.34[11]). This finding was not replicated in our study (r = 0.21). It did however give the highest extraoral correlation (r = 0.38) with canine tip to canine tip distance. As photographs were taken of relaxed subjects it did not follow the same protocol for reassessment of 'relaxed lip position'. This resulted in higher mean scores, larger range of scores (40-61 mm) and a larger standard deviation than previously reported in the literature.

When the width of the maxillary incisor and circumferential distance between the tips of the maxillary canines were compared with external facial measurements (interpupillary, intercanthal, interalar distance and intercommissural), only a weak positive correlation was found. This study corroborates the weight of evidence over the past 30 years with the interalar width having the highest extraoral association (r = 0.38) arch width (r = 0.41) and arch length (r = 0.38), having only a marginally stronger, weak to moderate positive association. Hence, the findings of this study support the premise that no single intraoral or extraoral anatomical variable was strongly enough correlated to justify its selection in choosing appropriately sized maxillary anterior teeth. As correlations were weak, there is little benefit in using a single intraoral or extraoral anatomical variable as a biometric ratio to quantify tooth selection. This finding emphasizes the value of pre-extraction records in anterior tooth selection. As a result, it is recommended every effort be made to source dental records (plaster models, stored extracted teeth or teeth measured and recorded at the time of extraction) so that direct measurements can be obtained. If this is not possible the maxillary central incisor width can be obtained from a pre-extraction photograph. By calibrating the photograph using a ratio obtained from interpupillary distance of the photograph and of the individual, a distinct maxillary central incisor width may be calculated.[6] This method was shown to be precise enough for 'face on' photographs but statistical significance could not be obtained in an oblique projections views.[6] When teeth are either not visible or too small to be measured in a photograph and no pre-extraction records exist, the authors support using a scientifically based method as a starting point for tooth selection. In acknowledgment of previous research, the authors suggest the use of multiple intraoral anatomical measurements to assist with the preliminary stages of tooth selection.[11,17] This may be achieved by averaging arch width and length measurements using the incisive papilla and maxillary tuberosity as anatomical landmarks and then deducting the interalar distance which will give the average size of maxillary incisor as shown in Figures 2A and B. There is no available evidence to support this equation as maxillary anterior tooth selection is more of an art than a science.[11] Hence, this becomes only part of the solution with emphasis at the wax try-in stage placed on obtaining a balance with the interalar width and consultation and collaboration with the patient.[18]

CONCLUSION

Width and length of the maxillary arch and interalar width are the most highly validated indicators of anterior tooth size selection ($r = 0.38$-0.40). Combining these measures can improve the strength of the correlation. Using these dimensions can be used to assist clinicians calculate maxillary incisor width. Although statistical correlation is weak to moderate, evidence supports its use as an initial guide to tooth selection in the absence of pre-extraction records. While multiple measures may be used to increase the strength of the correlation, the later remain weak and the implications and acceptance of these methods on clinical practice require further consideration.

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ABOUT THE AUTHORS

Ayman Ellakwa (Corresponding Author)

Senior Lecturer, Sub-Dean, Department of Biomaterials, Faculty of Dentistry, The University of Sydney, Westmead Oral Health Centre Level 1, Westmead Hospital, Darcy Road, Sydney-2145, NSW Australia, Phone: +61298457161, Fax: 61296334759, e-mail: ayman.ellakwa@sydney.edu.au

Kieran McNamara

Department of Conservative Dentistry, Faculty of Dentistry The University of Sydney, NSW, Australia

Jasdeep Sandhu

Department of Conservative Dentistry, Faculty of Dentistry The University of Sydney, NSW, Australia

Kedall James

Department of Conservative Dentistry, Faculty of Dentistry The University of Sydney, NSW, Australia

Amit Arora

Department of Dental Public Health, Faculty of Dentistry The University of Sydney, NSW, Australia

Iven Klineberg

Department of Oral Rehabilitation, Faculty of Dentistry The University of Sydney, NSW, Australia

Ali El-Sheikh

Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Tanta University, Tanta, Egypt

F Elizabeth Martin

Department of Conservative Dentistry, Faculty of Dentistry The University of Sydney, NSW, Australia