

v.4, n.1, 2024

RECISATEC – SCIENTIFIC JOURNAL SAÚDE E TECNOLOGIA
ISSN 2763-8405

DIGITAL ANALYSIS OF TOOTH SIZES AMONG INDIVIDUALS WITH DIFFERENT MALOCCLUSIONS: A STUDY USING THREE-DIMENSIONAL DIGITAL DENTAL MODELS

ANÁLISE DIGITAL DO TAMANHO DOS DENTES EM INDIVÍDUOS COM DIFERENTES OCLUSÕES: UM ESTUDO UTILIZANDO MODELOS DENTÁRIOS DIGITAIS TRIDIMENSIONAIS

ANÁLISIS DIGITAL DEL TAMAÑO DE LOS DIENTES ENTRE INDIVIDUOS CON DIFERENTES MALOCLUSIONES: UN ESTUDIO CON MODELOS DENTALES DIGITALES TRIDIMENSIONALES

Adriana Batista Pérez[1], Domenica Estefania Torres León[1], Christian David Mendez Guevara[1], Nube Fernanda Moreno Orellana[1], Manuel Estuardo Bravo Calderon[2]

e41333
https://doi.org/10.47820/recisatec.v4i1.333

RECEIVED: 12/08/2023 APPROVED: 01/08/2024 PUBLISHED: 01/22/2024

ABSTRACT
The objective of the study was to examine the sizes of teeth in digital models of patients with different malocclusions using three-dimensional measurement software. METHODS: 68 digital models of 34 patients, aged between 21 and 29 years, were analyzed. A review was conducted to classify the participants according to Angle's classification, resulting in 24 patients in the class I group and 10 patients in the class II group. Subsequently, the patients' plaster models were scanned using the Dentsply Sirona Cerec Omnicam Software 5.2 digital scanner to obtain their digital format. The NemoStudio-2022 software was then utilized to perform tooth size measurements. RESULTS: After analyzing the measurements, it was observed that there was no statistically significant relationship between the anterior and general mesiodistal sizes and the different malocclusions. Additionally, there was no difference between the groups in terms of the values of the anterior proportion, nor when evaluating the values of the general proportion between the groups. Finally, none of the malocclusion groups showed a significant relationship with the alteration of anterior or general mesiodistal size. CONCLUSION: The difference in mesiodistal tooth size between the upper and lower anterior teeth does not contribute to the development of Angle Class I, Class II, and Class III malocclusions, as no statistically significant relationships were found in this regard.

KEYWORDS: Digital analysis. Malocclusions. Tooth size.

RESUMO
O objetivo do estudo foi examinar os tamanhos dos dentes, em modelos digitais de pacientes com diferentes oclusões, com o auxílio de *softwares* de mensuração tridimensional. Foram analisados 68 modelos digitais de 34 pacientes com idade entre 21 e 29 anos. Uma revisão foi realizada para determinar os participantes de acordo com a classificação de Angle, restando 24 pacientes no grupo classe I e 10 pacientes no grupo classe II. Em seguida, os modelos de gesso dos pacientes foram escaneados, utilizando-se o scanner digital *Dentsply Sirona Cerec Omnicam Software* 5.2, obtendo-se, assim, o formato digital. O *software NemoStudio*-2022 foi então utilizado para realizar as medições do tamanho dos dentes. Após análise das medidas, observou-se que os tamanhos mesiodistal anterior e geral não se relacionaram estatisticamente com as diferentes oclusopatias. Também não houve diferença entre os grupos quanto aos valores da proporção anterior, nem quando avaliados os valores da proporção geral entre os grupos. Finalmente, nenhum grupo com má oclusão apresentou relação significativa com a alteração do tamanho mesiodistal anterior ou geral. A diferença no tamanho dos dentes mesiodistais dos dentes anterossuperiores e anteroinferiores não contribui para o aparecimento de más oclusões de Classe I de Angle, Classe II e Classe III, uma vez que não houve relações estatisticamente significativas a esse respeito.

PALAVRAS-CHAVE: Análise digital. Más oclusões. Tamanho do dente.

[1] Estudiante 7mo ciclo de la Facultad de odontología de la Universidad de Cuenca, Ecuador
[2] Docente De la Cátedra de ortodoncia de la Facultad de Odontología de la Universidad de Cuenca, Ecuador.



RECISATEC – SCIENTIFIC JOURNAL SAÚDE E TECNOLOGIA
ISSN 2763-8405

RESUMEN
El objetivo del estudio fue examinar los tamaños de los dientes, en modelos digitales de pacientes con diferentes maloclusiones, con la ayuda de un software de medición tridimensional. Se analizaron 68 modelos digitales de 34 pacientes con edades comprendidas entre los 21 y los 29 años. Se realizó una revisión para determinar los participantes según la clasificación de Angle, quedando 24 pacientes en el grupo de clase I y 10 pacientes en el grupo de clase II. A continuación, se escanearon los modelos de yeso de los pacientes, utilizando el escáner digital Dentsply Sirona Cerec Omnicam Software 5.2, obteniendo así su formato digital. A continuación, se utilizó el software NemoStudio-2022 para realizar mediciones del tamaño de los dientes. Después del análisis de las mediciones, se observó que los tamaños mesiodistal anterior y general no se relacionaron estadísticamente con las diferentes maloclusiones. Tampoco hubo diferencia entre los grupos en cuanto a los valores de la proporción anterior, ni a la hora de evaluar los valores de la proporción general entre los grupos. Finalmente, ningún grupo de maloclusión tuvo una relación significativa con la alteración del tamaño mesiodistal anterior o general. La diferencia en el tamaño de los dientes mesiodistales de los dientes antero-superiores y antero-inferiores no contribuye a la aparición de maloclusiones Angle Clase I, Clase II y Clase III, ya que no hubo relaciones estadísticamente significativas al respecto.

PALABRAS CLAVE: Análisis digital. Maloclusiones. Tamaño de los dientes.

INTRODUCTION

The objective of orthodontic treatment is to achieve optimal occlusion in patients, which requires an appropriate relationship between the sizes of the maxillary and mandibular teeth (1). One of the earliest researchers to analyze the mesiodistal width of human teeth and establish hypotheses regarding its role in malocclusions was Black in 1902 (2). Based on these measurements of individual teeth within the dental arch, tables of average tooth sizes were developed and continue to be used today as a reference for diagnosing and planning orthodontic treatments (3).

Several authors have conducted research on tooth size and its potential influence on the development of malocclusion (4-5-6). Karadede et al. (5) examined digital models of 252 patients aged 13 to 25 years to investigate the relationship between Angle malocclusions and the mesiodistal length of each permanent tooth. The measurements revealed significant differences in tooth sizes among individuals with different malocclusions. Specifically, individuals with class II malocclusion exhibited larger dimensions in both mesiodistal and buccolingual measurements compared to other groups. These findings suggest a potential relationship between tooth size and class II malocclusion.

In 1958, Bolton developed two types of analyses to evaluate the tooth proportions in the anterior sector. One of these analyses is the general proportion, which is determined by dividing the sum of the mesiodistal widths of the 12 mandibular teeth by the sum of the 12 maxillary teeth (7). The second analysis is the anterior proportion, which is calculated by dividing the sum of the mesiodistal widths of the six mandibular teeth by the sum of the mesiodistal widths of the six maxillary teeth. The average results of these two analyses were found to be 91.3% (+/- 1.91) and 77.2% (+/- 1.65) for the general

and anterior proportions, respectively. It is important to note that these two proportional relationships are still considered the "gold standard" in dental evaluation prior to orthodontic treatment (8).

Several prevalence studies have observed that there are significant differences in tooth size discrepancies between Class II division 1 malocclusions (9) and Class III malocclusions (10). Alsaigh conducted a study comparing tooth size proportions among malocclusion groups (Class I, II, and III), and found significant differences, particularly in patients with Class III malocclusion (eleven). It is believed that sex and racial factors also contribute to the differences in tooth sizes and Angle malocclusions (12). Some studies suggest that men have larger tooth sizes and a stronger correlation with malocclusion (13), while other studies conducted on Turkish populations by Basaran et al. (14) and Akyalcin et al. (15) found no significant differences in tooth size among different malocclusion groups.

In another interesting study conducted by Mullen et al. (16), they evaluated the Bolton indices in both analog models and digital models. The study found that there were no significant differences in measurement precision between the two methods. However, it was discovered that digital measurements were 65 times faster than the manual method. This led to the conclusion that measurements on digital models are not only equally precise but also faster than the analysis of plaster models. Therefore, digital models are considered capable of replacing traditional plaster models effectively.

There are several advantages to using digital platforms for dental analysis prior to the initiation of orthodontic treatment. One of these advantages is the ease of accessing data when needed, eliminating the need for measuring instruments. Another significant benefit is the ability to store scanned intraoral models without taking up physical space, as all patient models can be archived in a dedicated computer memory. Lastly, the most significant advantage is the considerable reduction in the time required to manage these models. These advantages collectively make intraoral digital modeling an essential replacement for plaster models, which will bring about a significant change in analysis procedures in the short to medium term.

To validate the aforementioned statements, we conducted a study with the objective of evaluating digital models from various malocclusion groups in order to analyze tooth sizes using the 3D measurement software 3Shape.

METHODOLOGY

A retrospective study was conducted in which 3D digital models were obtained from plaster models of 33 seventh-cycle students from the Faculty of Dentistry at the University of Cuenca-Ecuador. Two groups were formed consisting of individuals with Class I and Class II molar relationships based on Angle's classification, with 11 patients in each group. The participants included in the study ranged in age from 21 to 29 years. The age distribution between the groups is presented in Table 1.

RECISATEC – SCIENTIFIC JOURNAL SAÚDE E TECNOLOGIA
ISSN 2763-8405

Table 1. Age distribution by malocclusion groups

Cluster	average age	standard deviation
Class 1 (n: 24)	23	1.80
Class 2 (n: 10)	23	1.61
Class 3 (n: 0)	0	0
Total (n: 34)	23	

The following inclusion criteria were used to select the study models:

1. Patients between the ages of 21 and 29, including those who have undergone orthodontic treatment, were included in the study.
2. All molars, excluding wisdom teeth, must be present in the dental arches.
3. The mesiodistal size of the teeth should not be affected by caries, loss of dental structure, or restorations.
4. The models should not exhibit structural or developmental abnormalities such as macrodontia or microdontia in the teeth.
5. The study included models of individuals without mesiodistal wear and with identifiable contact points.

All high-quality study models that met the inclusion criteria were digitized and converted into a digital format using a Dentsply Sirona Cerec Omnicam Software 5.2 scanner. The NemoStudio2022 Software was utilized for image processing and to obtain the necessary measurements.

The measurements made in the digital models were:

1. Total Maxillary 12: The sum of the mesiodistal widths of the 12 upper teeth, from the right first molar to the left first molar.
2. Total Maxillary Anterior 6: The sum of the mesiodistal widths of the upper anterior teeth.
3. Total Mandibular 12: The sum of the mesiodistal widths of the 12 lower teeth, from the right first molar to the left first molar.
4. Total Mandibular Anterior 6: The sum of the mesiodistal widths of the six lower anterior teeth.
5. General Ratio: The ratio between the mesiodistal width of the lower 12 teeth and the sum of the mesiodistal widths of the upper 12 teeth.
6. Anterior Proportion: The ratio between the mesiodistal width of the lower anterior teeth and the sum of the mesiodistal widths of the upper anterior teeth.

Statistical analyses were conducted using the SPS program. The measurement of each tooth in the three malocclusion groups allowed for the calculation of the mean value and standard deviation of

the anterior ratio and overall ratio. Descriptive statistics were reported, including the number of units (n), percentage (%), mean ± standard deviation (x ± SD), and confidence intervals (95% CI). The normal distribution of numerical variables was assessed using the Shapiro-Wilk normality test. Comparisons between groups were performed using one-way analysis of variance, and Tukey's test was utilized to determine differences between groups. Additionally, comparisons of the overall proportion and anterior proportion between the study group and the Bolton group were conducted using the two independent samples t-test. A significance level of $P < 0.05$ was considered statistically significant.

RESULTS

When evaluating the mesiodistal dimensions of the upper teeth among different malocclusion groups, higher values were observed in the Class I malocclusion group. Similarly, when assessing the mesiodistal dimensions of the lower teeth among the various malocclusion groups, higher values were observed in the Class I malocclusion group (Table 2).

Table 2. Evaluation of the mesiodistal dimensions of permanent teeth according to the different malocclusions

maxillary	Tooth	Class I	Class II	Class III	*p*
Superior	U1	8.03	7.99	0	0.045
	U2	6.51	6.66	0	0.033
	U3	7.08	7.33	0	0.10
	U4	6.42	6.64	0	0.038
	U5	6.55	6.38	0	0.020
	U6	9.52	9.90	0	0.020
lower	L1	9.92	5.00	0	0.001
	L2	5.42	5.58	0	0.050
	L3	6.20	6.31	0	0.001
	L4	6.62	6.70	0	0.123

RECISATEC – SCIENTIFIC JOURNAL SAÚDE E TECNOLOGIA
ISSN 2763-8405

	L5	6.83	6.70	0	0.378
	L6	10.25	10.30	0	0.098

No statistically significant difference was found when evaluating the values of the anterior index and the general index between the malocclusion groups under study (Table 3).

Table 3. Evaluation of Bolton indices in different malocclusion groups

	Class I	Class II	Class III	*p*
Previous ratio	72.85±2.88	74.10±3.5	-	0.22
Overall ratio	90.09±1.64	89.93±2.14	-	0.83

DISCUSSION

Several authors have unanimously concluded that there is a direct proportional relationship between an ideal occlusion and the mesiodistal dimensions of the maxillary and mandibular teeth (17,18,19). The scientific literature states that the mesiodistal widths of the upper anterior and lower anterior teeth should align with occlusal details, including maximum posterior intercuspation, adequate overbite, and correct anterior guidance. Therefore, it is crucial to adhere to these mesiodistal width averages in order to achieve a precise occlusal fit following orthodontic treatment (20).

Several factors, including genetics, environment, race, and sex, are associated with tooth size (21). Some authors have examined the variations in the Bolton ratio and the occurrence of malocclusions among individuals of different races. However, statistical analysis has not found a significant relationship between these factors. In earlier studies, Bolton did not consider race as a determining factor in the mesiodistal size ratio.

Other studies have examined the potential correlation between the mesiodistal dimensions of maxillary and mandibular teeth and various malocclusions, taking into account sex as a potential independent variable. In certain instances, it has been observed that male patients with Class III malocclusions tend to have larger teeth, while women with certain types of malocclusions are more likely to have smaller teeth compared to men (22). Authors such as Oktay and Ulukaya have investigated disparities in intermaxillary tooth size among different malocclusion groups and have

identified potential sex-related variations. According to their research, there were statistically significant differences in posterior proportions among males, but no statistically significant differences were found between the groups for anterior proportions (23).

On the other hand, Tomasetti (24) was one of the first authors to compare the results of manual measurement methods with measurements obtained using computer programs for Bolton analysis. The study concluded that the differences between the two methods were not statistically significant, and that the computer measurement program was much easier for researchers to use. Subsequent studies have consistently demonstrated that measurements obtained from digital models are not significantly different from those obtained from plaster models (25,26,27). Furthermore, evaluations conducted with digital models have been found to be significantly faster and more accurate in measuring and verifying, providing orthodontists with sufficient information to make diagnostic and treatment planning decisions comparable to those made using plaster models (28).

Some authors have conducted analyses on the changes in mesiodistal sizes of anterior teeth in relation to age. For example, it has been observed that between the ages of 17 and 60 years, there is a decrease in the mesiodistal size of teeth (29). Lundström (30) and other authors have also noted that proximal contacts undergo surface changes as individuals age. It is reasonable to assume that over time, dental structures and composition undergo changes due to constant use and exposure to a moist environment. In our study, participants with an average age between 23 and 29 years (+/-7) showed a higher percentage of class I and II malocclusion. It would be interesting to observe the changes that may occur over time in this same population using digitally analyzed Bolton proportion.

On the other hand, studies have been conducted to compare the mesiodistal size of the upper anterior and lower anterior teeth among three groups of individuals classified as Angle's Class I, Class II, and Class III malocclusions. The results showed that the Angle Class I and Class III malocclusion groups had significantly larger tooth sizes compared to the Class II malocclusion group. Additionally, the average difference in tooth size was found to be significantly greater in the Angle Class III group compared to both the Class I and Class II malocclusion groups (31).

However, in another study conducted by Mollabashi (32), the anterior, posterior, and overall Bolton values of four different malocclusion groups were investigated and compared to a Class I normal occlusion group. The results showed that the normal occlusion group had the highest values, while the Class II division 1 group had the lowest values for the posterior Bolton value.

Likewise, in another study (33), the tooth size proportions of patients belonging to different malocclusion groups (Class I, Class II division 1, Class II division 2, and Class III) were compared. The results showed statistically significant differences in the overall proportion between all groups, as well as in the average value of the anterior proportion between the Class I and Class III groups.

Based on this background, we were able to compare the results obtained in our study. We observed that there was no statistically significant difference between the Class I and Class II malocclusion groups in terms of the general index and the mesiodistal anterior index. When comparing the overall ratio values between the groups, no statistically significant difference was observed between

the Class I and Class II malocclusion groups. It is important to note that there were no participants with Class III malocclusion, so a comparison with this group could not be made.

Thanks to advancements in three-dimensional imaging systems, it is now possible to digitally evaluate various dimensional and morphological characteristics of dental arches (34). Specifically, 3D digital models allow for precise analysis and measurement, enabling multiple comparisons to be made between individual dental characteristics and more complex conditions such as Angle malocclusions (17,18,34). This study focuses on the Bolton proportion, which involves measuring the mesiodistal dimensions of the anterosuperior and anteroinferior teeth, and its relationship to maxillomandibular malocclusions classified according to Angle. By identifying specific individual characteristics associated with certain dental groups, it becomes possible to recognize potential risk factors for the development of complex occlusal disorders and take preventative measures in a timely manner. It is recommended to conduct further studies utilizing this 3D imaging technology in both research and daily clinical practice, as its precision and ease of use are important considerations for accurate diagnosis and treatment planning in orthodontics.

The mesiodistal width of the posterior teeth is important in malocclusion due to its relationship with the size of the dental arch and the distribution of the teeth within it. Malocclusion refers to the misalignment of the teeth and jaws, which can affect chewing function, aesthetics, and overall oral health. The mesiodistal width of the posterior teeth, such as molars and premolars, can influence malocclusion in several ways:

Insufficient space: If the posterior teeth are too wide in relation to the size of the dental arch, there may be a lack of space to accommodate all the teeth properly. This can result in dental crowding, where the teeth overlap or bunch up.

Lack of space for eruption: If the posterior teeth are too wide, there may be insufficient space for the permanent teeth to erupt properly. This can lead to the retention of baby teeth or the displaced eruption of permanent teeth, which can cause alignment problems and malocclusion.

Occlusal interference: The mesiodistal width of the posterior teeth can also affect the way the upper and lower teeth fit together when closing the mouth. If the posterior teeth are too wide, there may be occlusal interferences, where the teeth do not meet in a proper bite position. This can cause bite problems, such as an open bite or a crossbite. It is important to note that the mesiodistal width of the posterior teeth is just one of the many factors that can contribute to malocclusion. Other factors, such as the position of the anterior teeth, the relationship between the jaws, and the presence of harmful oral habits, can also play a role in malocclusion.

CONCLUSIONS

Considering the limitations of the current study, it can be concluded that the Bolton proportion, which refers to the difference in mesiodistal dental size of the anteroupper and anteroinferior teeth, does not have a significant impact on the development of Angle's Class I, Class II, and Class III

malocclusions. No statistically significant relationships were found in this regard. However, it is still highly recommended to proactively assess any deviations in this measurement within the dental arches using digital media and 3D models. This approach will yield optimal results in terms of diagnosis and treatment planning for orthodontic interventions.

REFERENCES

1. Batista KB, Thiruvenkatachari B, Harrison JE, O'Brien KD. Orthodontic treatment for prominent upper front teeth (Class II malocclusion) in children and adolescents. Cochrane Database Syst Rev 2018 Mar 13;3(3):CD003452.

2. Bernardi S, Angelone AM, Macchiarelli G. Anatomy in dentistry: From the beginnings to contemporary reality. Clin Anat. 2022 Sep;35(6):711-722. doi: 10.1002/ca.23869. Epub 2022 Apr 9. PMID: 35368109.

3. Black GV. Descriptive anatomy of the human teeth. Philadelphia: S.S. White Manufacturing Company, 1897.http://resource.nlm.nih.gov/67610310R

4. Jabri MA, Wu S, Zhang Y, Ma J, Wang L. A Review on Comparison of Tooth Size Discrepancies among Angle's Class I, II, and III Malocclusion: Is There a Significance? J Contemp Dent Pract. 2019 Aug 1;20(8):994-999. PMID: 31797860.

5. Karadede Ünal B, Dellaloğlu D. Digital analysis of tooth sizes among individuals with different malocclusions: A study using three-dimensional digital dental models. Sci Prog. 2021 Jul-Sep;104(3):368504211038186. doi: 10.1177/00368504211038186. PMID: 34490798; PMCID: PMC10367186.

6. Dindaroğlu F, Duran GS, Aras I. Three-dimensional evaluation of morphologic tooth symmetry in various malocclusions. Am J Orthod Dentofacial Orthop. 2016 Sep;150(3):459-66. doi: 10.1016/j.ajodo.2016.04.017. PMID: 27585774.

7. Rakhshan V, Ghorbanyjavadpour F, Ashoori N. Buccolingual and Mesiodistal Dimensions of the Permanent Teeth, Their Diagnostic Value for Sex Identification, and Bolton Indices. Biomed Res Int. 2022 Feb 10;2022:8381436. doi: 10.1155/2022/8381436. PMID: 35187172; PMCID: PMC8853791.

8. Mollabashi V, Soltani MK, Moslemian N, Akhlaghian M, Akbarzadeh M, Samavat H, Abolvardi M. Comparison of Bolton ratio in normal occlusion and different malocclusion groups in Iranian population. Int Orthodox. 2019 Mar;17(1):143-150. doi: 10.1016/j.ortho.2019.01.005. Epub 2019 Feb 13. PMID: 30770330.

9. Alsaigh H, Alrashdi M. Morphometric analysis of tooth morphology among different malocclusion groups in a Hispanic population. BMC Oral Health. 2023 Apr 3;23(1):199. doi:10.1186/s12903-023-02882-7. PMID: 37013534; PMCID: PMC10071771.

10. Hussein FA, Mohamed RE, El-Awady AA, Ali MM, Al-Khalifa HN, Abdallah KF, Abouelnour AM. Digital evaluation of Bolton's tooth size discrepancies among different malocclusions categories of Egyptian adolescent orthodontic population: A retrospective study. Int Orthodox. 2022 Sep;20(3):100660. doi: 10.1016/j.ortho.2022.100660. Epub 2022 Jun 21. PMID: 35739004.

11. Alsaigh H, Alrashdi M. Geometric analysis of tooth size among different malocclusion groups in a Hispanic population. Am J Orthod Dentofacial Orthop. 2023 Nov;164(5):646-656. doi: 10.1016/j.ajodo.2023.03.022. Epub 2023 Jun 3. PMID: 37278676.

12. Smith SS, Buschang PH, Watanabe E. Interarch tooth size relationships of 3 populations: "does Bolton's analysis apply?". Am J Orthod Dentofacial Orthop. 2000 Feb;117(2):169-74. doi: 10.1016/s0889-5406(00)70228-9. PMID: 10672217.

13. Arya BS, Savara BS, Thomas D, Clarkson Q. Relation of sex and occlusion to mesiodistal tooth size. Am J Orthodox. 1974 Nov;66(5):479-86. doi: 10.1016/0002-9416(74)90109-2. PMID: 4621246.

14. Basaran G, Selek M, Hamamci O, Akkuş Z. Intermaxillary Bolton tooth size discrepancies among different malocclusion groups. Angle Orthodox. 2006 Jan;76(1):26-30. doi: 10.1043/0003-3219(2006)076[0026:IBTSDA]2.0.CO;2. PMID: 16448265.

15. Akyalçin S, Doğan S, Dinçer B, Erdinc AM, Oncağ G. Bolton tooth size discrepancies in skeletal Class I individuals presenting with different dental angle classifications. Angle Orthodox. 2006 Jul;76(4):637-43. doi: 10.1043/0003-3219(2006)076[0637:BTSDIS]2.0.CO;2. PMID: 16808571.

16. Mullen SR, Martin CA, Ngan P, Gladwin M. Accuracy of spatial analysis with emodels and plaster models. Am J Orthod Dentofacial Orthop. 2007 Sep;132(3):346-52. doi: 10.1016/j.ajodo.2005.08.044. PMID: 17826603.

17. Al-Khateeb SN, Abu Alhaija ES. Tooth size discrepancies and arch parameters among different malocclusions in a Jordanian sample. Angle Orthodox. 2006 May;76(3):459-65. doi: 10.1043/0003-3219(2006)076[0459:TSDAAP]2.0.CO;2. PMID: 16637727.

18. Wedrychowska-Szulc B, Janiszewska-Olszowska J, Stepień P. Overall and anterior Bolton ratio in Class I, II, and III orthodontic patients. Eur J Orthodox. 2010 Jun;32(3):313-8. doi: 10.1093/ejo/cjp114. Epub 2009 Dec 16. PMID: 20018795.

19. Lombardo L, Setti S, Molinari C, Siciliani G. Intra-arch widths: a meta-analysis. Int Orthodox. 2013 Jun;11(2):177-92. English, French. doi: 10.1016/j.ortho.2013.02.005. Epub 2013 Apr 2. PMID: 23558045.

20. Ocak I, Karsli N, Altug AT, Aksu M. Relationship between vertical facial morphology and dental arch measurements in class II malocclusion: a retrospective study. PeerJ. 2023 Sep 5;11:e16031. doi: 10.7717/peerj.16031. PMID: 37692120; PMCID: PMC10487581.

21. Kaur, Avninder, et al. "Evaluation and applicability of Moyers mixed dentition arch analysis in Himachal population." Dental Journal of Advance Studies. 2014;2(02):096-104.

22. Janson GR, Metaxas A, Woodside DG, de Freitas MR, Pinzan A. Three-dimensional evaluation of skeletal and dental asymmetries in Class II subdivision malocclusions. Am J Orthod Dentofacial Orthop. 2001 Apr;119(4):406-18. doi: 10.1067/mod.2001.113267. PMID: 11298314.

23. Oktay H, Ulukaya E. Intermaxillary tooth size discrepancies among different malocclusion groups. Eur J Orthodox. 2010 Jun;32(3):307-12. doi: 10.1093/ejo/cjp079. Epub 2009 Sep 3. PMID: 19729399.

24. Tomassetti JJ, Taloumis LJ, Denny JM, Fischer JR Jr. A comparison of 3 computerized Bolton tooth-size analyzes with a commonly used method. Angle Orthodox. 2001 Oct;71(5):351-7. doi: 10.1043/0003-3219(2001)071<0351:ACOCBT>2.0.CO;2. PMID: 11605868.

25. Sousa MV, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofacial Orthop. 2012 Aug;142(2):269-73. doi: 10.1016/j.ajodo.2011.12.028. PMID: 22858338.

26. White AJ, Fallis DW, Vandewalle KS. Analysis of intra-arch and interarch measurements from digital models with 2 impression materials and a modeling process based on cone-beam computed

tomography. Am J Orthod Dentofacial Orthop. 2010 Apr;137(4):456.e1-9; discussion 456-7. doi: 10.1016/j.ajodo.2009.09.019. PMID: 20362900.

27. De Luca Canto G, Pachêco-Pereira C, Lagravere MO, Flores-Mir C, Major PW. Intra-arch dimensional measurement validity of laser-scanned digital dental models compared with the original plaster models: a systematic review. Orthod Craniofac Res. 2015 May;18(2):65-76. doi: 10.1111/ocr.12068. Epub 2015 Feb 11. PMID: 25677755.

28. Grünheid T, McCarthy SD, Larson BE. Clinical use of a direct chairside oral scanner: an assessment of accuracy, time, and patient acceptance. Am J Orthod Dentofacial Orthop. 2014 Nov;146(5):673-82. doi: 10.1016/j.ajodo.2014.07.023. Epub 2014 Oct 28. PMID: 25439218.

29. Paulino V, Paredes V, Cibrian R, Gandia JL. Tooth size changes with age in a Spanish population: percentile tables. Med Oral Pathol Oral Cir Bucal. 2011 Sep 1;16(6):e840-4. doi: 10.4317/medoral.17093. PMID: 21196845.

30. Lundstrom A. Intermaxillary tooth width ratio and tooth alignment and occlusion. Acta Odontol Scand. 1955 Feb;12(3-4):265-92. doi: 10.3109/00016355509028167. PMID: 14375894.

31. Mishra RK, Kafle D, Gupta R. Analysis of Interarch Tooth Size Relationship in Nepalese Subjects with Normal Occlusion and Malocclusions. Int J Dent. 2019 Nov 18;2019:2761427. doi: 10.1155/2019/2761427. PMID: 31827516; PMCID: PMC6885765.

32. Mollabashi V, Soltani MK, Moslemian N, Akhlaghian M, Akbarzadeh M, Samavat H, Abolvardi M. Comparison of Bolton ratio in normal occlusion and different malocclusion groups in Iranian population. Int Orthodox. 2019 Mar;17(1):143-150. doi: 10.1016/j.ortho.2019.01.005. Epub 2019 Feb 13. PMID: 30770330.

33. Rakhshan V, Ghorbanyjavadpour F, Ashoori N. Buccolingual and Mesiodistal Dimensions of the Permanent Teeth, Their Diagnostic Value for Sex Identification, and Bolton Indices. Biomed Res Int. 2022 Feb 10;2022:8381436. doi: 10.1155/2022/8381436. PMID: 35187172; PMCID: PMC8853791.

34. Tian Y, Chen C, Xu X, Wang J, Hou X, Li K, Lu X, Shi H, Lee ES, Jiang HB. A Review of 3D Printing in Dentistry: Technologies, Affecting Factors, and Applications. Scanning. 2021 Jul 17;2021:9950131. doi: 10.1155/2021/9950131. PMID: 34367410; PMCID: PMC8313360.