INTRODUCTION

Interarch tooth size ratio is a valid diagnostic tool that limits the need for diagnostic setups to predict treatment outcomes in complex orthodontic cases. In the finishing stages of orthodontic therapy one usually encounters difficulties in settling the teeth in Class I occlusion with proper overbite and overjet. Such difficulties could easily be managed if one knows the discrepancies in the interarch tooth sizes right at the start of the treatment.

Treatment planning should always take into consideration a discrepancy of the tooth size ratios and should include compensating esthetic procedures such as composite bonding, prosthetic reconstruction, stripping and crown recontouring.1

Similarly, ignoring the tooth sizes can compromise the final results in extraction cases if the chosen extraction pattern leads to a clinically significant mandibulo-maxillary tooth size discrepancy.

Pioneer work on tooth sizes was conducted by Black2 in 1902 and Neff3 in 1949. Later it was Bolton4,5 who provided the widely accepted normative data on the mandibular to maxillary tooth size ratios and it was then named after him as Bolton ratio;

\[
\text{Overall Ratio}(X) = \frac{\text{Sum of mesiodistal width of Mandibular 12 teeth (6-6)}}{\text{Sum of mesiodistal width of Maxillary 12 teeth (6-6)}} \times 100
\]

\[
\text{Anterior Ratio}(Y) = \frac{\text{Sum of mesiodistal width of Mandibular 6 teeth (3-3)}}{\text{Sum of mesiodistal width of Maxillary 6 teeth (3-3)}} \times 100
\]

Bolton selected 55 cases with normal occlusions for his study and calculated the mandibular to maxillary tooth size ratios. In measurement from right first molar to left first molar it came out to be 91.3 with the standard deviation of 1.91. From right canine to left canine the ratio came out to be 77.2 with a standard deviation of 1.91.
Mesiodistal crown dimensions and Bolton ratio in the Khan Research Laboratories

deviation of 1.65. This ratio of interarch tooth mass is known as Bolton ratio. Studies to set norms for Bolton ratio have been carried out on various ethnic groups.1,6,7

Similarly, normative data for tooth sizes amongst different population groups is also available.1,6,8 As far as the factors responsible for the determination of the tooth size dimensions, several studies have been carried out. Discrepancies outside 2 standard deviation are quite significant as it has been found that these have caused failure to achieve optimal occlusion. Any discrepancy outside 2 standard deviation amounts to 2 to 3mm discrepancy between the mandibular and maxillary dentition which is clinically relevant.1

Genetic influences are considered important and the first reports were related to clinical observations within families. Studies on twins however helped in understanding the genetic contribution of tooth size in that a greater tooth size correlation was found in monozygotic twins.11,12 Other studies described the determination of tooth size as multifactorial, with the environment playing an important role. Teratogenic and nutritional factors have been associated with the mechanism of tooth formation. Space limitations and nutrition have been described as important in the development of a healthy tooth germ and have been related to alterations in number, shape and size of permanent teeth.13 Although it is widely accepted that both genetic and environmental factors affect tooth development it is virtually impossible to identify and describe the role each of these variables play in the determination of tooth size.14

Much work has been done internationally, however no study has been carried out in our population to set the norms for mesiodistal crown dimensions and interarch tooth size ratio. A study on these lines would greatly improve the quality of orthodontic finishing in our population and lead to a more sound understanding of one of the most complex variables affecting orthodontic malocclusion. The purpose of this study is to set a baseline data to encourage the researchers of this region to carry out more research on this subject in the Pakistani population.

METHODOLOGY

This study was carried out at the Dental OPD of KRL Hospital, Islamabad. It took 12 months to complete the study. Six months were spent in the collection and compilation of data. First a mixed sample of 500 patients consisting of both male and female individuals belonging to different ethnic groups of Pakistani population having class I occlusion was selected through a non-probability (convenient) sampling technique. Out of this sample 120 patients (figure 1) were selected using Probability (simple random) sampling procedure. Inclusion criteria for this study were patients with normal (Class I) occlusion and permanent teeth. Patients with mesiodistal tooth loss due to caries, trauma etc, mesiodistal excess of tooth material due to restoration, prosthetic replacement, dental anomalies were excluded.

A Boley gauge (3M Unitek) with vernier scale and precision reading to the nearest 0.1 mm was used to measure the mesiodistal crown dimensions of the teeth by placing the pointed ends on the contact points of each tooth from first molar on the right to the first molar on the left on the dental casts of the selected patients. To avoid random errors in measuring the mesiodistal crown dimensions the measurements were repeated 10 times by the same person after an interval of a week and then the mean of the measurements were recorded.

RESULTS

Figure 2 and Table 1 show that the mean overall interarch ratio of the KRL sample which consisted of 120 cases with optimal occlusion is 91.546 S.D 2.165 which is slightly different while anterior interarch tooth width ratio is 79.028 S.D 2.796 which is markedly different from the mean overall interarch ratio of 91.3 S.D 1.91 and mean anterior interarch ratio of 77.2 S.D 1.65 respectively as evaluated by Bolton.4

Table 2 shows that the comparison of the mean overall ratio of the KRL sample and the Bolton ratio is statistically nonsignificant with the value of p>0.05.

Table 3 shows that the comparison of the mean anterior ratio of this sample and the anterior Bolton ratio is statistically significant with the value of p<0.05.

Figure 3 gives a graphic representation of mesiodistal crown widths of the KRL sample. The narrow range of values for the mesiodistal width of teeth in the KRL sample demonstrates low variability as is evident.
from Table 4. This might be attributed to the high accuracy with which the measurements were taken. Table 4 shows that the greatest mean mesiodistal width is that of lower left first molar (LL6) i.e 11.03mm followed by lower right first molar (LR6) i.e 11.007mm while the smallest mean mesiodistal width is that of lower right central incisor (LR1) i.e 5.674mm followed by lower left central incisor (LL1) i.e 5.678 mm. Table 4 also shows that the maxillary teeth have more variation in their size as compared to mandibular teeth except mandibular molars which show relatively more variations in their mesiodistal dimensions.

LR6 has mean mesiodistal crown dimension of 11.007mm S.D 0.819 followed by LL6 with mean mesiodistal crown dimension of 11.03mm S.D 0.819.

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**TABLE 1: MEAN OVERALL AND ANTERIOR INTERARCH TOOTH WIDTH RATIOS OF THE KRL SAMPLE WITH THEIR S.D AND RANGE**

<table>
<thead>
<tr>
<th></th>
<th>Mean overall ratio</th>
<th>Mean anterior ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Mean</td>
<td>91.546</td>
<td>79.028</td>
</tr>
<tr>
<td>S.D</td>
<td>2.165</td>
<td>2.796</td>
</tr>
<tr>
<td>Range</td>
<td>11.2</td>
<td>16.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>85.5</td>
<td>71.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>96.7</td>
<td>88</td>
</tr>
</tbody>
</table>

**TABLE 2: ONE SAMPLE T-TEST USED TO SHOW SIGNIFICANCE OF THE AVERAGE RESULTS FOR THE OVERALL INTERARCH TOOTH WIDTH RATIO OF THE KRL SAMPLE ON THE BASIS OF STANDARD OVERALL INTERARCH TOOTH WIDTH RATIO RESULT OF BOLTON GIVEN AS THE TEST VALUE**

<table>
<thead>
<tr>
<th>Test</th>
<th>t</th>
<th>Test Value</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-test for the overall interarch tooth width ratio</td>
<td>1.246</td>
<td>91.3</td>
<td>0.215&lt;sup&gt;NS&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*NS = Non significant*
distal crown dimension of 11.038 mm S.D 0.791. If we consider Table 4 the presence of high variability of the anterior interarch tooth width ratio of the KRL sample (mean 79.028 S.D 2.796) is probably attributed to the high variability in the sizes of upper central and lateral incisors. This was also the finding of Santoro and colleagues in their study on Dominican Americans.

** = Highly significant

<table>
<thead>
<tr>
<th>Test</th>
<th>t</th>
<th>Test Value</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-test for the anterior interarch tooth width ratio</td>
<td>7.164</td>
<td>77.2</td>
<td>0.000**</td>
</tr>
</tbody>
</table>

** = Highly significant

TABLE 4: MEAN MESIODISTAL WIDTH OF TEETH OF THE KRL SAMPLE WITH THEIR STANDARD DEVIATION AND RANGE

<table>
<thead>
<tr>
<th>Tooth</th>
<th>UR1</th>
<th>UR2</th>
<th>UR3</th>
<th>UR4</th>
<th>UR5</th>
<th>UR6</th>
<th>UL1</th>
<th>UL2</th>
<th>UL3</th>
<th>UL4</th>
<th>UL5</th>
<th>UL6</th>
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<tbody>
<tr>
<td>n</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
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</tr>
<tr>
<td>S.D</td>
<td>0.696</td>
<td>0.699</td>
<td>0.587</td>
<td>0.593</td>
<td>0.545</td>
<td>0.71</td>
<td>0.728</td>
<td>0.587</td>
<td>0.601</td>
<td>0.539</td>
<td>0.616</td>
<td>0.686</td>
</tr>
<tr>
<td>Range</td>
<td>3.5</td>
<td>4.3</td>
<td>3.2</td>
<td>3.6</td>
<td>2.7</td>
<td>4.4</td>
<td>3.5</td>
<td>3.7</td>
<td>3.3</td>
<td>2.7</td>
<td>2.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Minimum</td>
<td>6.8</td>
<td>5.2</td>
<td>6.6</td>
<td>6.2</td>
<td>6.2</td>
<td>7.9</td>
<td>7</td>
<td>5.8</td>
<td>6.5</td>
<td>6.2</td>
<td>6</td>
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<tr>
<td>Maximum</td>
<td>10.3</td>
<td>9.5</td>
<td>9.8</td>
<td>9.8</td>
<td>8.9</td>
<td>12.3</td>
<td>10.5</td>
<td>9.5</td>
<td>8.9</td>
<td>8.9</td>
<td>12</td>
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</table>

<table>
<thead>
<tr>
<th>LR1</th>
<th>LR2</th>
<th>LR3</th>
<th>LR4</th>
<th>LR5</th>
<th>LR6</th>
<th>LL1</th>
<th>LL2</th>
<th>LL3</th>
<th>LL4</th>
<th>LL5</th>
<th>LL6</th>
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</thead>
<tbody>
<tr>
<td>n</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Mean</td>
<td>5.674</td>
<td>6.145</td>
<td>7.103</td>
<td>7.284</td>
<td>7.397</td>
<td>11.007</td>
<td>5.678</td>
<td>6.194</td>
<td>7.149</td>
<td>7.37</td>
<td>7.397</td>
</tr>
<tr>
<td>S.D</td>
<td>0.491</td>
<td>0.534</td>
<td>0.532</td>
<td>0.533</td>
<td>0.564</td>
<td>0.819</td>
<td>0.532</td>
<td>0.534</td>
<td>0.513</td>
<td>0.571</td>
<td>0.564</td>
</tr>
<tr>
<td>Range</td>
<td>2.3</td>
<td>2.6</td>
<td>2.6</td>
<td>2.2</td>
<td>2.5</td>
<td>3.8</td>
<td>2.4</td>
<td>2.3</td>
<td>2.6</td>
<td>2.7</td>
<td>2.5</td>
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<tr>
<td>Minimum</td>
<td>4.5</td>
<td>4.9</td>
<td>5.9</td>
<td>6.4</td>
<td>6.4</td>
<td>9.4</td>
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<td>4.9</td>
<td>5.9</td>
<td>6.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Maximum</td>
<td>6.8</td>
<td>7.2</td>
<td>8.5</td>
<td>8.6</td>
<td>8.9</td>
<td>13.2</td>
<td>6.8</td>
<td>7.2</td>
<td>8.5</td>
<td>8.9</td>
<td>8.9</td>
</tr>
</tbody>
</table>

UR1=Upper right central incisor, UR2=Upper right lateral incisor, UR3=Upper right canine, UR4=Upper right first premolar, UR5=Upper right second premolar, UR6=Upper right first molar, UL1=Upper left central incisor, UL2=Upper left lateral incisor, UL3=Upper left canine, UL4=Upper left first premolar, UL5=Upper left second premolar, UL6=Upper left first molar, LR1=Lower right central incisor, LR2=Lower right first premolar, LR3=Lower right second premolar, LR4=Lower right first molar, LL1=Lower left central incisor, LL2=Lower left lateral incisor, LL3=Lower left canine, LL4=Lower left first premolar, LL5=Lower left second premolar, LL6=Lower left first molar
The least variation in size is that of LR1 with mean mesiodistal crown dimension of 5.674mm and S.D of 0.491 followed by LL3 with mean mesiodistal crown dimension of 7.149mm and S.D of 0.513. The highest variability in size is that of lower first molars as is evident from Table 4.

Table 5 depicts the difference of the mean mesiodistal crown dimensions of the KRL sample and the American Caucasian population.

DISCUSSION

Originally Bolton suggested that a ratio greater or lesser than 1 S.D from his reported mean values of 91.3 S.D 1.91 and 77.4 S.D 1.65 for the overall and anterior ratio respectively, indicated a need for diagnostic consideration. Santoro, Ayoub et al found mean overall tooth size ratio of 91.3 S.D 2.22 in their sample on Dominican individuals, equivalent to the Bolton overall ratio of 91.3 S.D 1.91. Since overall ratio of KRL sample 91.548 S.D 2.165 (table 1) is within one S.D of Bolton sample this implies that the Bolton overall ratio can be applied to the KRL as well as to the Dominican population. In 1996, Freeman and colleagues studied the frequency of tooth size discrepancies in a sample of 157 orthodontic patients and found that 13.4% of them had an overall Bolton ratio outside 2 standard deviations from the Bolton mean, and 30.6% of the sample presented an anterior Bolton ratio outside 2 standard deviation from the mean.

In 2004, Tong et al carried out a study on the effect of premolar extractions on interarch tooth size ratios and found that the overall ratios decreased in specific premolar extraction patterns. High overall ratios changed to normal overall ratios with extraction of all four second premolars or upper second and lower first premolars.

The mean anterior interarch ratio of the KRL sample is 79.028 S.D 2.796 (table 1). This value is significantly different from the mean anterior interarch tooth width ratio as evaluated by Bolton which was 77.2 S.D 1.65. This finding is coincident with the results of Heusden, Dermaut and Verbeeck, who found in their study that the mean overall interarch ratios calculated from four studies carried out on different populations were almost same as calculated by Bolton in his sample while the mean anterior interarch ratios were significantly different from the mean anterior ratio calculated by Bolton in his sample. It is a fact that there is a large variation in the size of the maxillary front teeth. This phenomenon may account for significant difference between Bolton anterior ratio and the anterior ratio of the KRL sample as well as the sample of Heusden, Dermaut and Verbeeck. However, this variation has less effect mathematically when the overall ratio is calculated.

Ta, Ling and Hagg in their study on Chinese children found an overall mean tooth size ratio for their sample of 90.9 S.D 1.1. This is again in close proximity to the value obtained in this study. While mean anterior interarch tooth width ratio of their sample was 77.5 S.D 1.8 which is significantly different from the anterior mean interarch ratio value for the KRL sample.

As far as the mean anterior ratio of the KRL sample, it closely matches the anterior tooth width ratio evaluated by Smith, Buschang and Watanabe on white population group which was 79.6.

Proffit stated that tooth width discrepancies less than 1.5mm are rarely significant. He suggested that larger discrepancies create problems that should be considered in treatment planning but he did not indicate whether this minimum value was for anterior or overall tooth width analysis or for both. From table 5 it can be concluded that generally the mesiodistal crown widths of the of the KRL sample are larger than the American white population except the upper central incisors where the difference is only 0.06.

In a recent study, Bernabe et al showed that based on Peruvian tooth-size averages, 2 S.D from the Bolton mean for the anterior ratio is probably clinically significant for the low range (-2 S.D) but not for the high range (+2 S.D), whereas 1 S.D from the Bolton mean for the total ratio is probably clinically significant. They asserted that 2 S.D from the Bolton mean for the overall ratio would be a gross tooth width ratio discrepancy.

More recently, a clinically significant tooth width ratio discrepancy has generally been devised as 2 S.D outside Bolton’s published mean ratio.

By using this definition an anterior ratio below 73.9 or above 80.5 and an overall ratio below 87.5 or above 95.1 would be considered clinically significant. In
this study, both the mean anterior ratio (79.028) and the overall ratio (91.546) fall within the 2 S.D of the Bolton’s mean of 91.3 so the occlusion set on these norms would give good occlusion.

CONCLUSIONS

1. Mean overall interarch tooth width ratio of the KRL sample was found to be 91.5.

2. Mean anterior interarch tooth width ratios of the KRL sample was found to be 79.02.

3. The mean of overall and anterior ratios of the KRL sample are within the 2 S.D of the Bolton’s ratio\(^1,10,21,22\), therefore the Bolton’s overall and the anterior ratio can be applied to the KRL sample.

REFERENCES


22. Lundstrom A. The etiology of crowding of the teeth (based on studies of twins and on morphological investigations) and its bearing on orthodontic treatment (expansion or extraction). Eur Orthod Soc Trans 1951;176-91.