Original Article

A New, Accurate and Fast Digital Method to Predict Unerupted Tooth Size

Vanessa Paredes[a]; Jose Luis Gandia[b]; Rosa Cibrian[c]

Abstract: The sum of the lower incisor tooth width has been proposed as the best predictor for calculating unerupted canine and premolar mesiodistal tooth sizes. The aims of this study were to develop a new, fast, and accurate computerized method to predict unerupted mesiodistal tooth sizes and to determine which reference tooth or combination of reference teeth was the best predictor for canines and premolars in a Spanish sample. The dental casts of 100 Spanish adolescents with permanent dentition were measured to the nearest 0.05 mm with a two-dimensional computerized system. The goal was to predict unerupted canine and premolar mesiodistal tooth sizes using the sizes of the upper central incisor, upper and lower first molar, or a combination of these as a reference and using a specific mesiodistal tooth-size table. The results showed that the Digital Method proposed was very accurate in predicting unerupted canine and premolar tooth size. The combination of the sums of the permanent upper central incisor and the lower first molar was the best predictor for canines and premolars in this sample. Upper arch teeth were better predicted than lower arch teeth. The upper lateral incisor provided the worst predictions. (*Angle Orthod* 2006;76:14–19.)

Key Words: Digital casts; Mixed dentition analysis; Mesiodistal tooth size

INTRODUCTION

Prediction of unerupted tooth sizes of both canines and premolars is an important objective for diagnosis in orthodontics.[1,2] Several mixed dentition analyses have been developed and proposed for this goal.

Up to now, three basic groups have been used to determine the mesiodistal widths of unerupted canines and premolars.[3–11]

Analyses based on linear regression equations

Moyers[7] regression scheme has achieved widespread clinical acceptance because of its simplicity and ease of application. Moyers devised a table giving the predicted mesiodistal widths of permanent canines and premolars on the basis of mandibular incisor widths.

Since then, several simple linear regression equations have been proposed for populations of different ethnic origins.[12–16]

Bernabe and Flores-Mir[17] found the combination of upper and lower central incisors and upper first molars to be the best predictor, whereas Nourallah et al[18] reported that the sum of the lower central incisors and the upper first molars had better results.

Analyses based on measurements of the unerupted teeth on radiographs

Nance[3] proposed one of the first analyses to measure unerupted mesiodistal tooth size on intraoral radiographs.

Later, De Paula et al[11] introduced a technique using a 45° cephalometric radiographs.

Analyses based on a combination of linear regression equations and measurements on radiographs

Hixon and Oldfather[19] proposed measuring central and lateral incisors on dental casts and premolars on radiographs to ascertain canine mesiodistal tooth size. Later, Bishara and Staley[9] used a revised version of

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the study of Hixon and Oldfather[19] in an attempt to determine an improved equation.

However, some of these methods (such as multiple regression equations) are not usually carried out because they are time consuming, and in some of them, the correlation coefficients between real sizes of ''reference teeth'' and ''real values'' of predicted teeth are not high enough to ensure a good prediction.

Because we have not found a Digital Method to predict unerupted tooth sizes in the mixed dentition,[20–25] the aims of this study were to develop an easy, accurate, fast, and automatic Digital Method using reference teeth and tooth-size tables and an easily programmable interpolation algorithm. The second objective was to determine which reference tooth, or combination of reference teeth, showed the best predictive values for canines and premolars in a Spanish sample.

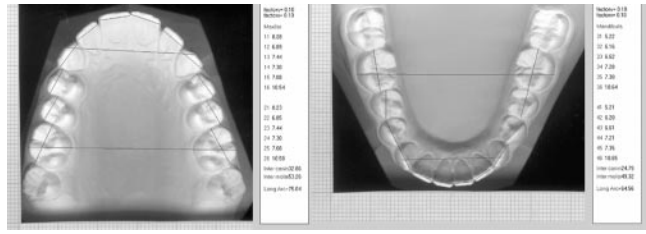
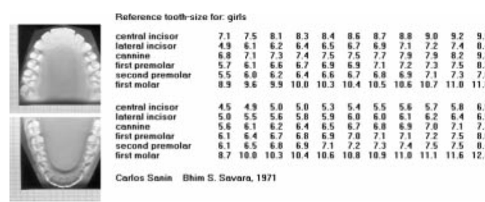


FIGURE 1. Results of mesiodistal tooth sizes with the Digital Method in the upper and lower arch.



Reference tooth-size for: girls

central incisor	7.1	7.5	8.1	8.3	8.4	8.6	8.7	8.8	9.0	9.2	9.9
lateral incisor	4.9	6.1	6.2	6.4	6.5	6.7	6.9	7.1	7.2	7.4	8.4
cannine	6.8	7.1	7.3	7.4	7.5	7.5	7.7	7.9	7.9	8.2	9.2
first premolar	5.7	6.1	6.6	6.7	6.9	6.9	7.1	7.2	7.3	7.5	8.2
second premolar	5.5	6.0	6.2	6.4	6.6	6.7	6.8	6.9	7.1	7.3	7.6
first molar	8.9	9.6	9.9	10.0	10.3	10.4	10.5	10.6	10.7	11.0	11.8
central incisor	4.5	4.9	5.0	5.0	5.3	5.4	5.5	5.6	5.7	5.8	6.5
lateral incisor	5.0	5.5	5.6	5.8	5.9	6.0	6.0	6.1	6.2	6.4	6.9
cannine	5.6	6.1	6.2	6.4	6.5	6.7	6.8	6.9	7.0	7.1	7.7
first premolar	6.1	6.4	6.7	6.8	6.9	7.0	7.1	7.1	7.2	7.5	8.0
second premolar	6.1	6.5	6.8	6.9	7.1	7.2	7.3	7.4	7.5	7.5	8.4
first molar	8.7	10.0	10.3	10.4	10.6	10.8	10.9	11.0	11.1	11.6	12.4

Carlos Sanin Bhim S. Savara, 1971

FIGURE 2. Carlos Sanin and Bhim Savara tooth-size tables for girls.

MATERIALS AND METHODS

The dental casts of 100 patients attending the Orthodontic Department of the University of Valencia, Spain, were used in this study. The sample included 30 girls and 70 boys, with a mean age of 14.8 years (11.2–22.7 years) similar for both.

To predict unerupted tooth sizes under the best conditions, the selection criteria of the casts were:

- Permanent dentition from first molar to first molar;
- Lower and upper first molar totally erupted and without the gingiva overlapping the distal surface of the tooth;
- Good quality casts;
- No tooth agenesis or extractions;
- No large restorations or teeth with anomalous shapes that could change the mesiodistal diameter of the tooth.

All the study casts were digitized with a conventional scanner. Before making any measurements, an accurate and easy calibration system was constructed to obtain the real cast dimensions. In this calibration system, the stone dental casts were surrounded by a millimeter paper sheet. When the arches have been digitized, the magnification of the millimeter paper in the two axes is known and the dental cast magnification can be calculated.

With the aid of the mouse as a user interface, we marked the mesiodistal size of each permanent tooth on the image of the casts. The software designed for this purpose, which we have tested and found accurate and reliable, determines dental sizes in millimeters automatically.[26] From this data, we were able to predict the rest of unerupted tooth sizes (Figure 1).

This Digital Method for prediction is based on the knowledge of mesiodistal tooth size of reference teeth (permanent teeth measured) and mesiodistal tooth-size tables introduced in the program and classified by percentiles.[26]

We carried out our tests using four different permanent reference teeth: two in the upper arch, first molar and central incisor, and another two in the lower arch, first molar and central incisor, and a combination, upper central incisor and lower first molar. We chose these reference teeth (or independent variables) because of their early eruption in the arches and stability in mesiodistal dimension.

We chose the girls and boys tooth-size tables of Sanin and Savara[27] (Figure 2) because the tooth sizes are divided by percentiles and are separate for girls and boys. The prediction algorithm determines the percentile that corresponds to the patient's complete dentition and calculates the rest of the tooth sizes (width of individual dependent variables) by an adequate interpolation.

Each mesiodistal tooth size is represented in the tables as Xi, j, where i represents the table row (type of tooth) ($i = 1$ to 12) and j the column (the percentile) ($j = 1$ to 11). Taking d_k as the mesiodistal size of the chosen reference teeth, we are able to localize between which percentiles reference tooth $X_{k,j}$ and $X_{k,j+1}$ are situated. We can determine the relative distance (RD) for tooth size between the reference tooth and its lower percentile (equation 1):

$$RD = (d_k - X_{k,j})/(X_{k,j+1} - X_{k,j}). \qquad (1)$$

Patient tooth-size prediction (Pi) is obtained with equation 2 for every tooth:

$$Pi = X_{i,j} + (X_{i,j+1} - X_{i,j})RD. \qquad (2)$$

If $d_k < X_{k,1}$ or $di > X_{k,11}$, it is not possible to make the

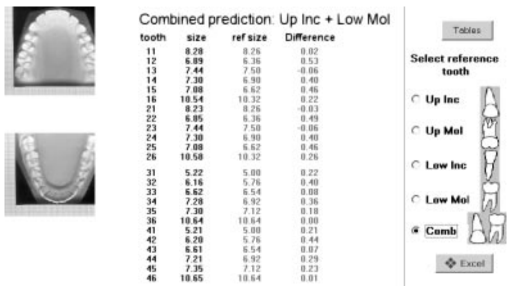


FIGURE 3. Real values and predicted values with the upper central incisor and lower first molar combination as reference.

interpolation and the tooth-size measurements will be those closest to the percentile.

We have introduced this algorithm in our Digital Method for casts to obtain ''predicted values'' for every reference tooth and compared these predicted values with the real values measured by the Digital Method and localized the differences between them automatically. It is also possible to use a two reference-tooth combination to make the prediction, using one to predict some values and the other to predict others.

Figure 3 shows the predicted and real values with the combination of the upper central incisor and lower first molar as reference teeth. At the top of the image, we can see the reference teeth chosen. In the middle of the image, we can see three different columns; the first one on the left side corresponds to the real values, the middle one to the predicted values, and the last one to the difference between them.

The SPSS© Vs. 10.0 Inc 1989–1999 Copyright (statistics package for Windows, Chicago, IL) was used, analyzing the comparison of paired measurement means and the correlation between variables by the analysis of linear regression and correlation coefficients. The proportion comparison test was also used to validate statistically the greater or lesser proportions of correct predictions.

RESULTS

We prepared linear regression graphics in which we represented and compared real values and predicted ones for each tooth type for every reference tooth. Our results showed the upper central incisor and lower first molar combination was the best reference teeth. We can see all the linear regression coefficients for every reference tooth in Table 1.

When we used the upper central incisor as a reference tooth, the better and higher linear regression coefficients were for the upper and lower lateral incisors, $r = 0.55$ and $r = 0.71$, respectively. However, the canines and premolars presented better linear regression coefficients when they were predicted using the lower first molar as a reference tooth, from $r = 0.53$

TABLE 1. Linear Regression Coefficients for Every Predicted Tooth by Every Reference Tooth

	Reference Tooth				
	Upper Arch		Lower Arch		
Predicted Teeth (r)	Central Incisor (UCI)	First Molar (UFM)	Central Incisor (LCI)	First Molar (LFM)	UCI + LFM
2 + 2	**0.55**	0.33	0.37	0.52	**0.55**
3 + 3	0.40	0.50	0.31	**0.53**	**0.53**
4 + 4	0.38	0.47	0.40	**0.57**	**0.57**
5 + 5	0.37	0.44	0.65	**0.73**	**0.73**
2 − 2	**0.71**	0.41	0.51	0.47	**0.71**
3 − 3	0.58	0.53	0.45	**0.59**	**0.59**
4 − 4	0.36	0.45	0.41	**0.57**	**0.57**
5 − 5	0.37	0.51	0.38	**0.61**	**0.61**

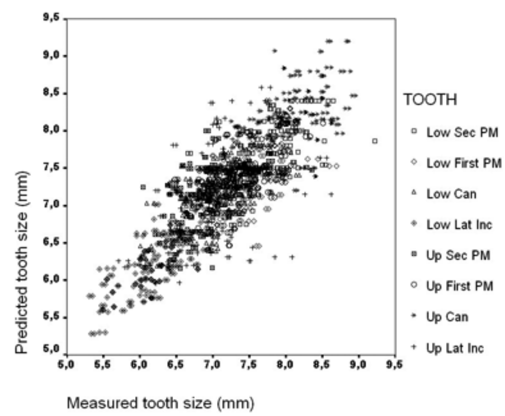


FIGURE 4. Linear regression graphic for the total teeth using the upper central incisor and lower first molar as reference teeth.

for the upper canine to $r = 0.61$ for the lower second premolar.

Consequently, we used a combination of prediction reference teeth: the upper central incisor for predicting upper and lower lateral incisors and the lower first molar for the rest of the teeth. The regression equation for the total of teeth for this combination is:

$$\text{predicted values} = (0.805 \times \text{real values}) + 1.461.$$

The linear regression coefficient is $r = 0.81$, as shown in Figure 4, and the standard error of estimate for this combination is 0.385.

For these reference combination teeth, we have classified the differences between real values and predicted values for each patient, as shown in Figure 5.

Table 2 shows the frequency of the type of prediction and the number of teeth. Eighty-three percent of the teeth are predicted with less than 0.5 mm of error, 15% with errors between 0.5 and one mm, and just 1.7% of the predictions have errors between one and 1.5 mm. To know which teeth are the best predictors, we classified the differences between real and predicted values into the following categories:

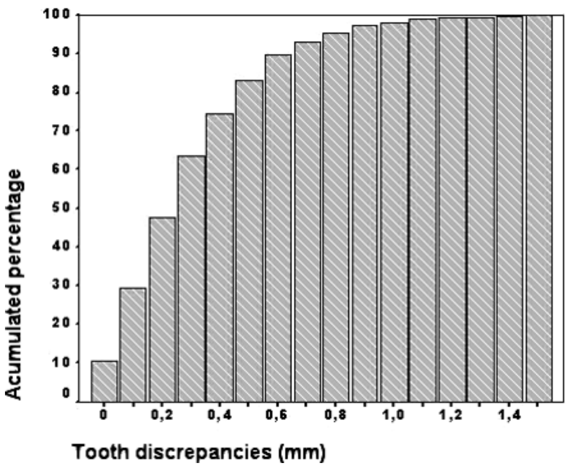


FIGURE 5. Differences between predicted and real values using the upper central incisor and first lower molar as reference teeth.

- Good predictions: Differences up to 0.5 mm;
- Acceptable predictions: Differences 0.5–1 mm;
- Poor predictions: Differences 1–1.5 mm;
- Bad predictions: Differences >1.5 mm.

Figure 6 shows the predictions for each tooth with the combination of upper central incisor and lower first molar as reference. We made no bad predictions (>1.5 mm). Lower teeth were better predicted than upper teeth. The lateral upper incisor was the worst predicted tooth whereas the lower lateral incisor the best.

Because some patients accumulated several bad predictions, we calculated the total difference between real values and predicted values for each arch (eight teeth) to evaluate the number of patients that have a correct or an incorrect total prediction (Figure 7). Because the differences between predicted and real values can be positive or negative and because some of these differences could compensate for others, we calculated the total of the absolute values of such differences. The results are shown in Figure 6. The results for the lower arch are better.

Taking this into account, we have considered differences of four mm between real values and predicted values for each arch as a good total prediction. Again, the results were better for the lower arch. Ninety-six percent of patients were well predicted in their lower arch, and 83% of patients were well predicted in their upper arch.

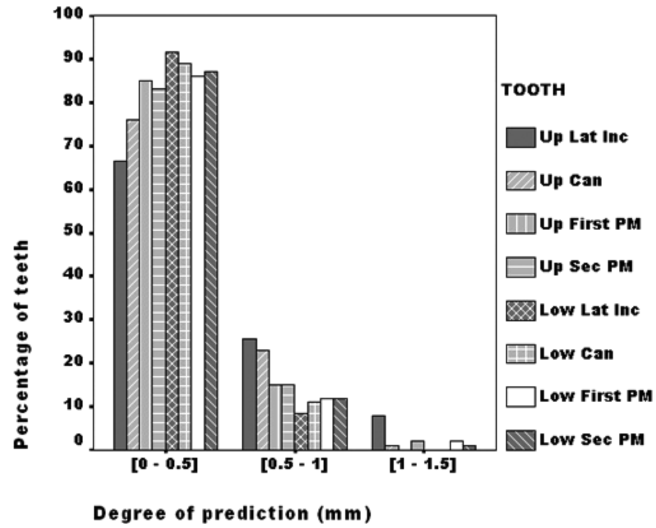


FIGURE 6. Degree of prediction for every tooth using upper central incisor and first lower molar as reference teeth.

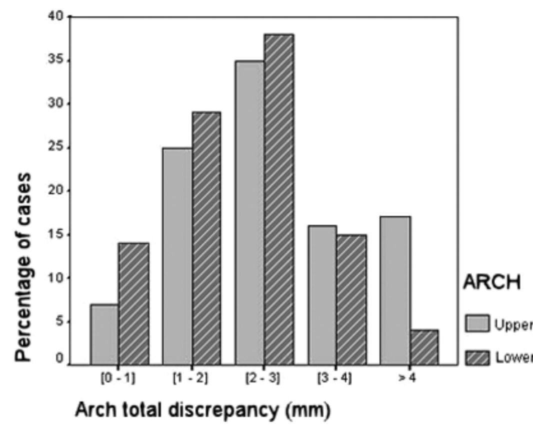


FIGURE 7. Total arch discrepancy using upper central incisor and first lower molar as reference teeth.

DISCUSSION

Our Digital Method[26] cannot be classified under any of the known categories because it uses reference teeth and tooth-width tables to predict unerupted teeth mesiodistal sizes. A great advantage of this Digital Method is the ability to predict tooth size in each arch individually, an advantage over previous procedures.[5–8]

Because significant differences according to arch and sex have been found in previous articles,[13,15,16] we used separated tooth-width tables for boys and girls.

TABLE 2. Frequency and Type of Prediction Expressed as a Percentage (%) and Number (N) of Teeth

Type of Prediction						
Good (up to 0.5 mm)		Acceptable (0.5–1 mm)		Poor (1–1.5 mm)		N Teeth
83%	1330 teeth	15%	242 teeth	1.7%	28 teeth	1600

Using the combination of the upper central incisor and lower first molar, we obtained one of the highest linear regression coefficients ($r = 0.81$) compared with other studies reported in the literature that used only lower incisors.[8,14,16]

Upper lateral incisors were not included as predictors because of their form variability. This combination produced a very high number of ''good predictions'' (1330/1600 teeth), which represented the biggest percentage (83%), a low number of ''poor predictions'' (28/1600 teeth), and no ''bad ones.''

Only three recent studies[17,18,28] reported that the tooth-width sum of the lower mesiodistal incisors was not the best predictor, and our results agree with theirs. Bernabe and Flores-Mir[17] found the combination of upper and lower central incisors and upper first molars the best predictor for canines and premolars. It is important to note that lower first molars were not included as predictors in that study because they were still covered by gingival tissue. Nourallah et al[18] reported that the sum of the lower central incisors and the upper first molars had the highest predictor value.

In our study, lower teeth were better predicted than upper ones and the upper lateral incisor was the worst predicted tooth because of its size variability.[29–31] Differences of four mm for every arch were considered good predictions.

In the upper arch, differences of four mm (considered good) were found in 83% of our patients, whereas in the lower arch, this percentage was even greater (96%). On the other hand, most of the patients with total differences of more than four mm had Bolton index alterations[32,33] including the reference teeth. Further studies with larger and representative samples are required to confirm these findings.

CONCLUSIONS

- The Digital Method uses an easily programmable interpolation algorithm and has proved to be accurate, fast, and sensitive in predicting lower and upper tooth sizes.
- The upper central incisor and lower first molar combination was the best predictor and obtained many good predictions and fewer acceptable or poor ones.
- Upper arch teeth were better predicted than lower arch teeth.
- The lateral upper incisor was the worst predicted tooth.

REFERENCES

1. Gardner RB. A comparison of four methods of predicting arch-length. *Am J Orthod.* 1979;75:387–399.
2. Irwin RD, Herold JS, Richardson A. Mixed dentition analysis: a review of methods and their accuracy. *Int J Pediatr Dent.* 1995;5:137–142.
3. Nance HN. The limitation of orthodontic treatment I. Mixed dentition diagnosis and treatment. *Am J Orthod Oral Surg.* 1947;33:177–233.
4. Moorrees CFA, Reed RB. Biometrics of crowding and spacing of the teeth in the mandible. *Am J Phys Anthropol.* 1954; 12:77–88.
5. Moorrees CFA, Reed RB. Correlations among crown diameters of human teeth. *Arch Oral Biol.* 1964;9:685–697.
6. Hixon EH, Oldfather RE. Estimation of the sizes of unerupted cuspid and bicuspid teeth. *Angle Orthod.* 1958;28:236–240.
7. Moyers RE. *Handbook of Orthodontics,* 3rd ed. Chicago, Ill: Mosby Year Book; 1973;230–240.
8. Tanaka MM, Johnston LE. The prediction of the size of unerupted canines and premolars in a contemporary orthodontic population. *J Am Dent Assoc.* 1974;88:798–801.
9. Bishara SE, Staley RN. Mixed dentition mandibular arch analysis. *Am J Orthod.* 1984;86:130–135.
10. Staley RN, Kerber RE. A review of the Hixon and Oldfather mixed dentition prediction method. *Am J Orthod Dentofacial Orthop.* 1980;78:296–302.
11. De Paula S, Almeida de Oliveira MA, Lee PCF. Prediction of mesiodistal diameter of unerupted lower canines and premolars using 45° cephalometric radiography. *Am J Orthod Dentofacial Orthop.* 1995;107:309–314.
12. Al-Khadra BH. Prediction of the size of unerupted canines and premolars in a Saudi Arab population. *Am J Orthod Dentofacial Orthop.* 1993;104:369–372.
13. Yuen KK, Tang EL, So LL. Mixed dentition analysis for Hong-Kong Chinese. *Angle Orthod.* 1998;68:21–28.
14. Lee-Chan S, Jacobson BN, Chwa KH, Jacobson RS. Mixed dentition analysis for Asian Americans. *Am J Orthod Dentofacial Orthop.* 1998;113:293–299.
15. Diagne F, Diop-Ba K, Ngom PI, Mbow K. Mixed dentition analysis in Senegalese population: elaboration of prediction tables. *Am J Orthod Dentofacial Orthop.* 2003;124:178–183.
16. Jaroontham J, Godfrey K. Mixed dentition space analysis in a Thai population. *Eur J Orthod.* 2000;22:127–134.
17. Bernabe E, Flores-Mir C. Are lower incisors the best predictors for the unerupted canine and premolars sums? An analysis of a Peruvian sample. *Angle Orthod.* 2005;75:198–203.
18. Nourallah AW, Gesch D, Khordaji MN, Splieth C. New regressions equations for predicting the size of unerupted canines and premolars in a contemporary population. *Angle Orthod.* 2002;72:216–221.
19. Hixon EH, Oldfather RE. Estimation of the sizes of unerupted cuspid and bicuspid teeth. *Angle Orthod.* 1958;28:236–240.
20. Tomassetti JJ, Taloumis LJ, Denny JM, Fischer JR. A comparison of 3 computerized Bolton tooth-size analyses with a commonly used method. *Angle Orthod.* 2001;71:351–357.
21. Tran AM, Rugh JD, Chacon JA, Hatch JP. Techno Bytes: reliability and validity of a computer-based Little irregularity index. *Am J Orthod Dentofacial Orthop.* 2003;123:349–351.
22. Redmond WR, Redmond WJ, Redmond MJ. Clinical implications of digital orthodontics. *Am J Orthod Dentofacial Orthop.* 2002;117:240–241.
23. Mok KH, Cooke MS. Space analysis: a comparison of sonic digitization (DigiGraph Workstation) and the digital caliper. *Eur J Orthod.* 1998;20:653–661.
24. Mckeown HF, Robinson DL, Elcock C, Al-Sharood M, Brook AH. Tooth dimensions in hypodontia patients, their unaffected relatives and a control group measured by a new image analysis system. *Eur J Orthod.* 2002;24:131–141.

25. Garino F, Garino GB. Comparison of dental arch measurement between stone and digital casts. *World J Orthod.* 2002;3:250–254.
26. Paredes V. *Desarrollo de un método digital para la medición y predicción de tamaños dentarios; Aplicaciones para determinar alteraciones en el Indice de Bolton* [doctoral thesis]. Spain: University of Valencia; 2003.
27. Sanin C, Savara BS. An analysis of permanent mesiodistal crown size. *Am J Orthod Dentofacial Orthop.* 1971;59:488–500.
28. Legovic M, Novosel A, Legovic A. Regression equations for determining mesiodistal crown diameters of canines and premolars. *Angle Orthod.* 2003;73:314–318.
29. Ballard ML, Wylie WL. Mixed dentition case analysis—estimating size of unerupted permanent teeth. *Am J Orthod Oral Surg.* 1947;33:754–760.
30. Keene HJ. Mesiodistal crowns diameters of permanent teeth in male American Negroes. *Am J Orthod Dentofacial Orthop.* 1979;76:95–99.
31. Lysell L, Myrberg N. Mesiodistal tooth size in the deciduous and permanent dentitions. *Eur J Orthod.* 1982;4:113–122.
32. Bolton WA. Disharmony in tooth size and its relation to the analyses and treatment of malocclusion. *Angle Orthod.* 1958;28:113–130.
33. Bolton WA. The clinical application of a tooth-size analysis. *Am J Orthod.* 1962;48:504–529.