Correlation between Facial Measurements and the Mesiodistal Width of the Maxillary Anterior Teeth

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ABSTRACT

One of the most difficult aspects during the selection of maxillary anterior teeth for a removable prosthesis is determining the appropriate mesiodistal width of the six maxillary anterior teeth. Many attempts have been made to establish methods of estimating the combined width of these anterior teeth, and improving the esthetic outcome. The proportion of facial structures and the relationship between facial measurements and natural teeth could be used as a guide in selecting denture teeth. The aim of this study was to verify the relation between the combined mesiodistal width of the six maxillary anterior teeth and the facial segments: the width of the eyes, the inner canthal distance (ICD), the interpupillary distance (IPD), the interalar width, and the intercommissural width (ICm). Standardized digital images of 81 dentate Brazilian subjects were used to measure both facial and oral segments when viewed from the frontal aspect through an image processing program. To measure the distance between the upper canines on a curve, accurate casts were made from the upper right first premolar to the upper left first premolar. The Spearman rank correlation coefficient was conducted to measure the strength of the associations between the variables ($\alpha = 0.05$). The results showed a significant correlation between all facial elements and the combined mesiodistal width of the six teeth, when observed from the frontal aspect. The ICD, IPD, and ICm showed the highest probability of being correlated to the mesiodistal width of the teeth ($p = 0.000$).

CLINICAL SIGNIFICANCE

This article considers facial analysis with digital photography as a practical and efficient application to select the mesiodistal width of artificial anterior teeth in an esthetically pleasing and natural appearance during an oral rehabilitation treatment.

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INTRODUCTION

It is safe to say that no one contemplates with pleasure becoming edentulous and acquiring artificial dentures. The patient who wears a complete denture for the first time wants it to appear similar to natural teeth. First, during the rehabilitation treatment, the patient demands comfort, followed by harmonious appearance, and lastly, efficiency.[1] The esthetic restoration

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of the edentulous patient has an important psychological effect. It improves the self-esteem and self-confidence of a patient and, therefore, is an important part of the oral rehabilitation treatment.[2]

According to the *Dentogenic Restorations*, to guarantee a suitable denture that is pleasant for the user, it must exhibit the sex, personality, and age attributes of the user.[3] It is known that the size, shape, and color of the teeth must be in harmony with the surrounding oral and facial structures. Selecting and aligning replacement teeth to proper proportions facilitates a natural and esthetic appearance.[1,4,5]

During the selection of the maxillary anterior teeth for a complete removable denture, the mesiodistal width of the upper anterior teeth is considered by some as a harder aspect to be established than their length.[1,6–8] When no pre-extraction records of the natural teeth such as casts or photographs are available, selecting the proper anterior teeth size can be difficult.[1,4,6] Some authors have investigated a relationship between certain anthropometric measurements of the face and the mesiodistal width of the upper anterior teeth to define a ratio between facial size and tooth size, which could be used as a guide in selecting denture teeth.[6,9–11]

Berry has said that the width of the maxillary central incisor exists in a ratio of 1:16 to that of the bizygomatic width.[12] Later, House and Loop evaluated the ratio published by Berry, and found a range of ratios from 1:13 to 1:19, with 1:16 as an average midpoint.[12,13] In view of this range, it is questionable whether an average facial measurement would be appropriate to estimate the width of the central incisor for a patient who is partially toothless.[5,14,15]

Another facial structure investigated was the width of the nose. When measured in bone structure, the nasal width showed equal or nearly equal measurements to the width of the four maxillary incisors in 93% of the skulls analyzed.[1] However, when measured in soft tissue, the interalar width (IA) is not correlated to the width of the four maxillary incisors but rather to the width of the six maxillary incisors.[9,11] On the other hand, Smith, in 1975, found that neither the nasal width nor the IA correlated to the width of the six upper anterior teeth.[16]

A factor of 6.6 was found by Cesário and Latta to exist between the mean interpupillary distance (IPD) and the mean of mesiodistal width of the upper central incisor.[10] According to Al Wazzan, the distance between the inner canthal distance (ICD) is correlated to the dental widths: the mean widths of two central incisors, the combined widths of the central incisors, the combined widths of the four incisors, and the combined widths of the six upper anterior teeth.[6] Clapp and Tench published that the distal surfaces of the maxillary canines should be located at the commissural of the mouth, but Al Wazzan and colleagues found no correlation between the width of the mouth and the mesiodistal width of the upper anterior teeth.[17,18] Latta, Weaver, and Conkin, who measured in edentulous patients the width of the mouth, the IA, the bizigomatic width, and the IPD, concluded that more than one variable is needed to predict the width of maxillary anterior teeth.[19]

Because a number of these methods of establishing esthetic parameters exhibit questionable validity, many dentures have an obviously artificial appearance. Moreover, as no universally accepted parameter currently exists for the selection of anterior teeth, this study was developed to investigate the potential relationship between the combined mesiodistal width of the six upper anterior teeth and some facial segments: width of the right eye—measured from its outer to its inner canthus (RE); width of the left eye—measured from its outer to its inner canthus (LE); IA—measured from the widest points on either ala; ICD—measured between the

points at the medial angle of a palpebral fissure of the right and left eyes; IPD—measured from midpupil to midpupil; and intercommisural width—measuring the maxillary lip vermilion, between the points at the corner of the mouth (ICm). After finding a correlation between facial and oral dimensions, it is hoped that a reliable guide can be defined to improve tooth selection and enhance the final esthetic result.

MATERIALS AND METHODS

A total of 81 dentate Brazilian subjects (37 men and 44 women) were randomly selected from the student body at the Federal University of Uberlandia (MG, Brazil). They ranged from 17 to 33 years of age, with a mean of 21 years. All subjects answered a questionnaire to investigate their dental arch conditions; and they should possess six maxillary anterior teeth with no severe attrition, no artificial crowns or large restorations. Exclusion criteria included subjects whose six upper anterior teeth exhibited severe attrition, artificial crowns, large restorations, facial alterations, or a history of congenital facial anomalies or facial surgery.

Two standardized digital photographs of the face, generated from a frontal aspect, were made using a digital camera (FD97, Mavica, Sony, Mexico City, Mexico). During the capture of the first photo (Figure 1A), the student was asked to sit, look forward to the horizon line, and rest the facial muscles in order to relax the facial and stomatognathic muscles to achieve what has been referred to by Tamaki as the vertical dimension of rest position.[20] Then, for the second photo, the student was asked to smile (Figure 1B), thereby revealing the maxillary anterior teeth, allowing a measurement to be made, in a straight line, of the following parameters: the distance between the tip of the maxillary canines (TTP) and the widest mesiodistal distance between the distal surfaces of the maxillary canines.

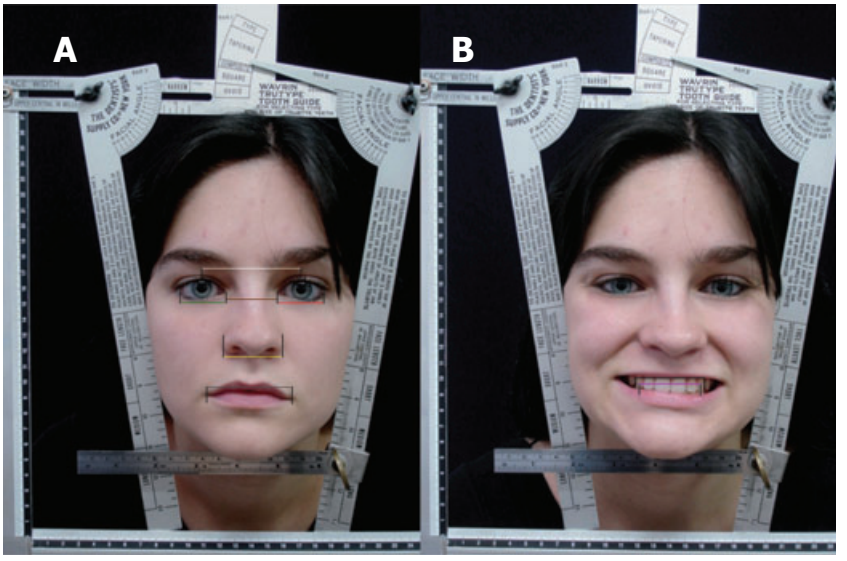


Figure 1. Picture while the student was in vertical dimension or rest position, smiling. A, To measure the width of the right eye (green), width of the left eye (red), interalar width (yellow), inner canthal distance (brown), interpupillary distance (white), and intercommissural distance (gray). B, To measure both the distance between the tips of the upper canines (pink), and between the distal surfaces of the upper canines (black).

The photographic images were made by just one trained photographer. A distance of 56.0 cm between the digital camera lens and the tip of the subject's nose was established by the use of a top cord (CCL, SL-P319, Lufkin, Kerrville, Texas, USA). The digital camera was positioned on a tripod (Tron, VT-40, Manaus, Amazonia, Brazil), which was 112.0 cm in height. The subject was instructed to position his face at a Wavrin modified set square, which standardized the head position and provided a measurable relationship between the image and the actual dimension. An image processing program was used to measure the

apparent width of the distances (HL IMAGE ++97, Western Vision Software, LC, East Layton, Utah, USA).

In addition to measuring the apparent mesiodistal width of the teeth, through an image measurement program, dense silicone (Silon2 APS, Dentsply, Petropolis, RU, Brazil) was manipulated according to the manufacturer's instruction and impressed onto the buccal surfaces of both the lower and upper dental arches. Then, casts were fabricated from hard plaster (Empresa e Indústria Gesso Mossoró SA, Rio de Janeiro, RJ, Brazil) that extended from the first upper left premolar to the first upper right premolar. These casts were used to measure the mesiodistal width on a curve, when they are placed on the dental arch (Figure 2). A flexible millimeter ruler was used to measure on a curve both the distances between the tips of maxillary canines (TTC), and between the distal surfaces of the maxillary canines (DDC), from the region of the proximal contact points.

For the sake of consistency, the same examiner made all the records and performed all of the measurements three times, on different days and times. From the three results, a mean value was calculated to establish the consistency of the measurements and the intrarater reliability of the evaluator.

Figure 2. Cast to measure the distance between the maxillary canines on a curve. A, Viewed from the frontal aspect. B, Viewed from the lateral aspect showing the points of reference. C, Flexible millimeter ruler to measure, on a curve, both the distance between the tips of the upper canines, and between distal surfaces of maxillary canines.

RESULTS

Based on the fact that the sample distribution was not normal and the data available for the analysis were less than 100 observations, nonparametric statistical tests were conducted. For each recorded measurement, Table 1 lists the median value. Like the central tendency, the median is the value for which one-half (50%) of the observations will lie above that value and one-half will lie below that value. Minimum and maximum values also are listed in Table 1.

The sample was divided according to gender and history of orthodontic treatment. The Mann-Whitney U test was used to verify specific group differences ($\alpha = 0.05$). The results are presented in Tables 2 and 3, and the median values to

TABLE 1. MEDIAN VALUES AND RANGE OF THE MEASUREMENTS RECORDED

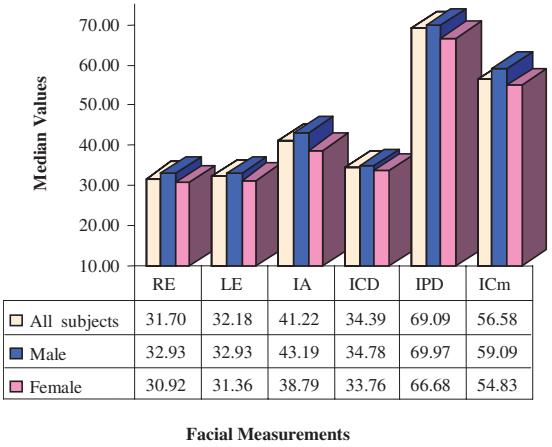
Measurements	Minimum (mm)	Median (mm)	Maximum (mm)
RE	27.970	31.700	39.610
LE	27.950	32.180	39.340
IA	32.930	41.220	48.310
ICD	28.860	34.390	44.260
IPD	57.900	69.090	79.890
ICm	48.600	56.580	76.240
TTP	31.580	37.440	43.350
TTC	36.330	44.000	50.670
DDP	37.210	42.340	48.290
DDC	45.000	53.670	60.330

RE = width of the right eye; LE = width of the left eye; IA = interalar width; ICD = inner canthal distance; IPD = interpupillary distance; ICm = intercommissural distance; TTP = distance between the tip of the upper canines, on the photo; TTC = distance between the tips of upper canines, on the cast; DDP = distance between the distal surfaces of the upper canines, on the photo; DDC = distance between the distal surfaces of the upper canines, on the cast.

different genders are compared in Figures 3 and 4.

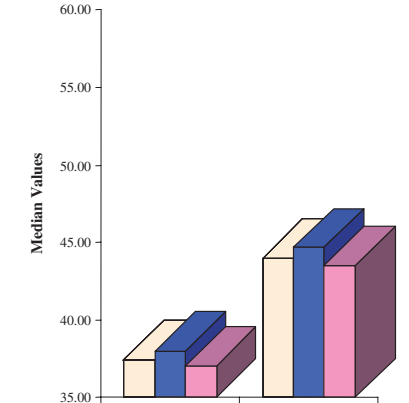
A statistically significant difference was found relative to gender regarding the size of all facial measurements recorded (Table 2), with the exception ($p = 0.125$) of the ICD, which showed a median value of 34.39 mm (Table 1). For the combined widths of the maxillary teeth measured on the cast, there were no significant differences relative to gender (Table 2), which showed a median value of 44.00 mm for the distance TTC and 53.67 mm for the distance DDC (Table 1).

The Mann-Whitney U test showed a statistically significant difference relative to history of orthodontic treatment only for the IA. This difference remains when the same analysis (difference according to history of orthodontic treatment) was performed with individuals of



	RE	LE	IA	ICD	IPD	ICm
All subjects	31.70	32.18	41.22	34.39	69.09	56.58
Male	32.93	32.93	43.19	34.78	69.97	59.09
Female	30.92	31.36	38.79	33.76	66.68	54.83

Figure 3. Median values of the facial measurements of all subjects, and when sample was divided according to gender. RE = width of the right eye; LE = width of the left eye; IA = interalar width; ICD = inner canthal distance; IPD = interpupillary distance; ICm = intercommissural distance.



	TTP	TTC
All subjects	37.44	44.00
Male	38.01	44.67
Female	37.05	43.50

Figure 4. Median values of the distance between the tips of maxillary canines of all subjects, and when sample was divided according to gender. TTP = distance between the tip of the upper canines, on the photo; TTC = distance between the tips of upper canines, on the cast.

TABLE 2. MANN-WHITNEY TEST RESULTS FOR SIGNIFICANT DIFFERENCE ACCORDING TO GENDER

Measurements	RE	LE	IA	ICD	IPD	ICm	TTP	TTC	DDP	DDC
Probabilities	0.000	0.000	0.000	0.125	0.000	0.000	0.033	0.081	0.015	0.068

Abbreviations listed in footnote to Table 1.

TABLE 3. MANN-WHITNEY TEST RESULTS FOR SIGNIFICANT DIFFERENCE ACCORDING TO HISTORY OF ORTHODONTIC TREATMENT

Measurements	RE	LE	IA	ICD	IPD	ICm	TTP	TTC	DDP	DDC
Probabilities	0.342	0.641	0.002	0.392	0.672	0.537	0.403	0.515	0.898	0.764

Abbreviations listed in footnote to Table 1.

the same gender, which indicates that people who had already undergone an orthodontic treatment have an IA smaller than those who had never undergone treatment. There was no data concerning the effect of orthodontic treatment on the IA; therefore, people who need an orthodontic treatment in general have a facial profile (dolichocephalic) that reflects a reduced width of the nose in relation to the people that do not need orthodontic treatment.

The Spearman rank correlation coefficient was used to provide a careful measure of a relationship between the two (tabulated) variables ($\alpha = 0.05$), and the results are shown in Table 4. A significant correlation was found between all facial measurements analyzed and the combined width of the teeth measured in a straight line, as seen in each photograph. When the facial measurements were compared to the combined width of the teeth measured on the cast, only ICD, IPD, and ICm were correlated to the width of the maxillary teeth while positioned on the dental arch.

DISCUSSION

Many attempts have been made to quantify the selection of anterior teeth for complete dentures, but little agreement on an effective method has been reached. The present research revealed a significant positive correlation between the apparent size of all facial structures and the mesiodistal width of the anterior teeth, when measured from the frontal aspect (Table 4). Probabilities of correlation were higher ($p = 0.000$) to the distances ICD, IPD, and ICm, when comparing them to both mesiodistal width measured on the photo, TTP and DDP. Moreover, those facial structures mentioned (ICD, IPD, and ICm) were the only ones correlated to the mesiodistal width measured on a cast (TTC and DDC), as presented in Table 4.

The ICD showed a median of 34.39 mm, ranging from 28.86 to 44.26 mm. Abdullah found a mean of 28.30 mm and Al Wazzan, measuring the facial segment with a modified Boley gauge, described a range from 25.00 to 39.00 mm, with a mean of 31.92 mm.[6,7] Laestadius, Aase, and Smith published a mean of 30.00 mm for the ICD.[21] A higher mean value (33.90 mm), which was close to the median value presented in this study, was described by Murphy and Laskin.[22] The different values cited previously possibly could be a result of the ethnic variation of the study sample analyzed. In the present study, the maximum value (44.26 mm) corresponded to a man

TABLE 4. SPEARMAN RANK CORRELATION COEFFICIENT RESULTS TO THE ASSOCIATIONS OF EACH FACIAL MEASUREMENT TO THE FOUR TEETH WIDTHS RECORDED

Measurements	Photo (TTP)		Cast (TTC)		Photo (DDP)		Cast (DDC)	
	rs	*p*	rs	*p*	rs	*p*	rs	*p*
RE	0.256	0.021	0.032	0.776	0.328	0.003	0.153	0.171
LE	0.239	0.031	0.071	0.526	0.285	0.010	0.204	0.067
IA	0.326	0.003	0.189	0.091	0.362	0.001	0.205	0.066
ICD	0.466	0.000	0.211	0.049	0.477	0.000	0.232	0.037
IPD	0.462	0.000	0.258	0.020	0.489	0.000	0.287	0.009
ICm	0.522	0.000	0.273	0.014	0.573	0.000	0.296	0.007

rs = correlation coefficient values; p = probabilities.
Abbreviations listed in footnote to Table 1.

of Asiatic descent, who exhibited strong Asiatic features. This result is in contrast to the range adopted as normal (from 28.00 to 35.00 mm) by Freihofer (Switzerland, in 1980), while studying a sample of 100 subjects, ranging from 14 to 76 years of age.[23] Freihofer reported values between 2.00 and 38.00 mm, with a mean of 31.20 mm. In the first year of age, 80% of ICD growth has been achieved, and maturity is reached between 8 and 11 years.[21,24] The ICD was the only facial segment that shows no significant difference relative to gender (Table 2), according to the data.[6,21,23] The ICD showed correlation (rs = 0.466; $p = 0.000$), both when associated to the CCP and when associated to DDP (rs = 0.477; $p = 0.000$). Al Wazzan also has shown high probabilities of these structures being correlated.[6]

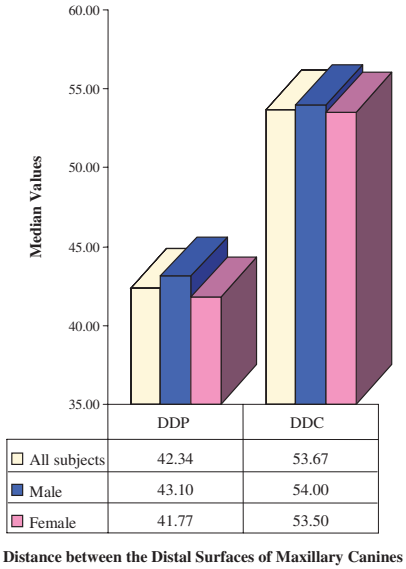


Figure 5. Median values of the distance between distal surfaces of maxillary canines: of all subjects, and when sample was divided according to gender. DDP = distance between the distal surfaces of the upper canines, on the photo; DDC = distance between the distal surfaces of the upper canines, on the cast.

The IPD, according to the data, is a facial segment that does not modify after achieving the adult measure at about 14 years of age.[25,26] This distance showed a median value of 69.09 mm, to the total sample, ranging between 57.90 and 79.89 mm. Cesário and Latta showed a mean value of 59.16 mm, after measuring 100 subjects of the US Army.[10] Latta, Weaver, and Conkin found in 109 edentulous patients a mean of 63.51 mm, and a range from 38.00 to 73.00 mm; Lucas and Pryor described a mean of 58.00 mm.[19,25] This sample of 81 subjects revealed higher IPD values for males than for females ($p = 0.000$), according to the literature.[10]

The ICm distance showed a median value of 56.58 mm to the total sample, and a range between 48.60 and 76.24 mm. Latta, Weaver, and Conkin, after measuring edentulous patients, found a mean of 53.74 mm, ranging from 36.00 to 68.00 mm, with a significant difference relative to gender.[19] Also, the ICm distance presented ($p = 0.000$) a higher value for males (59.09 mm) than for females (54.83 mm).

The distance between the tips of maxillary canines measured in the photo (CCP) showed a median of 3.44 mm, ranging from 31.58 to 43.35 mm. Hoffman, Bomberg, and Hatch also measured the distance between the tips of the maxillary canines in a straight line, but used a Boley gauge situated on a wax registration.[11] The authors found a mean of 35.35 mm, and a range from 30.00 to 46.00 mm. A mean of 34.30 mm was published by Mavroskoufis and Ritchie, who recorded the intercanine distance with dividers to an accuracy of 0.1 mm.[9]

The distance between the apparent distal surface measured in a photo (DDP) showed a median value of 42.34 mm, ranging from 37.21 to 60.33 mm. Al Wazzan described a mean value of 45.23 mm, and a range from 37.00 to 52.00 mm.[6] Abdullah and colleagues found a mean of 43.00 mm, which was nearest the value found in this research.[27]

When measured on the cast, the distance between the tips of the maxillary canines (TTC) showed a median value of 44.00 mm, and a range from 36.33 to 50.67 mm, as presented in Table 1. The distance between the distal surfaces on the cast (DDC) presented values between 45.00 and 60.33 mm, and a median of 53.67 mm, similar to the mean value of 53.70 mm (Figure 5)

published by McArthur.[14] The author measured the circumferential distance on a cast with a flexible millimeter ruler, and found a range from 47.00 to 63.00 mm.

The mesiodistal width of the teeth in the photo showed statistically significant differences relative to gender (TTP, $p = 0.033$ and DDP, $p = 0.015$). On the other hand, the mesiodistal width, when measured on a curve, showed no significant difference relative to gender (TTC, $p = 0.081$ and DDC, $p = 0.068$). Of the 81 volunteer students, 45 had a history of orthodontic treatment. The results of the Mann-Whitney test for all the mesiodistal teeth widths recorded revealed no significant difference between the students who had a history of orthodontic treatment and the ones who had no history of orthodontic treatment (TTP, $p = 0.403$ and DDP, $p = 0.898$; TTC, $p = 0.515$ and DDC, $p = 0.764$).

A curious result was the significant difference found relative to the IA between students who had a history of orthodontic treatment and the ones who did not ($p = 0.002$). The highest values corresponded to those who did not have a history of orthodontic treatment (Table 3). The IA of the total sample showed a median of 41.22 mm, ranging from 32.93 to 48.31 mm (Table 1). Latta, Weaver, and Conkin found in edentulous patients a mean of 43.93 mm, with a range from 29.00 to 63.00 mm.[19] Mavroskoufis and Ritchie, on the other hand, found a mean of 35.30 mm, after recording the IA with a Willis gauge.[9] Hoffman, Bomberg, and Hatch, after measuring the IA with a Boley gauge, published a mean of 34.28 mm, with minimum and maximum values from 26.90 to 50.00 mm, respectively.[11]

The IA was significantly correlated to the mesiodistal width measured on the photo, both between the tips of the maxillary canines, TTP (rs = 0.326 and $p = 0.003$), and between the distal surfaces, DDP (rs = 0.362 and $p = 0.001$). Mavroskoufis and Ritchie also found the IA and the distance between the tips of maxillary canines correlated.[9]

After the literature review, another analysis was performed on the sample of 81 subjects. Hoffman, Bomberg, and Hatch, after measuring some structures by a Boley gauge, found mean values of 34.28 mm to the IA, 35.35 mm to the distance between the tips of maxillary canines, and 44.85 mm to the circumferential arch distance between the distal surfaces.[11] The authors concluded that when IA was multiplied by 1.31 (or increased by 31%), the calculated value was equal to the circumferential arch distance between the distal surfaces. When the IA width was multiplied by 1.03 (increased by 3%), the result was equal to the distance between the tips of maxillary canines.

In order to test if the same result occurred in this sample, the Wilcoxon test statistic was conducted to verify if there were significant differences between the calculated values, from the IA width, and the mesiodistal width of the maxillary teeth (DDC and TTC). The results showed a statistically significant difference between IA width multiplied by 1.03 and the TTC distance ($p = 0.000$). However, there was no significant difference between the IA width multiplied by 1.31 and the DDC distance ($p = 0.777$), despite the fact that the Spearman rank correlation coefficient did not reveal these variables being correlated (rs = 0.205 and $p = 0.066$).

After the conclusion that facial and oral structures are correlated in this research, it must be pointed out that the facial segments were measured from the frontal aspect, through an image processing program. Future studies should involve a broad clinical research program that would include the same analysis for an edentulous population, and then define a mathematical relationship of such structures. Nevertheless, the results presented in this article indicated facial segments as a reliable parameter to

improve the final esthetic outcome in denture tooth selection.

CONCLUSION

When measured from the frontal aspect, by the use of photographs, all facial measurements (RE, LE, IA, ICD, IPD, and ICm) correlated to the mesiodistal width of the maxillary teeth (TTC and DDC), with a high probability.

The ICD, IPD, and ICm showed the highest probability ($p = 0.000$) of being correlated to the mesiodistal width measured from the frontal aspect (TTC and DDC), and were the only ones that correlated to the mesiodistal width measured on the cast (TTC and DDC).

The ICD was the only facial segment that did not show significant differences to gender ($p = 0.125$).

As previously described by Hoffman, Bomberg, and Hatch, the IA, when multiplied by a factor of 1.31 (or increased by 31%), can suggest the circumferential distance of the six upper anterior teeth, between the distal surfaces, because there was no difference between the calculated value to that of the mesiodistal width ($p = 0.777$).[11]

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COMMENTARY

CORRELATION BETWEEN FACIAL MEASUREMENTS AND THE MESIODISTAL WIDTH OF THE MAXILLARY ANTERIOR TEETH

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This article explores a topic that creates difficulties for the treating clinician, but is not as common today as it was 40 years ago in the United States. Complete edentulism of the maxillary anterior teeth does not occur often, except in situations where trauma has resulted in tooth avulsion. If all maxillary anterior teeth are to be replaced, and no former smiling photographs or dental casts are available to identify the sizes of the original natural anterior teeth, selection of the appropriate replacements is a challenge. This study investigates the possibility of using specific facial landmarks to establish an overall tooth width range for the maxillary anterior teeth. It was surprising to me that the measurement of interpupillary distance and intercommissural width produced such a strong correlation with the combined widths of the maxillary anterior teeth. Of course, the anterior arch form influences this relationship significantly. If the maxillary arch form were broad and U-shaped, then the distance across the arch would be greater. If the arch were V-shaped, then this distance would be decreased. Some of the subjects in the sample had had previous orthodontic treatment, and others had not. We know that orthodontics has a direct influence on the arch form, as the shape of the anterior dental arch follows the shape of the archwires. Could there have been a difference between the orthodontic portion of the sample and the nonorthodontic subgroup? The other issue that would be interesting to explore, in perhaps a follow-up study, would be to compare the esthetic appearance of the anterior teeth, when calculated from the interpupillary distance or the intercommissural width. This could be done with computer simulation, and would test whether this method of selecting the widths of the maxillary anterior produces esthetically pleasing tooth proportions. I congratulate the authors for a very good article and hope that they continue to test their proposed correlation of anterior tooth size with specific facial measurements.

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