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Prediction of arch perimeter based on arch width as a guide for diagnosis and treatment planning

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Abstract

Background: The choice between extraction and expansion treatment is an endless debate in orthodontics. Ethnic and secular variations showed that there was a change in arch perimeter over the last 50 years. Accordingly, the purpose of this study was to investigate the relation between the arch perimeter and the intercanine and intermolar widths in normal occlusion. Also, to design regression equations for the prediction of the arch perimeter based on arch width, in a sample of the Egyptian population. The images of 340 cast pairs for 11 to 13-year-old patients were traced using TracerNet. Intercanine width, intermolar width and arch perimeter were measured, statistical analysis was performed and regression equations for both arches were formulated.

Results: There was a positive correlation between the lower arch AP, ICW and IMW and between the upper arch AP and ICW. Lower arch perimeter = $0.536 I33 + 71.642$, lower arch perimeter = $0.828 I66 + 58.604$ and upper arch perimeter = $1.988 U33 + 30.492$ were the significant derived equations.

Conclusions: The formulation of regression equations offers a tool for the prediction of arch perimeter or arch width that can act as a guide in diagnosis and treatment planning.

Keywords: Prediction of arch perimeter, Intercanine width, Intermolar width, Expansion, Regression equations

Background

The choice between extraction and expansion treatment is an endless debate in orthodontics that has faced many phases throughout time. The amount of arch perimeter that transverse expansion normally creates was the point of concern for many researchers (Ricketts et al. 1982; Adkins et al. 1990; Germane et al. 1991; Hnat et al. 2000; Motoyoshi et al. 2002; Paulino et al. 2008), owing to its importance in diagnosis and treatment planning.

Adkins et al. (1990) showed that the arch perimeter increased 0.7 mm when transverse expansion was performed, while Ricketts et al. (1982) reported that any 1 mm increase in intercanine width or intermolar width caused an increase in arch length by 1 mm and 0.25 mm;

respectively. Motoyoshi et al. (2002) used 3D simulation of mandibular expansion and showed that every 1 mm increase in intermolar width resulted in 0.37 mm increase in arch perimeter in a Japanese sample. On the other hand, Sanin et al. (1970) derived an equation for the prediction of arch perimeter from intermolar and intercanine widths. Paulino et al. (2008) suggested a regression equation based on the Spanish population that reported a 1.36 mm increase in arch length for every 1 mm increase in intercanine width; considering that arch length was equal to arch perimeter. Al Ansari et al. (2019) proposed another regression equation to predict arch perimeter based on the arch width at the level of the canines, premolars and molars in Iraqi population. Kareem et al. (2020) conducted the same study on the Kurdish population, while Al-Khatieeb et al. (2012) attempted to predict the arch perimeter based on the arch width at the level of each tooth.

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Ethnic variations as well as the reports of Warren and Bishara (2001), which showed that there was a secular variation of arch perimeter over the last 50 years towards a smaller arch perimeter in white North Americans, resulted in the necessity for conducting separate investigations for different contemporary ethnic groups. Accordingly, the purpose of this study was to investigate the relation between the arch perimeter and the intercanine and intermolar widths in normal occlusion. Also, to design regression equations for the prediction of the arch perimeter based on arch width, in a sample of the Egyptian population.

Methods

The sample consisted of 340 pairs of maxillary and mandibular stone casts of subjects with an age range of 13–16 years. They were randomly selected from the dental casts of school children from Al-Fayoum Governorate collected as a part of a project by the National Research Centre. The inclusion criteria were good quality casts with a full set of permanent teeth from first molar to contralateral first molar without any tooth size discrepancies, no large restorations that could change the tooth dimensions, no previous orthodontic treatment and normal occlusion or having 2-3 mm of crowding.

For tracing the casts, TracerNet (Nile Delta Co., version II) was used (El-Wakeel and Hassan 2020). Photographs were taken for all the casts, imported to the software and calibrated in the vertical and horizontal dimension with a

millimeter ruler, and when the magnification of the ruler in the two axes is known, the cast magnification can be determined. Maximum accuracy was achieved when the two scales were perpendicular. The points needed for every measurement were marked by two well-trained operators, and the software automatically determined the measurements in millimeters. The following linear measurements were performed:

Inter canine width (ICW): the linear distance between the cusp tips of canines in both the maxilla and the mandible. The upper ICW was symbolized on the software as U33 and the lower as I33; Fig. 1.

Intermolar width (IMW): the linear distance between the mesiopalatal cusp tips of first permanent molars and mesiobuccal cusp tips in both the maxilla and the mandible; respectively. The upper IMW was symbolized on the software as U66 and the lower as I66; Fig. 1.

Arch perimeter (AP): the best fit smooth curve was drawn from the mesial of the first permanent molar to the contralateral first permanent molar, passing through the cusp tips of molars and canines and the incisal edges of incisors (Fig. 2).

The mean and standard deviation values were calculated for each variable. Pearson correlation coefficient and linear regression analysis were used to determine the correlation between variables. Repeated measure ANOVA was used to test the significance of the created regression model. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 for Windows.

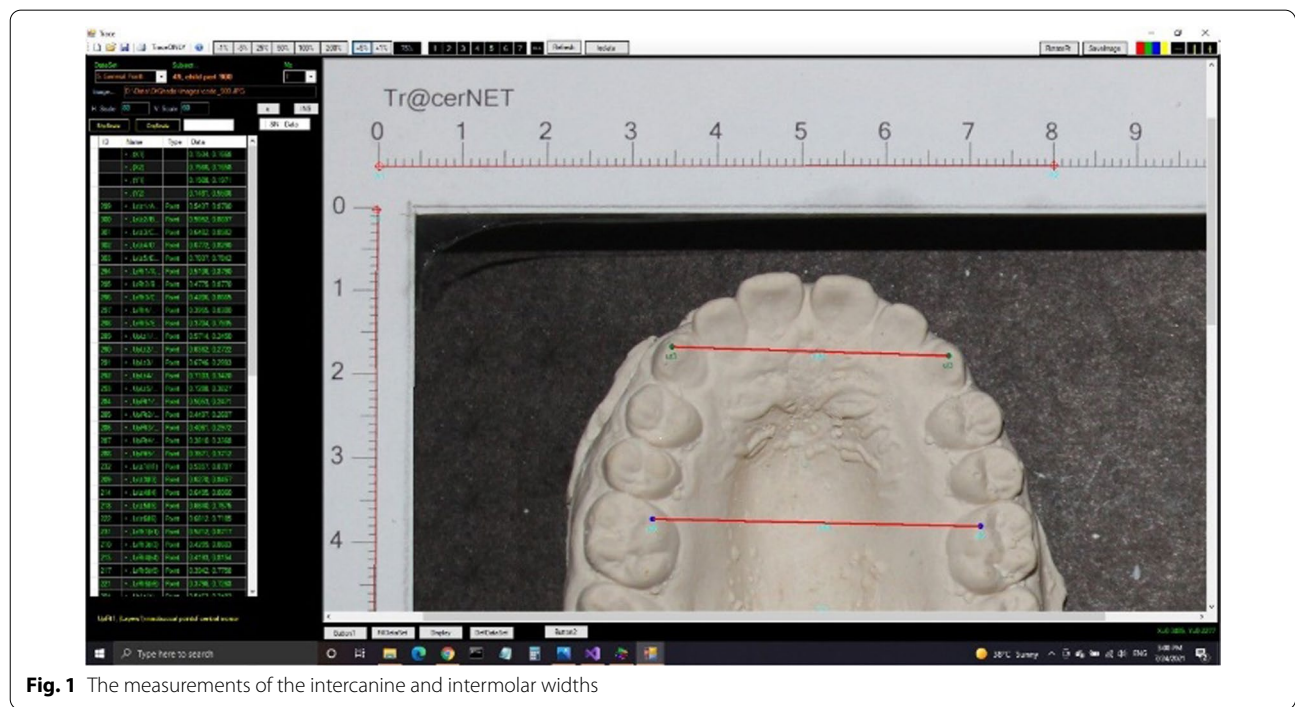


Fig. 1 The measurements of the intercanine and intermolar widths

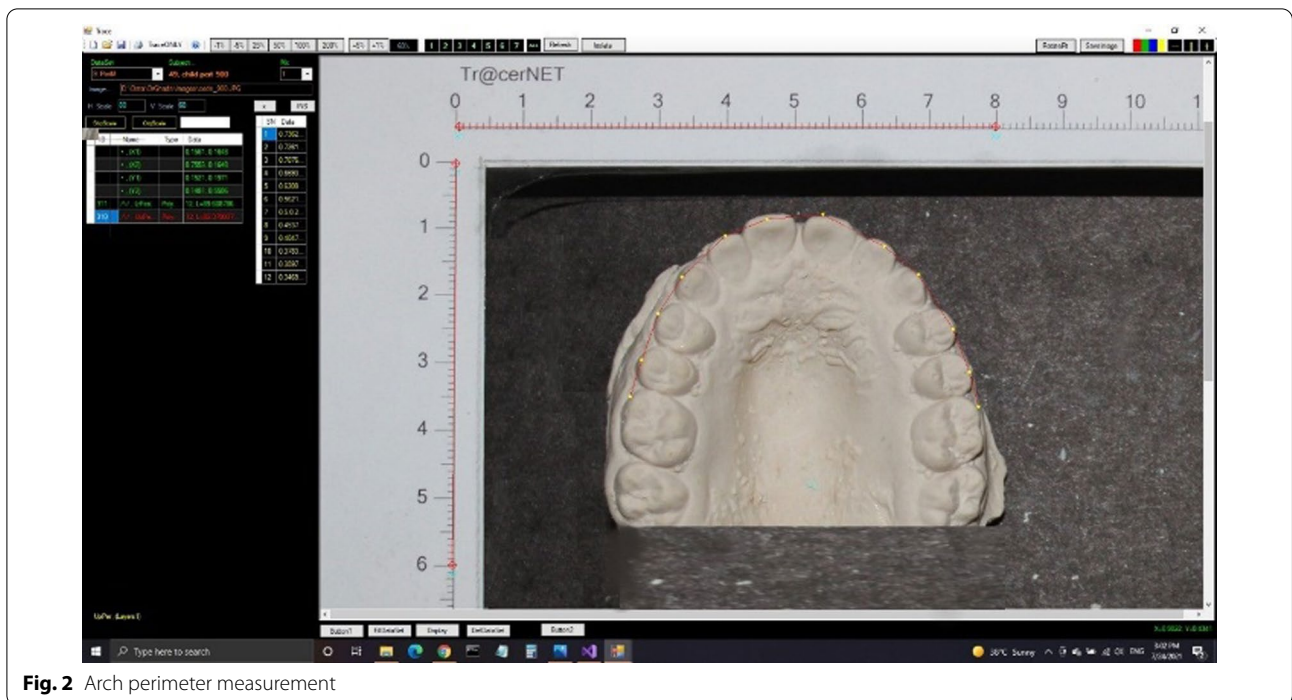


Fig. 2 Arch perimeter measurement

Table 1 Descriptive statistics for the different variables

	Minimum	Maximum	Mean	Std. Deviation
Lower arch perimeter	86.17	99.81	93.56	4.45
Upper arch perimeter	79.04	108.35	100.10	6.30
I33	23.50	31.87	27.95	2.48
I66	37.28	46.44	42.68	2.79
U33	31.08	38.76	35.18	2.22
U66	43.03	52.05	46.95	3.21

The reproducibility of measurements was determined by randomly selecting 20 casts from the sample, and the measurements were repeated by the same operator (intra-examiner error) and two different operators (inter-examiner error). The deviation of measurements for either situation fell within the accepted range of accuracy (3%-5%) as was proven statistically by the calculation of the mean and the standard deviation of the measurements taken.

Results

Means and standard deviations of the measured variables are shown in Table 1. The lower arch perimeter was significantly positively correlated with I33 as well as I66. I33 was also significantly positively correlated with I66 as shown in Table 2. The upper arch perimeter was only

positively correlated with U33 (Fig. 3), while U33 was positively correlated with U66 as shown in Table 2.

The regression analysis for the lower perimeter on I33 shows that the regression equation is: lower arch perimeter = 0.536 I33 + 71.642. This model is border line significant as $p = 0.049$ and $R^2 = 0.199$.

The regression analysis for the lower perimeter on I66 shows that the regression equation is: lower arch perimeter = 0.828 I66 + 58.604. This model is significant as $p = 0.012$ and $R^2 = 0.3$.

The regression analysis for the upper arch perimeter in relation to U33 shows the regression equation to be: upper arch perimeter = 1.988 U33 + 30.492. This model is significant as $p = 0.01$ and $R^2 = 0.496$.

The regression analysis for the upper arch perimeter on U66 shows the regression equation to be: upper arch perimeter = 0.536 U66 + 75.986. This model is not significant as $p = 0.07$ and $R^2 = 0.171$.

Table 2 Correlations between upper arch variable and between lower arch variables

Lower arch perimeter		I33	I66
133	r	.446*	.548*
	p	0.049	0.012
	r		.626**
	p		0.004
Upper arch perimeter		U33	U66
U33	r	.704**	.414
	p	0.001	0.07
	r		.682**
	p		0.002

r Pearson correlation

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

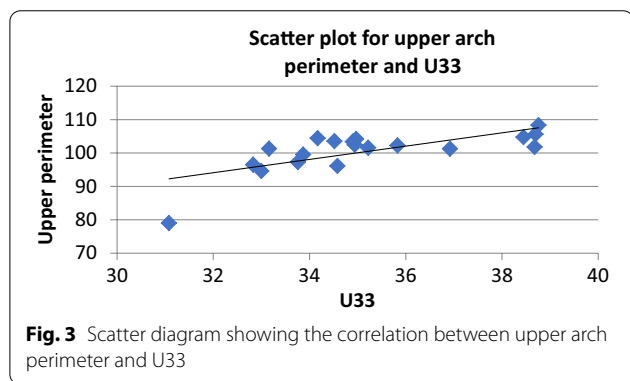
Discussion

Digitization of the study models has become the recent trend in orthodontics. Digital systems and software programs are being widely used, and the ease and accuracy of their measurements were the subject of many researches reporting their applicability for orthodontic use (Proffit et al. 2019; Chung and Wolfgramm 2015). In

more variables is considered as an indication that one magnitude might be dependent on the other (Paulino et al. 2008), and as a consequence, knowing the magnitude of one allows the estimation of the other (Kareem et al. 2020).

On analyzing the data, a significant positive correlation was found between the arch perimeter and the arch width at the level of the canines and molars in the mandible, while in the maxilla, it was only positively correlated to the intercanine width. Those findings were in line with the findings of Paulino et al. (2008) who reported that there was a positive correlation between the AP and the ICW in both arches; however, it was weaker for the IMW. Similarly, Sanine et al. (1970) reported that the dental arch perimeter was closely related to the arch width and devised a regression equation for it. On the other hand, Tibana et al. (2004) reported a weak correlation between the AP and the ICW in the same arch, while Adkins et al. (1990) reported that the best correlation was between the AP and the interpremolar width. These contrasting reports could be attributed to the differences in the investigated ethnic groups and the design of the study, such as the measurement method. In addition, Adkins et al. (1990) investigated patients following rapid palatal expansion treatment.

Furthermore, the occurrence of such positive correlations between the investigated variables allowed for the formulation of prediction regression equations. Unlike other research (Paulino et al. 2008; Sanine et al. 1970; Al-Ansari et al. 2019; Kareem et al. 2020; Chung and Wolfgramm 2015; Aghera et al. 2016), separate equations were derived for each arch and within each arch; for correlating AP to ICW or IMW. This might account for the differences between the values reported by other research and the derived values, also taking into consideration



the current research, a previously investigated tracing software was used with a reported measurement accuracy of 99.603%. The software has the privilege of being able to make calibrated measurements on imported pictures from photographs rather than using expensive laser scanners (El-Wakeel and Hassan 2020).

The knowledge of the correlations between the different dental arch measurements in different ethnic groups is an absolute necessity for proper diagnosis and treatment planning (Warren and Bishara 2001; Defraia et al. 2006), especially during the extraction/expansion decision (Adkins et al. 1990; Germane et al. 1991). Normally, the presence of a positive correlation between two or

that some research evaluated either treated or a mixture of treated and untreated subjects (Adkins et al. 1990; Paulino et al. 2008; Sanine et al. 1970). In the maxillary arch, it was found that for approximately every 2 mm increase in ICW, there is a 1 mm increase in the arch perimeter. On the other hand, in the mandibular arch, it was noted that approximately every 0.8 mm increase in IMW is opposed by a 1 mm increase in AP, and every 0.5 mm increase in ICW causes a 1 mm increase in AP.

Within the limitations of this study, it could be assumed that using these equations could provide a predictor tool for the amount of arch perimeter that expansion creates, or looking from the other way round; the amount of intercanine or intermolar width increase needed in each case. This is while all other diagnostic factors being considered.

Conclusions

Positive correlations were observed between the arch perimeter and the intercanine width in both arch and between the arch perimeter and the intermolar width in the lower arch which allowed the formulation of useful regression equations. These equations offer a tool for prediction of arch perimeter or arch width that can act as a guide in diagnosis and treatment planning.

There is a 1 mm increase in arch perimeter for every increase in intercanine width of approximately 2 mm in the maxilla and 0.5 mm in the mandible. For every 1 mm increase in arch perimeter, there is an increase in the intermolar width of 0.8 mm in the mandible.

Abbreviations

ICW: Intercanine width; U33: Upper intercanine width in the software; I33: Lower intercanine width in the software; IMW: Intermolar width; U66: Upper intermolar width in the software; I66: Lower intermolar width in the software; AP: Arch perimeter.

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Authors' contributions

EOA: Shared in developing the research idea, shared in the practical work of the research, wrote the manuscript. GAS: Shared in developing the research idea and the practical work of the research. MAE: Shared in developing the research idea, Supervision. All authors read, edited and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Written informed consents were signed by the parents/guardians of the participants. The study was approved by the Medical Research Ethical Committee of the National Research Centre, reference number: (16-343).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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