Taiwanese Journal of Orthodontics

Volume 33 | Issue 1 Article 3

2021

Compare Two Methods of Dental Arch Length Measurements on Digital Dental Models

Ying-Chen Chen
Department of Craniofacial Orthodontic, Chang Gung Memorial Hospital, Taoyuan, Taiwan

Carol Yi-Hsuan Chen
Department of Craniofacial Orthodontic, Chang Gung Memorial Hospital, Taoyuan, Taiwan

Ellen Wen-Ching Ko
Department of Craniofacial Orthodontic, Chang Gung Memorial Hospital, Taipei, Taiwan

Recommended Citation

Chen, Ying-Chen; Chen, Carol Yi-Hsuan; and Ko, Ellen Wen-Ching (2021) "Compare Two Methods of Dental Arch Length Measurements on Digital Dental Models," *Taiwanese Journal of Orthodontics*: Vol. 33 : Iss. 1 , Article 3.
DOI: 10.38209/2708-2636.1093
Available at: https://www.tjo.org.tw/tjo/vol33/iss1/3

Compare Two Methods of Dental Arch Length Measurements on Digital Dental Models

Cover Page Footnote

FUNDING None. CONFLICT OF INTEREST The authors declare no conflicts of interest. ETHICAL APPROVAL This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (No. 2102180062). PATIENT CONSENT Not required

ORIGINAL ARTICLE

Compare Two Methods of Dental Arch Length Measurements on Digital Dental Models

Ying-Chen Chen [a,b], Carol Yi-Hsuan Chen [a,d], Ellen Wen-Ching Ko [b,c,d,*]

[a] Department of Craniofacial Orthodontic, Chang Gung Memorial Hospital, Taoyuan, Taiwan
[b] Graduate Institute of Craniofacial and Dental Science, Chang Gung University, Taoyuan, Taiwan
[c] Department of Craniofacial Orthodontic, Chang Gung Memorial Hospital, Taipei, Taiwan
[d] Craniofacial Research Center, Chang Gung Memorial Hospital, Linkuo, Taiwan

ABSTRACT

Purpose: **Accurate space discrepancy evaluation is important in treatment planning. Straight-line segments and brass wire method are the most common methods in arch length assessment. However, using segments causes underestimation, while more reliable brass wire method shows lower reproducibility. The aim of our study is (1) to compare the difference between conventional segmental distance method (SD) and a new method, ideal arch form (IA), and (2) to assess the reproducibility and reliability of two methods by means of digital models.**

Materials and methods: **Thirty sets of digital dental models presented full permanent dentition and Angle's Class III malocclusion were included. The dental arch length was assessed with two methods: SD method and IA method. Paired-t test was used to compare two methods; Pearson's correlation coefficient was used to analyze the correlated variables with inter-group difference; and interclass correlation coefficient was used to evaluate the reproducibility.**

Result: **Arch length in IA group was 1.86 and 0.86 mm larger than SD group in upper and lower arch, respectively ($p < 0.05$). The upper arch inter-group difference was negatively correlated to arch length ($r = -0.39$, $p < 0.05$) and lower arch inter-group difference was positively correlated to space deficiency ($r = 0.40$, $p < 0.05$). Both SD and IA method showed excellent reproducibility.**

Conclusion: **The SD method showed high consistency but low reliability in short upper arches and crowding lower arches. On the other hand, the IA method can represent the real arch length regarding to the basal bone, and simply be constructed and measured with digital software with high reproducibility.** *Taiwanese Journal of Orthodontics 2021;33(1):19−25*

Keywords: Digital dental model; Dental arch length; Tooth-arch length discrepancy; Ideal arch form

INTRODUCTION

To achieve a better treatment plan, an accurate evaluation of tooth-arch length discrepancy (TALD), which calculate the difference between space required and space available, is important. To evaluate TALD in plaster model, clear ruler, divider, or digital caliper are used to measure the mesiodistal width of each tooth for space required.[1-9] Previous studies have described several methods to measure the available space, included individualized arch form graphing,[1] clear plastic arch form ruler,[2] arcogramme,[3] 4- or 6- segment arch length,[4,5] and direct wire measurement.[6−8]Among these methods, straight-line segments and brass wire method are the most common methods nowadays. For the segmental lines, even though the method is simple, reduction of the round arch perimeter into straight-line segments will result in underestimation of the space available.[9] On the other hand, in the brass wire method, a 0.020-inch brass wire was applied smoothly passing through the contact points between every tooth, from mesial side of first molar on the one side to the opposite side. Then the wire length will be

Received 25 February 2021; revised 22 March 2021; accepted 17 April 2021.
Available online 16 June 2021.

* Corresponding author at: Department of Craniofacial Orthodontics, Chang Gung Memorial Hospital, Taipei, 6F, 199, Tung Hwa North Road, Taipei 105, Taiwan.
E-mail address: ellenko.wc@msa.hinet.net (Ellen W Ko).

https://doi.org/10.38209/2708-2636.1093

Taiwanese Journal of Orthodontics
2021;33(1):19–25

measured. Although the brass wire method follows the arch form of basal bone, it is more time consuming than segmental length measurement and the reproducibility is low.[10]

To standardized the method, the ideal arch form correlated to the scheme of skeletal base might be a solution for space available measurement.[7] In the previous studies, some methods to construct the ideal arch form were introduced, including geometric graphing,[12-13] mathematical equation model[14-16] and cast-CBCT image method.[17]

The first description based on the geometric rules was introduced by Bonwill and Hawley.[12-13] They constructed an arch form with a circle of which radius is the combination of the width of six anterior teeth, and an equilateral triangle represents the intercondylar width. Recently, with the growing of technology and mathematics, the length and the curve of arch form are calculated with a formula or regression.[14-16] Noroozi utilize the beta function formula to develop an accurate curve of equation based on inter-second-molar width, inter-canine width, second molar depth and canine depth.[14] However, for the clinical practice, the geometric graphic method and the mathematical equation model are not feasible. According to Andrew's six elements orthodontic philosophy, the anterior and lateral border of mandibular dental arch will follow the rule from WALA ridge, which is defined as the most prominent portion of mandible's mucogingival junction.[17] The distance from second premolar cusp tip, first premolar cusp tip, canine cusp tip to the WALA ridge are 4 mm, 3 mm, and 2 mm respectively.[17-20] The study of Ronay et al.[23] revealed the strong correlation of WALA ridge and tooth position, proving that WALA ridge is capable to predict the tooth position in the concept of apical basal bone. In addition, the tooth to basal bone relation was also described in the CBCT image research and confirmed the dental-to-skeletal relation.[20]

For orthodontists, it requires the accurate replicas of oral dentition from patients to make ideal diagnosis and treatment plan. Although conventional plaster dental models can provide sufficient information that professionals required, the general disadvantages are their physical weight, time consuming, the need for storage space, and the risk of wearing and fracture. In pace with the emergence of computed technology, digital dental model become an efficient material for clinical practice. Nowadays, digital dental models can also assist space analysis and several studies were released to compare conventional and digital methods of measurement. Leifert et al.[10] in 2009 used plaster models as control group comparing with digital models, and the result shows digital model is a reliable material to analyze arch length discrepancies. For the accuracy assessment, Quimby's research showed the digital models appeal great reproducibility.[22] Controversially, the research from Sjögren revealed lower inter-examiner repeatability while using digital model and higher intra-examiner reproducibility for experienced examiner.[11]

In the past, it is difficult to assess the measurement on the imaginary line. However, by the assistance of digital analyze software, ideal arch form can be created on the virtual occlusal plane and measured with virtual rulers. Therefore, the purpose of this study is (1) to assess the reproducibility and reliability of a new method, ideal arch form (IA), and (2) to compare the difference between conventional segmental distance method (SD) and IA method by means of digital model measurement.

MATERIALS AND METHODS

The study was undertaken as an experimental approach. Thirty sets of maxillary and mandibular dental models were selected with criteria as following: Class III malocclusion patients before orthodontic treatment, absence of positive or negative bubbles, complete anatomical structure of the teeth without morphological defect, such as poor qualified restorations or large decays, and presence of full dentition from first molar on one side to first molar to the opposite side. The cases with obviously excessive space available were excluded. The present study followed the Declaration of Helsinki on medical protocols and ethics, and the Institutional Review Board of Chang Gung Memorial Hospital approved this study.

Digital cast Obtaining

The dental models were obtained by oral impression with Alginate (Cavex CA37®, Holland). After trimming the excess material to avoid occlusion and scan interference, the plaster casts were captured with an extraoral scanner, 3 shape R700™ (3Shape, Copenhagen, Denmark). The scanner contains 2-camera and 3-axis motion system which could capture full undercuts and reduce the interference. The Standard Tessellation Language (STL) files of the images were transferred to OrthoAnalyzer™ software (3Shape, Copenhagen, Denmark) for virtual cast analysis.

Preparation and orientation

The occlusal plane was defined as the plane passing through the mesiobuccal cusp of bilateral first molars and the most extruded point on the incisal edge of central incisors.

Measurements

Space required

The teeth were separated one by one to measure the tooth size from the most convex contour of both mesial and distal surface of the tooth. The cutting planes were parallel to the long axis of the tooth.

Space available (Arch length)

Two methods of arch length measurements were conducted.

1) Measurement method of segmental distance (SD group): The cast was oriented according the occlusal plane to which the visual angle is perpendicular. The segments were measured by connecting the points, including contact point of: right first molar and second premolar, right canine and lateral incisor, central incisors, left canine and lateral incisor, and left first molar and second premolar (Figure 1). However, most of the cases might show the teeth contacting with a contact area instead of a contact point. When encountering this situation, we would indicate the segmentation point in the middle of the area. In the canine completely blocked-out cases, the segmentation point will be adjusted to the most convex contour on the mesial side of the first premolar instead of the contact point of first premolar and the blocked-out canine. Similarly, the adjustment could be applied in severely malaligned lateral incisor and premolars.
2) Measurement method of individualized arch form (IA group): The casts were oriented according the occlusal plane to which the visual angle is perpendicular. First of all, the arch form was first selected as symmetric ellipse arch which passes through the anterior contour of the alveolar ridge or incisal edge, and the end-points were on the most mesial contour of first molars on both sides. According to Andrew's measurement, the projection distances of the incisor tips to mucogingival junction are about 0 mm. We registered the center of the ellipse curve on the midpoint between the “midpoint of two central incisors edge” and the “anterior contour of the alveolar ridge” in the occlusal view. The previous measurement was more related to conventional brass wire technique and the later one was more related to WALA ridge rule of Andrew. While moving the tip of ellipse within the range, the curve passing through posterior teeth could fit the WALA ridge well for final determination of the individual arch form.
The line medially to the WALA ridge of 4 mm and 3 mm on second premolars and first premolars respectively were connected (Figure 2). The adjusted line represents the optimal arch form which would pass through the buccal cusp of mandibular premolars and incisal edge of the mandibular incisors. Ultimately, the maxillary ellipse arch form would be coordinated according to the mandibular arch, for about 2 to 3 mm wider than the mandibular arch.

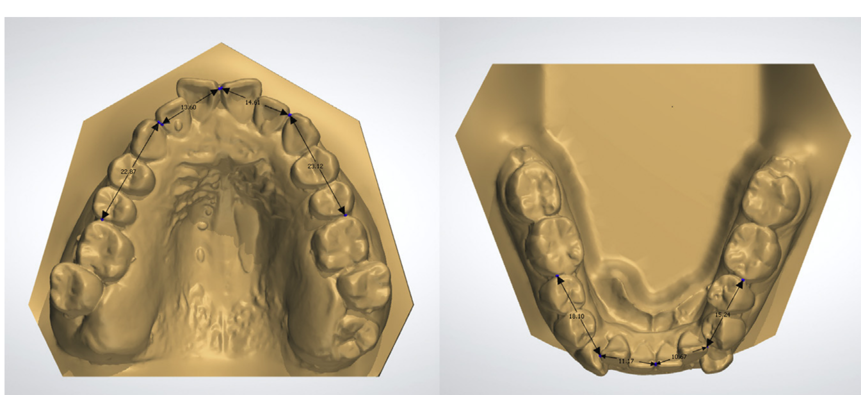

Figure 1. Segmental distance method. After orienting the digital models, the segments were obtained by connecting the points together: contact point of the right first molar and second premolar, the contact point of right canine and lateral incisor, the contact point of central incisors, the contact point of left canine and lateral incisor, and then the left first molar and second premolar.

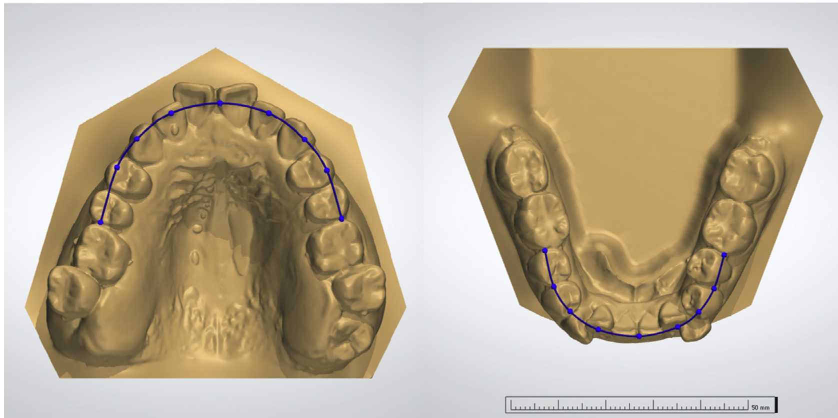

Figure 2. The mandibular arch form was developed according to the WALA ridge to individualize the arch form. The line medially to the WALA ridge 4 mm and 3 mm on second premolars and first premolars respectively can be registered when assisting with the scale below. After finishing lower arch making, the arch form can be reflected to the upper model, and 2-3 mm wider of upper arch could be marked successively.

Space deficiency

Tooth size-arch length discrepancy was defined as space available minus space required.

Measuring time

The time for space available measurement were recorded. For the SD group, the measure time included point marking and segmental distances calculation. For the IA group, the measure time included only arch form development, and the length will be calculated by the software automatically.

Consistency of the methods

All measurements were conducted by a single examiner (YC.C). For intra-observer consistency, 10 digital casts were randomly selected to conduct a re-examination after an interval of 2 weeks. The validation of segmentation consistency and arch form development were assessed.

Statistical analysis

Statistical analysis was carried out with SPSS 22.0 application (IBM, Chicago, IL, USA). The difference of space available acquired form two methods was assessed with paired-t test. Besides, the difference of discrepancy in SD group and IA group was also compared with paired-t test. To analyze the correlated variables with inter-group difference, Pearson's correlation coefficient was utilized. To test the intra-observer consistency, the validation of segmentation consistency and arch form development were assessed with interclass correlation coefficient. P-value < 0.05 was considered statistically significant.

RESULT

The statistical analysis showed there was significant difference between SD group and IA group. In average, the space available in IA group was 1.86 mm longer in maxillary model and 0.86 mm longer in mandibular model (Table 1).

In the upper models, the inter-group difference showed statistically significant correlation with arch length with IA method (UIA) (Pearson's correlation coefficient $r = -0.39$, $p < 0.05$). The result indicated the longer the upper arch, the smaller the difference between groups. On the other hand, the difference between two methods in the lower arch showed significant correlation to space deficiency with the SD method (LSDD) (Pearson's correlation coefficient $r = 0.40$, $p < 0.05$), indicating the more space deficiency noted with SD method, the more difference between two methods (Table 2). The time required to perform the two methods showed no statistically significant difference while 111.6 and 126.7 seconds were taken in SD and IA method, respectively. After the interclass correlation coefficient (ICC) test, both

Table 1. Space deficiency measured with two different methods.

	Ideal Arch form (IA) n = 30		Segmental distance (SD) n = 30		Inter-group difference (SD-IA)		p-value
	Mean	SD	Mean	SD	Mean	SD	
Upper arch							
Space available	75.4	5.74	73.6	5.29	−1.86	2.06	<0.001‡
Space deficiency	−2.38	5.33	−4.70	5.11			<0.001‡
Lower arch							
Space available	65.48	3.89	64.62	4.07	−0.86	1.53	.005‡
Space deficiency	−2.77	4.04	−3.64	4.4			.005‡

‡*p*-value <0.01.

Table 2. Correlation of inter-group difference and other measurements.

	Pearson's correlation coefficient, r=	p-value (2-tailed)
Upper arch inter-group difference compares to		
UIA	−0.39	0.03†
USD	−0.33	0.86
UIAD	−0.30	0.11
USDD	0.09	0.62
Lower arch inter-group difference compares to		
LIA	0.08	0.69
LSD	0.30	0.10
LIAD	0.06	0.76
LSDD	0.40	0.03†

UIA, upper arch length using ideal arch form method; USD upper arch length using segmental distance method; UIAD, upper arch space deficiency using ideal arch form method; USDD, upper arch space deficiency using segmental distance method; LIA, lower arch length using ideal arch form method; LSD lower arch length using segmental distance method; LIAD, lower arch space deficiency using ideal arch form method; LSDD, lower arch space deficiency using segmental distance method.
†p-value<0.05.

Table 3. Interclass correlation coefficient (ICC) of reproducibility.

	Interclass correlation coefficient	p-value
Upper arch		
Space required	0.95	<0.01‡
Space available (IA)	0.96	<0.01‡
Space available (SD)	0.97	<0.01‡
Lower arch		
Space required	0.97	<0.01‡
Space available (IA)	0.99	<0.01‡
Space available (SD)	1.00	<0.01‡

Two-way mixed model was used.
Type A interclass correlation coefficient using an absolute agreement definition.
‡p-value<0.01.

arch in SD groups and IA groups showed excellent reproducibility, upper arch 0.96 and lower arch 0.99 were found in IA group, while upper arch 0.97 and lower arch 1.00 were found in SD group (Table 3).

DISCUSSION

To develop the arch form measurement, we modified the arch curve based on Andrew's WALA ridge which is capable to predict the tooth position in the concept of apical basal bone. The limitation of this study was the variability of incisor crown position. The reason not to simply use 0 mm as the criteria is that we found out most of the articles assessing WALA ridge concerned more of the posterior transvers dimension instead of anterior region. Besides, using 0 mm as the rule in some cases would distort the arch form due to severe lingually inclination of incisors in skeletal Class III patients. On the other hand, keratinized gingiva thickness is also a determined factor of lower incisor proclination but cannot be estimated in this study. Given the above reasons, the quantity of incisor proclination is difficult to precisely estimate, thus the modified method which is adjusted to the range between "incisal edge" and "anterior contour of the alveolar ridge".

Since segmental distance method would underestimate the arch length, graphic discrepancy between natural rounded arch form and straight lines was assessed in this study. It shows upper and lower arch were underestimated 1.86 mm and 0.86 mm, respectively. According to the result which compares IA and SD method, the main difference between two methods in the upper dental model is correlated to arch length while the lower dental model was correlated to space deficiency with the SD method. For the upper models, most of the arch forms are ellipse.[21] Therefore, as longer the arch length, the segmental distance will be closer to the rounded-shape and reduce the difference between two methods. Besides, in the larger arches of Class III patients included in this study, the space deficiency always appears as labial tipping of upper incisors instead of irregularity. In this type of arch form, the straight segments will extend the anterior part to the contact point of proclined upper central incisors and balanced the underestimated measurement to become closer to the IA method measurement. On the other hand, most of the lower arches in Class III patients are squared due to dental compensated lingual tilted incisors, which was much closer to the shape of segmental lines. While space deficiency from the dentition increased, the more difference will occur due to the distorted dental arch form. Hence, the conventional segmental distance method is more reliable when the upper arch shows larger arch length and mild crowding with incisor proclination existed, and the lower arch shows mild crowding.

The result showed the difference in upper dental arch was only 1.86 mm difference between the two methods. The difference was statistically significant that indicates some underlying problems could be revealed when using segmental distance for arch length measurement. According to the result, we may pay more attention on the potential underestimation in upper arch length, especially in cases with shorter arch length as indicating in Table 2.

When it comes to time consumed in two methods, measuring with segmental distance method on plaster models is easier and faster than with curved arch form length. Nevertheless, assisted with digital dental model, the ideal arch form length can be developed and measured efficiently and eliminate the difference of the time required between these two methods.

In the previous study, it was considered that the reproducibility is low when using curved arch length.[1,12] Based on the consistency of tooth position and skeletal arch introduced by Andrew's six element philosophy and also confirm with CBCT image, WALA ridge provides a scheme for arch form development. In our study, although the reproducibility of ideal arch form is slightly lower than segmental distance, is still excellent (ICC = 0.99 in lower arch, 0.96 in upper arch). Assisted with digital software, the measuring curves can be consistently processed on the occlusal plane, and the scale could facilitate calibrating the position of wire to WALA ridge, eventually generate a method with high reproducibility and reliability. For the upper arch, since the limitation of the software which can only reflex the lower ideal arch form to the upper arch but not allow moving them as a guide, there might be lower consistent in the upper ideal arch form development of the patients with severe asymmetry or anteroposterior skeletal discrepancy.

The case selection which only included Class III malocclusion patients because the present study is the pilot study of an undergoing research in our institution. The methods of arch length measurements need to be validated for evaluation of occlusion characteristics in Class III patients. Thus preliminary assessment might be constructive to decide a better solution. Besides, the arch form in Class III malocclusion already has wide diversity, not to mention in different classification of malocclusion. Therefore, to reduce the analysis discrepancy, only patients with Class III malocclusion were included.

To assess the tooth size arch length discrepancy, space available measurement is an important issue which affects the variable considerably. First of all, to reflect the real arch length, curved length is more ideal and reliable than the segmental lines. Furthermore, the measurement regarding to the basal bone could reveal the hidden space once taking narrow arch expansion into consideration, and disclose the overestimated space when taking tooth proclination into account.

CONCLUSION

As the technology developing, using digital dental model for space deficiency assessment is efficient. Segmental distance method shows high consistency but low reliability in short upper arches and arches with crowding dentition. On the other hand, ideal arch form method can represent the real arch length regarding to the basal bone, and simply be developed and measured with digital software.

FUNDING

None

Conflict of interest statement

The authors declare no conflicts of interest.

ETHICAL APPROVAL

This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital (No. 2102180062).

PATIENT CONSENT

Not required.

REFERENCES

1. Beazley WW. Assessment of mandibular arch length discrepancy utilizing an individualized arch form. *Angle Orthod* 1971;**41**(1):45–54.
2. White LW. Accurate arch-discrepancy measurements. *Am J Orthod* 1977;**72**(3):303–8.
3. Herren P, Schmoker R, Jordi T. Arch shape and space balance determined by arcogramme technique. *Trans Eur Orthod Soc* 1973:61–73.
4. Moorrees CF, Reed RB. Biometrics of crowding and spacing of the teeth of the mandible. *Am J Phys Anthropol* 1954;**12**(1): 77–88.
5. Lundström A. The significance of early loss of deciduous teeth in the etiology of malocclusion. *Am J Orthod* 1955;**41**(11): 819–26.
6. Nance HN. The limitations of orthodontic treatment-II. Diagnosis and treatment in the permanent dentition. *Am J Orthod Oral Surg* 1947;**33**(5):253–301.
7. Carey CW. Treatment planning and the technical program in the four fundamental treatment forms. *Am J Orthod* 1958; **44**(12):887–98.
8. Huckaba GW. Arch size analysis and tooth size prediction. *Dent Clin North Am* 1964;**11**:413–40.
9. Johal AS, Battagel JM. Dental crowding: a comparison of three methods of assessment. *Eur J Orthod* 1997;**19**(5):543–51.
10. Machado LA, Vilella OD, Agostinho LM. Evaluation of two techniques to measure the available space in the mandibular dental arch using the method error. *Rev Odonto Cienc* 2012; **27**(3):228–32.
11. Sjögren AP, Lindgren JE, Huggare JÅ. Orthodontic study cast analysis—reproducibility of recordings and agreement between conventional and 3D virtual measurements. *J Digit Imaging* 2010;**23**(4):482–92.
12. Bonwill WGA. Geometrical and mechanical laws of articulation. *Trans Odontol Soc Pennsylvania* 1885:119–33.
13. Hawley CA. Determination of the normal arch and its application to orthodontia. *Dental Cosmos* 1905;**47**(5):541–52.
14. Noroozi H, Nik TH, Saeeda R. The dental arch form revisited. *Angle Orthod* 2001;**71**(5):386–9.
15. Al-Ansari NB, Ameer SAA, Nahidh M. A new method for prediction of dental arch parameter. *Clin Cosmet Investig Dent* 2019;**11**:393–7.

16. Noroozi H, Djavid GE, Moeinzad H, Teimouri AP. Prediction of arch perimeter changes due to orthodontic treatment. *Am J Orthod Dentofacial Orthop* 2002;**122**(6):601–7.
17. Andrews LF. The 6-elements orthodontic philosophy: Treatment goals, classification, and rules for treating. *Am J Orthod Dentofacial Orthop* 2015;**148**(6):883–7.
18. Triviño T, Siqueira DF, Andrews WA. Evaluation of distances between the mandibular teeth and the alveolar process in Brazilians with normal occlusion. *Am J Orthod Dentofacial Orthop* 2010;**137**(3):308.e1-4.
19. Rasmussen CM, Zhu P, Lohse CM, Volz JE, Salinas TJ. Use of the WALA ridge to evaluate mandibular molar inclination measured to American Board of Orthodontics standards. *J World Fed Orthod* 2019;**8**(2):51–6.
20. Glass TR, Tremont T, Martin CA, Ngan PW. A CBCT evaluation of root position in bone, long axis inclination and relationship to the WALA Ridge. *Semin Orthod* 2019;**25**(1):24–35.
21. Currier JH. A computerized geometric analysis of human dental arch form. *Am J Orthod* 1969;**56**(2):164–79.
22. Quimby ML, Vig KW, Rashid RG, Firestone AR. The accuracy and reliability of measurements made on computer-based digital models. *Angle Orthod* 2004;**74**(3):298–303.
23. Ronay V, Miner RM, Will LA, Arai K. Mandibular arch form: the relationship between dental and basal anatomy. *Am J Orthod Dentofacial Orthop* 2008;**134**(3):430–8.