Pesquisa Brasileira em Odontopediatria e Clínica Integrada 2021; 21(supp1):e0023
https://doi.org/10.1590/pboci.2021.121
ISSN 1519-0501 / eISSN 1983-4632

ORIGINAL ARTICLE

Correlation Between Mesio-Distal Teeth Diameters and Arch Width

Francesca Cremonini[1], Carla Provenzano[2], Mario Palone[1], Giorgio Alfredo Spedicato[3], Paolo Albertini[1]

[1]Department of Orthodontics, School of Dentistry, University of Ferrara, Ferrara, Italy.
[2]Private Practice, Ferrara, Italy.
[3]Department of Banking and Insurance, Catholic University of Milan, Milano, Italy.

Correspondence: Francesca Cremonini, Assistant Research, Department of Orthodontics, University of Ferrara, 44121, Ferrara, Italy. **E-mail:** dr.ssafrancescacremonini@gmail.com

Academic Editor: Alessandro Leite Cavalcanti

Received: 29 January 2021 / **Review:** 21 March 2021 / **Accepted:** 03 May 2021

How to cite: Cremonini F, Provenzano C, Palone M, Spedicato GA, Albertini P. Correlation between mesio-distal teeth diameters and arch width. Pesqui Bras Odontopediatria Clín Integr. 2021; 21:e0023. https://doi.org/10.1590/pboci.2021.121

ABSTRACT

Objective: To verify the existence of a correlation between the mesio-distal size of teeth and the arch width by analyzing the data separately for maxillary and mandibular arch in patients with ideal occlusion. **Material and Methods:** 58 patients with ideal occlusion were studied, for a total of 276 files analyzed. Dental casts were then scanned using a professional scanner (Epson Perfection v 330) and images were obtained in TIFF format at 600 dpi. All single teeth measurements were carried out for all teeth of both arches using the VAM software (Vectra, Canfield Scientific, Fairfield, NJ, USA). The repeatability and reproducibility of the measurement method were evaluated using the Gauge R&R method. In case a correlation between tooth size and arch size is found to be significant, a linear regression analysis can be applied through the following statistical relationship: y=a+b*x, where y is the result (inter-molar distance "AvgB66" or inter-canine distance "Cusp 33"), and x the specific tooth. The a and b respectively represent the intercept (point of intersection between the line and the y axis) and the slope of the line that describes the regression ratio. **Results:** The statistical analysis highlights a significant correlation ($p<1\%$) between the results of the mesio-distal measurements of each tooth and the two variables considered to define the size of each arch ("AvgB66" and "Cusp 33"). Based on these results, a numerical relationship "y=a+b*x" has been extrapolated. Thus, it is possible to calculate the estimated inter-molar or inter canine distance necessary to have the teeth aligned. **Conclusion:** The inter-canine and inter-molar distances can be estimated starting from measuring the mesio-distal diameter of a single tooth.

Keywords: Orthodontics; Dental Arch; Malocclusion.

Introduction

One of the most frequent problems to face in orthodontics is a dento-basal discrepancy, which depends on the relationship between the size of teeth and underlying alveolar bone [1]. There is no scientific evidence on the possibility of lengthening the arch that can support aligned teeth [2]; if necessary, the only possibility of gaining space is interproximal reduction (IPR) or tooth extractions. Therefore, the dimensions of dental crowns represent a factor, which needs to be carefully evaluated in the diagnostic phase [3-5], except for cases with implants or prostheses [6,7].

Many studies state that the mesio-distal dimensions of teeth in patients with crowding or diastemas are significantly larger and significantly smaller than in patients with ideal natural occlusion (never treated) [8,9]. Therefore, being conscious of dental dimensions and the maxillary and mandibular teeth relationship is important for obtaining appropriate occlusal contacts and correct overbite and overjet [10].

The best-known studies on tooth size discrepancies inter-arch are those of Bolton [11-13], developed in 1952-1962; he measured mesio-distal teeth diameters of 55 patients with excellent occlusion and compared the mandibular substance with maxillary one. The author thus obtained an overall inter-maxillary dental-dental relationship from the first molar to first molar (range 87.5-94.8%, mean 91.3%, SD 1.91) and an anterior relationship from canine to canine (range 74.5-80.4%, mean 77.2%, SD 1.65), giving the change of recognizing and localizing the discrepancy.

Dental arches width is very important for orthodontic diagnosis, influencing aesthetic smile, space available [14], and occlusion stability [15]: it is given by the sum of mesio-distal diameters of all teeth present [16].

The current study aims to verify the correlation between the mesio-distal size of teeth and the arch width by analyzing the data separately for maxillary and mandibular arch in patients with ideal occlusion. Moreover, the goal is to identify the ideal size of the arch necessary to obtain alignment by measuring a toot or a group of teeth in patients with crowing. The null hypothesis is that exists a correlation between a certain single permanent tooth diameter and the most suitable arch size to have teeth aligned.

Material and Methods

Study Design and Sample

In this retrospective study, tooth size measurements were obtained from a sample of 58 Caucasian patients, selecting according to precise inclusion criteria. First, they were all adult patients showing a completed dentition, except for third molars, with canine and molar class I, centered dental midlines and ideal Overjet and Overbite (1-3 mm). No previous orthodontic or prosthesis treatment was reported.

Data Collection

We evaluated dental crowding according to Little's Regularity Index (1975) [17], defined by "The sum of linear distances between the anatomical contact points of lower anterior teeth from the mesial point of the right canine to the mesial point of left canine" (Figure 1).

The index is equal to 0 if there is a perfect alignment, while between 1 and 3 indicates a minimal irregularity. In all patients selected, the little index was measured on digital dental casts and never overcame a value of 3. Indeed, all dental casts were scanned using a professional scanner - Epson Perfection v 330 (Seiko Epson Corporation, Nagano Japan), and images were obtained in TIFF format at 600 dpi.

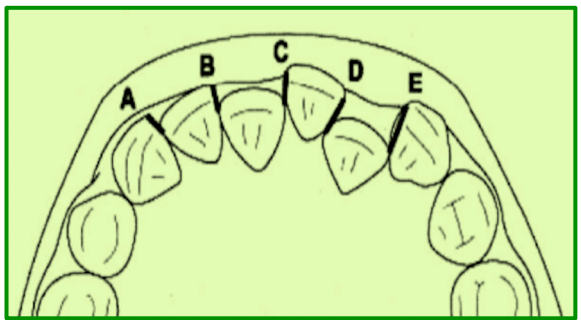

Figure 1. Little Index calculation.

All single teeth measurements were carried out for all teeth of both arches using the VAM software (Vectra, Canfield Scientific, Fairfield, NJ, USA) with the acquisition method previously described [18] (Figure 2).

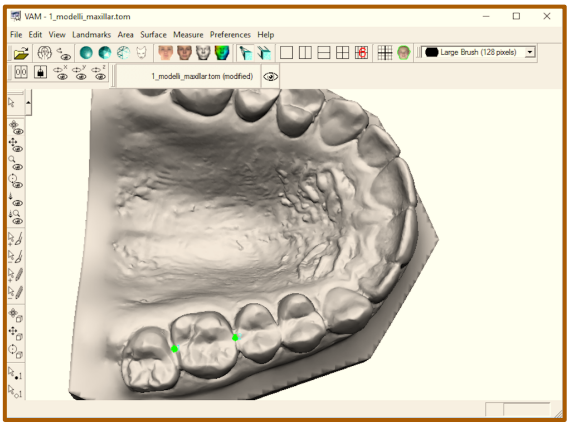

Figure 2. Mesiodistal distance of a single tooth according to the acquisition method described by Huanca Ghislanzoni et al. [18].

Regarding the arch length, the measurements were carried out from the cusp of canine to that of the contralateral and from the central fossa of the first molar to the contralateral one, as shown in Figure 3. The data were then classified according to the type of tooth and the inter-canine and molar distance. All measurements were carried out by two different clinicians: the first measured all casts twice, while the second just the ones of the first 10 patients.

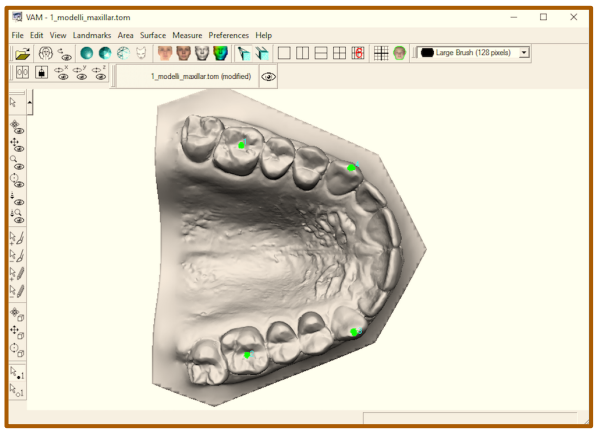

Figure 3. Inter-canine and inter-molar distance for both arches according to the acquisition method described by Huanca Ghislanzoni et al. [18].

Error Calculation

The repeatability and reproducibility of the measurement method were evaluated using the Gauge R&R method [19]. The methodology, based on the analysis of variance (ANOVA), decomposes the total variability into a Part-to-part component (intrinsic variability of the process) and a Gauge R&R. The latter term includes: 1) Repeatability: variability of the measurements made by a single operator; and 2) Reproducibility: variability caused by the measuments of the object between different operators. These sources are expressed as a percentage of the total error of measurements.

Statistical Analysis

Fifty-eight patients with ideal occlusion were studied, for a total of 276 files analyzed. The aim was to evaluate whether, in ideal arches, the mesio-distal dimension of each tooth (D11, D26, D31, D46) is significantly correlated with the arch dimension, defined by examining two variables (inter-molar distance "AvgB66" and inter-canine distance "Cusp 33"). The analysis was divided into maxillary and mandibular arches.

In case that the above correlations are found to be significant, a linear regression analysis can be applied through the following statistical relationship: y=a+b*x, where y is the result (or "Cusp33" or "AvgB66") and x the specific tooth. The a and b respectively represent the intercept (point of intersection between the line and the y axis) and the slope of the line that describes the regression ratio.

Therefore, considering the relatively small size of the sample, bivariate correlations based on Pearson's correlation index p, between -1 and +1, were used for this analysis. If the sign is positive, it means that a direct proportion is present, while if the sign is negative, it means that no proportion exists. Thus, a p-value equal to 1 in absolute value indicates strong linear dependence, while a value of p close to zero indicates no linear dependence.

The sample size assessment indicates that the given experiment can detect a minimum significant correlation (effect size measure) equal to p=0.358 given the size of the sample (n=58) and the usual threshold of type I (α=0.05) error and power (1-β=0.80).

The data processing analysis was performed using the R (R Core Team 2016) [20] software, and the ranges of statistical significance are reported in Table 1.

Table 1. Statistical significance range.

p-value	Significance
p > 10%	No significant
5% < p > 10%	*
1% < p < 5%	**
< 1%	***

Results

From the statistical analysis, the reliability of the measurement method through Vam Software is positive. Correlations were studied on each arch separately, analyzing the measurements of both operators, and they seem to be all statistically significant. The following tables show the correlation between the mesio-distal measurements of each tooth and two variables considered to define the size of each arch (Tables 2 and 3).

Therefore, the tables show a statistically significant correlation between the mesio-distal diameter of the dental crowns and the width of the arch: the larger the mesio distal dimension is, the greater the width of

the arch. Analyzing the data in the mandibular arch, the greater correlations are between the anterior teeth, all incisors, and the inter-canine distance. A less significant correlation is shown for second premolars and molars. On the other hand, for the maxillary arch, the correlations are important for all teeth, both for the inter-canine and inter-molar diameters. Based on these results, a numerical relationship "y=a + b * x" has been extrapolated, thanks to which it is possible to calculate the estimated inter-molar or inter-canine distance necessary to have the teeth aligned: x represents a specific tooth, a and b are two constants obtained from the regression analysis, and y is the result sought, therefore the inter-molar or inter-canine distance we want to know.

Table 2. Correlation between m-d diameters (d) of lower teeth with the mandibular arch width (Cusp 3-3, Avg 6-6).

Variable		Cusp 3-3			Avg 6-6	
D	Correlation	p-value	Significance	Correlation	p-value	Significance
D31	0.4	0.0	***	-0.01	0.95	
D32	0.57	0.0	***	0.42	0.0	***
D33	0.49	0.0	***	0.64	0.0	***
D34	0.5	0.0	***	0.52	0.0	***
D35	0.23	0.1		0.25	0.08	*
D36	0.11	0.44		0.18	0.22	
D41	0.51	0.0	***	0.14	0.33	
D42	0.57	0.0	***	0.36	0.01	**
D43	-0.03	0.86		-0.2	0.17	
D44	0.35	0.01	**	0.4	0.0	***
D45	0.26	0.06	*	0.29	0.04	**
D46	0.07	0.64		0.07	0.63	

Table 3. Correlation between m-d diameters (d) of upper teeth with the maxillary arch width (Cusp 3-3, Avg 6-6).

Variable		Cusp 3-3			Avg 6-6	
D	Correlation	p-value	Significance	Correlation	p-value	Significance
D11	0.53	0.0	***	0.31	0.0	***
D12	0.53	0.0	***	0.44	0.0	***
D13	0.53	0.0	***	0.3	0.0	***
D14	0.49	0.0	***	0.29	0.01	***
D15	0.45	0.0	***	0.24	0.02	**
D16	0.33	0.0	***	0.14	0.21	
D21	0.43	0.0	***	0.16	0.13	
D22	0.39	0.0	***	0.37	0.0	***
D23	0.58	0.0	***	0.33	0.0	***
D24	0.46	0.0	***	0.26	0.02	**
D25	0.35	0.0	***	0.2	0.07	*
D26	0.51	0.0	***	0.29	0.01	***

Tables 4 and 5 show the values of a and b extracted from the regression analysis, collect the dental elements that have shown a significant correlation with the inter-canine or inter-molar distance.

Table 4. Mandibular arch regression, a and b value, depending on the tooth and the inter-canine and inter-molar distance.

Variable	Cusp 3-3		Avg 6-6	
D	a	b	a	b
D41	13.4	2.8		
D42	10.6	3.1	27	2.8

D43	12.5	2.3	24	3.7
D44	12.7	2.1	34	2.8
D45			32	1.5
D31	9.2	3.6		
D32	10.7	3.0	30	2.3
D34	14.1	1.9	24	2.7
D35	16.8	1.5	29	2.0

Table 5. Maxillary arch regression, a and b value, depending on the tooth and the inter-canine and inter-molar distance.

Variable	Cusp 3-3		Avg 6-6	
D	a	b	a	b
D11	17	2.3	33	1.71
D12	24	1.8	35	1.90
D13	20	2.1	35	1.51
D14	22	2.0	36	1.49
D15	23	2.0	38	1.34
D16	23	1.2		
D21	21	1.8		
D22	27	1.3	37	1.59
D23	20	2.1	35	1.52
D24	23	1.9	37	1.35
D25	27	1.4	40	0.96
D26	17	1.9	33	1.36

Discussion

Successful orthodontic treatment is based on careful diagnosis and an adequate treatment plan. Some of the most important factors to analyze are certainly: analysis of space, size of teeth, arch size and shape, and dentoalveolar discrepancy. Dental casts evaluation is, therefore, part of the initial diagnosis. In the current study, we examined teeth mesio-distal dimension from one first molar to the over and the arch size through software 3D and looked for a correlation between the two. Fifty-eight Caucasian patients with an ideal occlusion and no previous orthodontic treatment were selected for this purpose. Therefore we analyzed intact dentition, with no interproximal enamel reduction or a tooth extraction for an orthodontic reason, to have unaltered mesio-distal teeth dimensions.

The accuracy and reliability of measurements carried out using software on digital models are widely confirmed by the literature [21-24]. Indeed, especially in crowding cases, measuring teeth size on plaster casts is imprecise due to the difficulty in identifying the mesial and distal contacts of teeth. On the other hand, the same procedure is easier if done on digital models since we have the possibility to rotate and enlarge the 3-dimensional model [21].

Zilberman et al. [25] compared the accuracy and repeatability of the analyzes performed on plaster casts and those performed digitally with 3D software. These researchers concluded that digital measurements produce high clinical accuracy and must be taken into consideration for research study work. Wan Hassan et al. [24] confirmed the same result: there are no significant differences between manual and digital measurements, as they all represent a valid and reliable alternative in orthodontic practice.

Several studies in literature correlate the size of teeth with numerous variables such as crowding, interarch spaces, and malocclusion in different ethnic groups. For example, it turned out that patients with crowding show narrow maxillary arches and larger tooth sizes than patients with no crowding [26].

Johe et al. [27] investigated in 306 subjects the size of teeth among several groups of malocclusion, ethnicitiess and sex. They concluded that there were no statistically significant differences between the size of groups studied. However, African-Americans had a higher prevalence of clinically significant anterior dental discrepancy compared to Caucasians or Hispanics. According to them, there were no statistically significant differences between sex. On the other hand, other studies found differences in tooth size between men and women, indicating slightly larger teeth for men [9,28]. Indeed, a limitation of the current study is that all patients were considered with no gender distinction.

Puri et al. [9] analyzed the difference in tooth size in 240 dental casts divided into three groups: normal dentition, crowded and presence of diastemas. The mesio-distal dimension of teeth is significantly greater in the crowded group than in the other two.

Only one study published by Al-Kathib et al. [29] in 2011 checked the correlation between the size of teeth and the size of arches. They analyzed 252 Malaysian subjects with ideal occlusion to investigate the relationship between the size of teeth and the perimeter and length of the arches. The results proved a significant correlation between the mesiodistal dimension of teeth and the size of the arch. Moreover, most of the mandibular arch measurements showed a relevant correlation with the inter-canine diameter.

Another important factor, which plays a central role in orthodontics, is the size of the dento-alveolar arch. Therefore, it is necessary to distinguish changes induced by orthodontic therapy from those that occur with natural growth. Sinclair and Little [30] stated that the mandibular inter-canine distance increases significantly with the change of dentition, but no longer after 12 years old. A review of the literature concluded that the expansion of the mandibular arch is more stable in the posterior region, while it is unstable at the canine level unless they initially showed a lingual position [31]. Artun et al. [32] analyzed a sample of 79 patients after the end of orthodontic treatment and confirmed that a high rate of relapse occurred in those who presented a reduced inter-canine distance. Therefore, we know that the mandibular arch cannot be subjected to major changes, while changes in the maxillary arch are more stable over time [33].

The current study shows a strong correlation between the mesio-distal diameter of lower incisors, especially the lateral incisors, and the inter-canine and inter-molar mandibular diameters. This means that we can predict the diameters necessary for alignment in growing patients or patients with crowded arches by measuring the lateral incisors dimensions.

This result could be helpful in the diagnostic phase of the orthodontic treatment: lateral incisors are the first to erupt and show low anatomical variability. Thus, in growing patients, we can predict the size of the arch needed for harmonic growth, while, in crowded patients, we can predict the adequate width to solve it.

The mesiodistal dimensions of dental crowns were standardized by Black more than a century ago and are still widely used today. Another, more current research was conducted at the University of Ferrara. Lombardo et al. [34] rated the mesio-distal size of teeth in a sample of 56 Caucasian subjects with ideal occlusion through multivariate cluster analysis. This study found three tooth-sized clusters: small, medium, and large for maxillary and mandibular arches, for males and females.

Instead, the current study results show significant correlations between the two variables, dental and arch dimension, both in the maxillary than in the mandibular jaw. The last of more interests, as its maintenance, determine a greater success of orthodontic treatment and less relapse [35,36].

The formula introduced in this study is intended as a mere approximation for the following reasons: 1) Because the number of observations was small, it was not possible to estimate more complex relationships, with the inclusion of other dental parameters and the validation of a more sophisticated functional formula; and

2) Even if the relationship between parameters is linear, the low number of observations increases the uncertainty on the estimation of the results.

Conclusions

Mesio-distal dimensions of upper teeth have a strong correlation with the maxillary arch size, both at canine and molar level. In addition, mesio-distal dimensions of lower teeth show correlation with the mandibular arch size, but it's statistically significant just between the central incisors and the inter-canine diameter, and between lateral incisors and inter-molar diameter. The statistical relation: y = a + b * x allows to estimate the inter-canine and inter-molar distances starting from the measurement of the mesio-distal diameter of a single tooth.

Given the importance of the lower central incisor as the first erupted tooth in the mandibular arch, and given the relevance of the inter-canine distance in orthodontic diagnosis and treatment plan, this formula can be very useful. If we use the following variables: y = 13.4 + 2.8 * x, where x represents the lower central incisor, we can estimate the mandibular inter-canine distance (y).

Authors' Contributions

FC	https://orcid.org/0000-0002-4641-2196	Methodology, Formal Analysis, Investigation, Writing - Original Draft and Writing - Review and Editing.
CP	---	Data Curation and Writing - Review and Editing.
MP	https://orcid.org/0000-0001-6198-3053	Data Curation and Writing - Review and Editing
GAS	https://orcid.org/0000-0002-0315-8888	Data Curation and Writing - Review and Editing
PA	https://orcid.org/0000-0002-4020-5065	Conceptualization, Writing - Review and Editing and Visualization
All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.		

Financial Support

None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

References

[1] Lombardo L, Gracco A, Zampini F, Stefanoni F, Mollica F. Optimal palatal configuration for miniscrew applications. Angle Orthod 2010; 80(1):145-52. https://doi.org/10.2319/122908-662.1

[2] Pisani L, Bonaccorso L, Fastuca R, Spena R, Lombardo L, Caprioglio A. Systematic review for orthodontic and orthopedic treatments for anterior open bite in the mixed dentition. Prog Orthod 2016; 17(1):28. https://doi.org/10.1186/s40510-016-0142-0

[3] Harris EF, Burris BG. Contemporary permanent tooth dimensions, with comparisons to G.V. Black's data. J Tenn Dent Assoc 2003; 83(4):25-9.

[4] Arreghini A, Trigila S, Lombardo L, Siciliani G. Objective assessment of compliance with intra- and extraoral removable appliances. Angle Orthod 2017; 87(1):88-95. https://doi.org/10.2319/020616-104.1

[5] Manfredini D, Stellini E, Gracco A, Lombardo L, Nardini LG, Siciliani G. Orthodontics is temporomandibular disorder-neutral. Angle Orthod 2016; 86(4):649-54. https://doi.org/10.2319/051015-318.1

[6] Lopez MA, Andreasi Bassi M, Confalone L, Gaudio RM, Lombardo L, Lauritano D. Retrospective study on bone-level and soft-tissue-level cylindrical implants. J Biol Regul Homeost Agents 2016; 30(2 Suppl 1):43-8.

[7] Lopez MA, Andreasi Bassi M, Confalone L, Gaudio RM, Lombardo L, Lauritano D. Clinical outcome of 215 transmucosal implants with a conical connection: a retrospective study after 5-year follow-up. J Biol Regul Homeost Agents 2016; 30(2 Suppl 1):55-60.

[8] Agenter MK, Harris EF, Blair RN. Influence of tooth crown size on malocclusion. Am J Orthod Dentofacial Orthop 2009; 136(6):795-804. https://doi.org/10.1016/j.ajodo.2007.12.030

[9] Puri N, Pradhan KL, Chandna A, Sehgal V, Gupta R. Biometric study of tooth size in normal, crowded, and spaced permanent dentitions. Am J Orthod Dentofacial Orthop 2007; 132(3):279.e7-14. https://doi.org/10.1016/j.ajodo.2007.01.018

[10] Arreghini A, Lombardo L, Mollica F, Siciliani G. Torque expression capacity of 0.018 and 0.022 bracket slots by changing archwire material and cross section. Prog Orthod 2014; 15(1):53. https://doi.org/10.1186/s40510-014-0053-x

[11] Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. A thesis submitted as partial fulfillment of the requirements for the degree of Master of Science in dentistry: Department of Orthodontics, School of Dentistry, University of Washington, 1952.

[12] Bolton WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod 1958; 28(3):113-30.

[13] Bolton WA. The clinical application of a tooth-size analysis. Am J Orthod 1962; 48(7):504-29. https://doi.org/10.1016/0002-9416(62)90129-X

[14] Lombardo L, Stefanoni F, Mollica F, Laura A, Scuzzo G, Siciliani G. Three-dimensional finite-element analysis of a central lower incisor under labial and lingual loads. Prog Orthod 2012; 13(2):154-63. https://doi.org/10.1016/j.pio.2011.10.005

[15] Di Fazio D, Lombardo L, Gracco A, D'Amico P, Siciliani G. Lip pressure at rest and during function in 2 groups of patients with different occlusions. Am J Orthod Dentofacial Orthop 2011; 139(1):e1-6. https://doi.org/10.1016/j.ajodo.2010.02.030

[16] Mutinelli S, Manfredi M, Cozzani M. A mathematic-geometric model to calculate variation in mandibular arch form. Eur J Orthod 2000; 22(2):113-25. https://doi.org/10.1093/ejo/22.2.113

[17] Little RM. The irregularity index: a quantitative score of mandibular anterior alignment. Am J Orthod 1975; 68(5):554-63. https://doi.org/10.1016/0002-9416(75)90086-x

[18] Huanca Ghislanzoni LT, Lineberger M, Cevidanes LH, Mapelli A, Sforza C, McNamara JA Jr. Evaluation of tip and torque on virtual study models: a validation study. Prog Orthod 2013; 14:19. https://doi.org/10.1186/2196-1042-14-19

[19] Cano E, Moguerza JM, Cordoba M. Quality Control with R. Use R!. New York: Springer; 2015.

[20] Team RC. A Language and Environment for Statistical Computing. Vienna: R Foundation for statistical computing; 2016.

[21] Gracco A, Buranello M, Cozzani M, Siciliani G. Digital and plaster models: a comparison of measurements and times. Prog Orthod 2007; 8(2):252-9.

[22] Tarazona B, Llamas JM, Cibrián R, Gandía JL, Paredes V. Evaluation of the validity of the Bolton Index using cone-beam computed tomography (CBCT). Med Oral Patol Oral Cir Bucal 2012; 17(5):e878-83. https://doi.org/10.4317/medoral.18069

[23] Zilberman O, Huggare JA, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. Angle Orthod 2003; 73(3):301-6.

[24] Wan Hassan WN, Othman SA, Chan CS, Ahmad R, Ali SN, Abd Rohim A. Assessing agreement in measurements of orthodontic study models: Digital caliper on plaster models vs 3-dimensional software on models scanned by structured-light scanner. Am J Orthod Dentofacial Orthop 2016; 150(5):886-95. https://doi.org/10.1016/j.ajodo.2016.04.021

[25] Zilberman O, Huggare JA, Parikakis KA. Evaluation of the validity of tooth size and arch width measurements using conventional and three-dimensional virtual orthodontic models. Angle Orthod 2003; 73(3):301-6.

[26] Poosti M, Jalali T. Tooth size and arch dimension in uncrowded versus crowded Class I malocclusions. J Contemp Dent Pract 2007; 8(3):45-52.

[27] Johe RS, Steinhart T, Sado N, Greenberg B, Jing S. Intermaxillary tooth-size discrepancies in different sexes, malocclusion groups, and ethnicities. Am J Orthod Dentofacial Orthop 2010; 138(5):599-607. https://doi.org/10.1016/j.ajodo.2008.11.031

[28] Garn SM, Lewis AB, Kerewsky RS. Sex difference in tooth size. J Dent Res 1964; 43:306. https://doi.org/10.1177/00220345640430022401

[29] Al-Khatib AR, Rajion ZA, Masudi SM, Hassan R, Anderson PJ, Townsend GC. Tooth size and dental arch dimensions: a stereophotogrammetric study in Southeast Asian Malays. Orthod Craniofac Res 2011; 14(4):243-53. https://doi.org/10.1111/j.1601-6343.2011.01529.x

[30] Sinclair PM, Little RM. Maturation of untreated normal occlusions. Am J Orthod 1983; 83(2):114-23. https://doi.org/10.1016/s0002-9416(83)90296-8

[31] Lee RT. Arch width and form: a review. Am J Orthod Dentofacial Orthop 1999; 115(3):305-13. https://doi.org/10.1016/S0889-5406(99)70334-3

[32] Artun J, Garol JD, Little RM. Long-term stability of mandibular incisors following successful treatment of Class II, Division 1, malocclusions. Angle Orthod 1996; 66(3):229-38.

[33] Ward DE, Workman J, Brown R, Richmond S. Changes in arch width. A 20-year longitudinal study of orthodontic treatment. Angle Orthod 2006; 76(1):6-13.

[34] Lombardo L, Marcon M, Arveda N, La Falce G, Tonello E, Siciliani G. Preliminary biometric analysis of mesiodistal tooth dimensions in subjects with normal occlusion. Am J Orthod Dentofacial Orthop 2016; 150(1):105-15. https://doi.org/10.1016/j.ajodo.2015.12.021

[35] Lombardo L, Carinci F, Martini M, Gemmati D, Nardone M, Siciliani G. Quantitive evaluation of dentin sialoprotein (DSP) using microbeads - a potential early marker of root resorption. Oral Implantol 2016; 9(3):132-42. https://doi.org/10.11138/orl/2016.9.3.132

[36] Perrini F, Lombardo L, Arreghini A, Medori S, Siciliani G. Caries prevention during orthodontic treatment: In-vivo assessment of high-fluoride varnish to prevent white spot lesions. Am J Orthod Dentofacial Orthop 2016; 149(2):238-43. https://doi.org/10.1016/j.ajodo.2015.07.039