A new calibration procedure for expectation of arch length

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ABSTRACT

Background: The aim of the current study was to determine the relationship between arch length and different arch widths, and the possibility of using different arch widths as predictors for expectation of arch length in upper and lower dental arches and in both genders. The current study is a first attempt to select the patients on the basis of gender in regard to different dental arch widths and length.

Subjects and method: The sampling procedure comprised 120 pairs of upper and lower dental casts of untreated Iraqi adult subjects (60 male and 60 females) aged 17-27 years old. The dental study casts of both upper and lower dental arches were scanned and digitized by special procedure, six inter-arch widths and the arch length were traced on images of upper and lower dental arches by the digitization procedure.

Results: Student’s t-test showed no marked gender differences for all measurements in both upper and lower dental arches, regarding the inter-relation between upper and lower dental arches, there were significant correlation coefficients at 0.01 level for the different arch widths and length, the predictability of the relationship between the arch length and the inter-central incisor width in the upper arch was found to be very strong, while in the lower arch the predictability of the relationship between the arch length and the inter-central incisor width was also found to be very strong, but it was just found to be strong between the lower arch length and the lower inter-first premolar width.

Conclusions: The manner of strong correlation between different arch widths and length may be due to that the dental arch variables are acting together as a single biological unit, rather than a collection of discrete entities. From the stepwise multiple linear regression analysis, it can be concluded that the upper inter-central incisor width plays an important role in the prediction of the upper dental arch length, while in the lower arch, the lower inter-central incisor and inter-first premolar widths play the same important role in the prediction of the lower dental arch length.

Keywords: Calibration procedure, Expectation, Different arch widths and length.

INTRODUCTION

The attainability of an ideal arch length, anterior arch width, posterior arch width and other dental arch dimensions is influenced by many factors including the relationship between the total mesiodistal width of maxillary and mandibular teeth. During the comprehensive orthodontic treatment, the inter-canine width can be increased, but many authors stated that any change to the lower inter-canine width was unstable; therefore, the original width has to be maintained to increase the long term stability.

The goal of every comprehensive orthodontic treatment planning is to obtain optimal occlusion, overjet, overbite, esthetic and function.
The scanning procedure was done in a dark room during which the dental casts were surrounded with a millimetric ruler, hence when the magnification of the millimetric ruler is known; the dental casts magnification in the image produced can be determined. The images from the scanning process were then imported into AutoCAD software program 2011 on a laptop computer (HP); Pavilion – DV6 – 2170ee, core I 7, 1.6 GHz (8CPUs), 6 GB RAM, and 1 GB video card with DirectX 11 version, where the digitization and calibration of the dental casts was performed with the aid of the mouse as a user interface for the digital method, so the AutoCAD software can determine the magnification in the scanned image from the millimetric ruler and specify the scale factor so that all the measurements will be in millimeters and without any magnification.

**Materials and Methods**

The sampling procedure comprised 120 pairs of upper and lower dental casts of untreated Iraqi adult subjects (60 male and 60 females) aged 17 - 27 years old attending the Orthodontic Department at the College of Dentistry, University of Baghdad, and private clinics in Baghdad city. The dental casts were selected from 385 subjects according to the following inclusion criteria:

1. All the subjects were classified as Angle's class I with minor crowding (less than 3 mm) (24).
2. All had permanent dentition from first molar to first molar without gingival overlapping on the surface of any tooth (no gingival enlargement).
3. The teeth had no evident loss of mesio-distal crown width due to dental caries, crown fracture, pathological wear, or congenital defects.
4. No previous history of orthopedic, orthodontic, or orthognathic surgery.
5. No cross bite or open bite relationships.

**Digitization:**

**Scanning the study models (Figure 1):**

The dental study casts of both upper and lower dental arches were placed approximately in the middle of the scanning surface (flat-bed) of a Hewlett Packard (HP) Scan Deskjet (F 2410) and scanned with the following scanner specifications:

- Scanner type Flat-bed (215 x 297 mm).
- Scan resolution (optical) up to 1200 dots per square inch.

**Figure 1: Scanning of study models.**

**Figure 2: landmarks were traced and verified in the images of upper and lower study models using the AutoCAD computer program 2011.**
Figure 3: Linear measurements for both arches

Landmarks identification (Figures 1 and 2):
The following landmarks were traced and verified in the images of upper and lower study models using the AutoCAD computer program 2011:

1. Mid-incisal points (R1, L1, R2 and L2): The midpoint of the incisal edges of the right and left central, and lateral incisors respectively, in the upper and lower dental arches (25, 26).

2. Canine points (R3 and L3): The cusp tips of the right and left permanent canines in the upper and lower dental arches (14, 25, 26).

3. First premolar cusp tips (R4 and L4): The buccal cusp tips of the right and left first premolars in the upper and lower dental arches (26, 27).

4. Second premolar cusp tips (R5 and L5): The buccal cusp tips of the right and left second premolars in the upper and lower dental arches (26, 27).

5. Mesiobuccal cusp tips of first permanent molar (R6 and L6): The mesiobuccal cusp tips of the right and left first permanent molars in the upper and lower dental arches (14, 26, 27).

Linear measurements (figures 2 and 3):
The following linear dental arch measurements were performed:

1. Inter-central width (R1L1): The linear distance between the midincisal points of the right and left central incisors in the upper and lower dental arches (26).

2. Inter-lateral width (R2L2): The linear distance between the midincisal points of the right and left lateral incisors in the upper and lower dental arches (26).

3. Inter-canine width (R3L3): The linear distance between the cusp tip points of the right and left permanent canines in the upper and lower dental arches (14, 26).

4. Inter-first premolar width (R4L4): The linear distance between the buccal cusp tip points of the right and left first premolars in the upper and lower dental arches (26, 27).

5. Inter-second premolar width (R5L5): The linear distance between the buccal cusp tip points of the right and left second premolars in the upper and lower dental arches (26).

6. Inter-molar width (R6L6): The linear distance between the mesiobuccal cusp tip points of the right and left first permanent molars in the upper and lower dental arches (14, 26, 27).

7. Arch length (AL): Ideal line between every mesial and distal contact point of each permanent tooth from the mesial of the first molar to the mesial of the first molar of the opposite side in the upper and lower dental arches (14, 26).

Statistical method
The data obtained from digitization measuring procedure were subjected to computerized statistical analysis by using Statistical Package for Social Science (SPSS Inc.; version 17.0) to get descriptive analysis (minimum, maximum, mean and standard deviation) and to compare measurements between the males and females using independent sample t-test. Pearson's correlation coefficient was used to show the correlation between the arch length and the different arch widths. Furthermore, the multiple linear regression model was applied on the variables to investigate if there was a valid regression equation among these variables. The multiple linear regression equation based on the following formula:

\[ \hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \ldots \]

\( \hat{Y} \): The value of dependent variable which is the arch length
\( \beta_0 \): The regression constant.
\( \beta_1, \beta_2 - \beta_6 \): The regression coefficients of each variable respectively.
\( X_1, X_2 - X_6 \): The values of independent variables (predictors) which are the different arch widths (inter-central, inter-lateral, inter-canine, inter-first premolar, inter-second premolar and inter-molar widths respectively).

Method errors: Ten pairs of dental casts (maxillary and mandibular) from the current study were randomly selected, the reproducibility of the digitization measurements was analyzed by intra- and inter-examiner calibrations, the coefficient of variation was used to determine the method errors (coefficient of variance = standard deviation x 100 /mean) (14, 28, 29). All coefficients of variation were very low (below 6.8 per cent) which were
1.01 to 6.11, and 1.3 to 6.7 for intra-examiner and inter-examiner calibrations respectively.

**RESULTS AND DISCUSSION**

The dental study casts have always been used as an important basic tool in orthodontic diagnosis and treatment planning, telling us about the patient’s occlusion in three planes of space, traditionally the casts have been held in the form of physical plaster models, which are subjected to loss, fracture and degradation. Digital storage eliminates inherent problems related to physical storage of models with up to 17 m³ of storage space required for storage of traditional models for one thousand patients. The current research replaces the plaster models with virtual information, which has further potential merits including:

1. Virtual images may be transferred anywhere in the world for instant referral or consultation.
2. Instant accessibility of the information without the need for retrieval of plaster models from a storage area.
3. The ability to perform accurate and simple diagnostic setup.

There is no data related to expectation of dental arch length based on different dental arch widths. The descriptive statistics and gender difference for all the linear measurements (different arch widths and arch length) of upper and lower dental arches were shown in table 1. It is obvious that the mean values of all measurements confirmed the accepted view that the maxillary dental arch is larger in measurements than that in the mandibular counterpart. This is in consistence with the principle that the maxillary dental arch overlaps the mandibular dental arch.

There were no significant gender differences for all the measurements in both the upper and lower dental arches using Student’s t-test, therefore Pearson’s correlation coefficient was conducted on both dental arches not assuming the gender as principle guideline for correlation between the variables. The Pearson correlation coefficients were found significant at the 0.01 level (2-tailed) between the dental arch length and the different arch widths (inter-central incisor, inter-lateral incisor, inter-canine, inter-first premolar, inter-second premolar and inter-molar widths) measured by the digitization process.

In the upper dental arch, the correlation coefficient (r) values obtained ranged from 0.423 to 0.810 and the p-values equal to 0.000, as shown in table 2, while in the lower dental arch, the correlation coefficient (r) values ranged from 0.370 to 0.731 and the p-values equal to 0.000, as shown in table 3. Regarding the inter-relation between upper and lower dental arches, there were significant correlation coefficients at 0.01 level (2-tailed) for the different arch widths and length, the r values ranged between 0.246 to 0.696, and the p-values equal to 0.000 except for the upper inter-lateral incisor width and the lower inter-molar width, the upper inter-second premolar width and lower inter-first premolar width, and the upper inter-second premolar width and lower inter-molar width, there were significant correlation coefficients at 0.05 level (2-tailed), the r values were 0.193, 0.213 and 0.229, and the p-values equal to 0.035, 0.019, and 0.012 respectively as shown in table 4.

This manner of strong correlation between different arch widths and length within the same dental arch and between the upper and lower dental arches may be due to their cross interaction between each other, so the dental arch variables are acting together as a single biological unit rather than a collection of discrete entities, thus indicating that changes in one magnitude may be directly related to the other.

The stepwise multiple linear regression analysis of the inter-central incisor, inter-lateral incisor, inter-canine, inter-first premolar, inter-second premolar and inter-molar widths (the independent variables) which were used to predict the dental arch length (the dependent variable) represented by the following equation:

$$\hat{Y} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \ldots$$

$\hat{Y}$: The value of dependent variable which is the arch length
$a$: The regression constant.
B₁, B₂ - B₆ : The regression coefficients of each variable respectively.
X₁, X₂ - X₆ : The values of independent variables (predictors) which are the different arch widths (inter-central, inter-lateral, inter-canine, inter-first premolar, inter-second premolar and inter-molar widths respectively).

Upper dental arch equation: (Equation 1)
$$\hat{Y} = \beta_0 + B_1(R1L1) + B_2(R2L2) + B_3(R3L3) + B_4(R4L4) + B_5(R5L5) + B_6(R6L6) + \ldots$$

Lower dental arch equation: (Equation 2)
$$\hat{Y} = \beta_0 + 2.59(R1L1) + 0.18(R2L2) + 0.03(R3L3) + 0.10(R4L4) + 0.003(R5L5) + 0.10(R6L6) + \ldots$$

The multiple correlation coefficients R-square were equal to 0.427, and p-value was equal to 0.000, explained a highly significant correlation between the different arch widths (independent variables) and the arch length (dependent variable). The predictability of the relationship between the arch length and the inter-central incisor width in the upper arch was found to be very strong (T= 4.385, and p = 0.000), as shown above in equation 1.

The lower dental arch equation: (Equation 2)
$$\hat{Y} = \beta_0 + 4.19(R1L1) + 0.21(R2L2) + 0.05(R3L3) + 0.47(R4L4) + 0.23(R5L5) + 0.10(R6L6) + \ldots$$

The multiple correlation coefficients R-square was equal to 0.573 and p-value was equal to 0.000, explained a highly significant correlation between the different arch widths and the arch length. The predictability of the relationship between the arch length and the inter-central incisor width in the lower arch was found to be very strong (T=3.911, and p=0.000), while it was found to be strong (T= 2.259, and p= 0.026) between the arch length and the inter-first premolar width in the lower arch, as shown above in equation 2.

From the stepwise multiple linear regression analysis, it can be concluded that the upper inter-central incisor width plays an important role in the prediction of the upper dental arch length because the t-value equals to 4.385 and p-value equals to 0.000, while in the lower arch, the lower inter-central incisor and inter-first premolar widths play the same important role in the prediction of the lower dental arch length because the t-values equal to 3.911 and 2.259, and p-values equal to 0.000 and 0.026 respectively.

The current findings cannot be compared with other researches (14, 37, 38), since those authors used a completely different methodology for evaluation, and it was applied on non-orthodontic treatment patients and not for patients who had undergone an orthodontic treatment.

It is known that the establishment of regression equations is strongly dependent on a considerable large sample size of population, while the current study has been done with a relatively not very large number of subjects due to the inclusion criteria. Because of this, the employment of regression analysis with future studies will be very helpful to the scientific community by too much increasing the sample size, testing statistical tests dealing with uncertainties, and finally responding to questions poorly clarified in the current study, furthermore; it would be of interest to test the current regression equation for prediction of arch length using a group of young persons to further examine its validity.

Clinical importance
The present findings must be considered in the space analysis, general and individual characters of malocclusion treatment, and proper treatment planning in designing of the dental arch expansion, furthermore, the knowledge of dental arch length and different arch widths is mandatory to have a stable orthodontic end result.

REFERENCES
Table 1: Descriptive and comparative statistics for both genders in the upper and lower dental arches.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total (N=120)</th>
<th>Males (N=60)</th>
<th>Females (N=60)</th>
<th>Gender difference (D.F.=118)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min. (mm)</td>
<td>Max. (mm)</td>
<td>Mean (mm)</td>
<td>S.D. (mm)</td>
</tr>
<tr>
<td>R1L1</td>
<td>8</td>
<td>10.8</td>
<td>9.9</td>
<td>0.55</td>
</tr>
<tr>
<td>R2L2</td>
<td>17.5</td>
<td>27</td>
<td>21.9</td>
<td>0.97</td>
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<tr>
<td>R3L1</td>
<td>28.8</td>
<td>39</td>
<td>33.4</td>
<td>2.2</td>
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<td>R4L1</td>
<td>35</td>
<td>47.5</td>
<td>40.8</td>
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<td>R5L1</td>
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<td>R6L1</td>
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<td>79</td>
<td>70.5</td>
<td>2.94</td>
</tr>
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<td>AL</td>
<td>4.5</td>
<td>6.5</td>
<td>5.32</td>
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</table>

R1L1: Inter-central width, R2L2: Inter-lateral width, R3L3: Inter-canine width, R4L4: Inter-first premolar width, R5L5: Inter-second premolar width, R6L6: Inter-molar width, and AL: Arch length. NS: Non-significant (P>0.05).

Table 2: Correlation between the variables for total gender in the upper arch

<table>
<thead>
<tr>
<th>Variables</th>
<th>Upper Dental Arch</th>
<th>Lower Dental Arch</th>
</tr>
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<tbody>
<tr>
<td>R1L1</td>
<td>r=0.637**</td>
<td>r=0.303**</td>
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<td></td>
<td>P=0.000</td>
<td>P=0.030</td>
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<tr>
<td>R2L2</td>
<td>r=0.488**</td>
<td>r=0.454**</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.000</td>
</tr>
<tr>
<td>R3L3</td>
<td>r=0.423**</td>
<td>r=0.472**</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.000</td>
</tr>
<tr>
<td>R4L4</td>
<td>r=0.475**</td>
<td>r=0.472**</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.000</td>
</tr>
<tr>
<td>R5L5</td>
<td>r=0.432**</td>
<td>r=0.487**</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.000</td>
</tr>
<tr>
<td>R6L6</td>
<td>r=0.452**</td>
<td>r=0.302**</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.000</td>
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</tbody>
</table>

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

Table 3: Correlation between the variables for total gender in the lower arch

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<tr>
<th>Variables</th>
<th>Lower Dental Arch</th>
<th>R1L1</th>
<th>R2L2</th>
<th>R3L3</th>
<th>R4L4</th>
<th>R5L5</th>
<th>R6L6</th>
<th>AL</th>
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<tr>
<td></td>
<td>P=0.000</td>
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</tr>
<tr>
<td>R2L2</td>
<td>r=0.375**</td>
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<td></td>
</tr>
<tr>
<td>R3L3</td>
<td>r=0.518**</td>
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<td></td>
</tr>
<tr>
<td>R4L4</td>
<td>r=0.453**</td>
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<tr>
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<td>P=0.000</td>
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</tr>
<tr>
<td>R5L5</td>
<td>r=0.402**</td>
<td></td>
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<tr>
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<tr>
<td>R6L6</td>
<td>r=0.569**</td>
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</table>

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

Table 4: Correlation between variables of the upper and lower dental arches for total gender.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Upper Dental Arch</th>
<th>Lower Dental Arch</th>
</tr>
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<tbody>
<tr>
<td>R1L1</td>
<td>r=0.629**</td>
<td>r=0.508**</td>
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<td>P=0.000</td>
<td>P=0.000</td>
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<tr>
<td>R2L2</td>
<td>r=0.569**</td>
<td>r=0.504**</td>
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<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.000</td>
</tr>
<tr>
<td>R3L3</td>
<td>r=0.492**</td>
<td>r=0.413**</td>
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<tr>
<td>R4L4</td>
<td>r=0.556**</td>
<td>r=0.399**</td>
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<td>P=0.000</td>
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<tr>
<td>R5L5</td>
<td>r=0.478**</td>
<td>r=0.396**</td>
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<tr>
<td>R6L6</td>
<td>r=0.533**</td>
<td>r=0.462**</td>
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<tr>
<td>AL</td>
<td>r=0.696**</td>
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<td></td>
<td>P=0.000</td>
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</tbody>
</table>

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

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