Comparison of overjet among 3 arch types in normal occlusion

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Introduction: The purposes of this study were to examine the amounts of overjet in the anterior and posterior segments of 3 arch forms by using facial axis points on 3-dimensional virtual models and to verify the minimum posterior extension required for classification of the arch form in normal occlusions. Methods: Facial axis points were digitized on 97 virtual models with normal occlusion, classified into 20 tapered, 25 ovoid, and 52 square arch forms. Intercanine and intermolar arch widths and depths were measured. The best-fitting curves were created, and overjet was measured at each facial axis point. Two-way analysis of variance (ANOVA) was performed to assess the relationship between arch form and overjet in different areas. The minimum posterior extension to determine arch type was analyzed with the chi-square test. Results: Subjects with a tapered arch form had larger overjet compared with those with ovoid and square forms, except at the central incisor. A significant difference in overjet among different areas was found in subjects with a square arch form (P <0.0001). No significant difference (P = 0.864) was found among the first and second premolar and the first molar groups for classifying arch-form types. Conclusions: A significant difference was found in anterior and posterior overjet according to arch types. The extension to the first premolar was sufficient to classify arch form type. It might be beneficial to consider more coordinated preformed superelastic archwires according to variations in overjet of different arch types. (Am J Orthod Dentofacial Orthop 2011;139:e253-e260)

The preservation of intercanine width is an indispensable part of treatment planning to reduce the risk of postretention relapse.1-4 In addition, improper occlusal relationships of teeth from morphologic variations were reported to cause recurrent crowding in the mandibular anterior region.5,6 Deviation from the normal transverse relationship might lead to root and alveolar bone resorption, tipping of teeth, periodontal damage, and esthetically compromised results.7-10 Consequently, proper arch coordination is a key element to obtain stable and functional treatment results.

Recently, new interactive treatment planning systems such as Suresmile (OraMetrix, Richardson, Tex), Incognito (Lingualcare, 3M Unitek, Dallas, Tex), and Insignia (Ormco, Orange, Calif) have offered better maxillary and mandibular arch coordination by individualizing archwires and brackets, resulting in shorter treatment times and more desired results.11-13

Many authors have analyzed arch-form dimensions and anterior overjet alone using 2-dimensional techniques involving photocopies.14-19 However, these reports used various landmarks that could not represent the correct clinical bracket position. With the recent development of 3-dimensional (3D) virtual technology, most arch-form parameters can now be measured on the 3D virtual models as reliably and accurately as on the plaster models.20,21

Kook et al22 compared overjet measured from the facial axis (FA) points to that measured from the bracket slot points to provide a guideline for arch coordination. Several authors have categorized arch forms into tapered, ovoid, and square shapes to evaluate their relationship.
characteristics. However, they limited their evaluations to the mandibular models only; therefore, they could not analyze overjet. Interestingly, these investigations included only up to the first premolars in their arch-form classification methods, even though no study has yet conclusively determined whether it is necessary to include the second premolars and the first molars when classifying arch-form types. Also, the relationship between overjet and arch-form type has not been sufficiently evaluated in the literature.

Therefore, the purposes of this study were (1) to examine the amount of overjet in the anterior and posterior segments among 3 arch forms by using FA points on 3D virtual models and (2) to verify the minimum posterior extension required for classification of the arch form in a sample with normal occlusion.

MATERIAL AND METHODS

The sample consisted of 97 young Korean adults with normal occlusion (58 men, 39 women). The subjects’ ages ranged from 20 to 25 years, with a mean of 23.3 years. The inclusion criteria were as follows: (1) Angle Class I molar and canine relationships; (2) 0° ≤ ANB ≤ 4°; (3) normal overbite and overjet (≥0 mm, <4 mm); (4) minimum arch-length discrepancy (<3 mm of crowding, <1 mm of spacing); (5) flat or slight curve of Spee (<2 mm); (6) no deviation in the dental midline or buccal crossbite; (6) permanent dentition with normal tooth sizes and shapes, except for the third molars; (7) no previous orthodontic treatment; and (8) no restorations extending to contact areas, cusp tips, incisal edges, or facial surfaces.

The amount of overjet was examined in the 3 arch types. The mandibular and maxillary casts were placed in the maximum intercuspation relationship and scanned with a 3D laser scanner (KOD-300, Orapix, Seoul, Korea) at 20-μm resolution. The FA points were digitized on each tooth of the virtual models by using Rapidform 2006 software (INUS Technology, Seoul, Korea) by 1 investigator (M.B.) with experience in the 3D technology (Fig 1).

Fig 1. The FA points marked on the 3D virtual models: A, right buccal view; B, frontal view.

Table I. Definitions of arch-dimension variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Intercanine width (mm)</td>
<td>Distance between the FA points of the right and left canines</td>
</tr>
<tr>
<td>Intermolar width (mm)</td>
<td>Distance between the FA points of the right and left first molars</td>
</tr>
<tr>
<td>Intercanine depth (mm)</td>
<td>The shortest distance from a line connecting the FA points of the right and left canines to the midpoint between the FA points of the right and left central incisors</td>
</tr>
<tr>
<td>Intermolar depth (mm)</td>
<td>The shortest distance from a line connecting the FA points of the right and left first molars to the midpoint between the FA points of the 2 central incisors</td>
</tr>
<tr>
<td>Canine W/D ratio</td>
<td>Ratio between intercanine width and depth</td>
</tr>
<tr>
<td>Molar W/D ratio</td>
<td>Ratio between intermolar width and depth</td>
</tr>
</tbody>
</table>
the fourth degree \( f(x) = ax^4 + bx^3 + cx^2 + dx + e \) was selected, since it most accurately represented the arch form and produced the smoothest curves with no wave-like properties.\(^{16,27,28}\) Overjet was measured as the shortest distance from each FA point on the mandibular arch to the maxillary one (Fig 3).

The measurements were made by 1 operator (M.B.) to eliminate interoperator variability. Ten cases were randomly selected and reassessed 2 weeks later by the same operator to evaluate intraoperator variability. The intraclass correlation test showed high reliability between the 2 assessments (\( > 0.8 \)).

The best-fitting curve of each mandibular cast was matched to arch-form templates by superimposing clear templates (OrthoForm, 3M Unitek, Monrovia, Calif) at the center of the curvature of the best-fitting curve. The sample was classified into 3 groups of 20 tapered, 25 ovoid, and 52 square arch forms.

Thirty randomly selected best-fitting curves were rematched with the OrthoForm template by the same operator. The difference between the 2 evaluations was analyzed by the Wilcoxon signed rank test and was negligible (\( P > 0.05 \)).

Since there was no significant association between sex and arch form (\( P = 0.153 \)) when assessed by the chi-square test, male and female data were combined. Analysis of variance (ANOVA) was applied to compare the arch dimensions among the 3 arch-form types.

A \( t \) test was performed to evaluate the difference in overjet between the right and left sides; since there were no statistically significant differences, the data from both sides were combined. Two-way ANOVA was performed to assess the effect of arch form and tooth area on overjet. Since the results showed a significant interaction, 1-way ANOVA tests were performed for each variable independently, followed by the Scheffé post hoc test to evaluate the homogeneous subgroups.

The images were shuffled and presented to a panel of 30 orthodontists, who were asked to match the arch forms to the OrthoForm templates using the same matching method as in this study. Thus, each orthodontist matched 18 arch forms, and their matching pattern was evaluated by assigning a score of 1 to the correct match and a score of 0 to the incorrect match. Then the scores were analyzed with chi-square tests to compare the correctness among the 3 groups.
RESULTS

In comparing the correctness of matching the arch forms to the templates, the chi-square test showed no significant differences among the first premolar, second premolar, and first molar groups (P = 0.864). On the other hand, it showed a significant difference among the arch types (P < 0.001). The percentage of correct matches was 90.2% (Table II). The most common mismatch in typing arch forms was failure to differentiate between the square and ovoid types; 33 of 53 incorrect matches were of this type.

Table III shows significant differences among the 3 arch forms for all arch-dimension variables, except for maxillary and mandibular intermolar depths. In the maxilla, the square arch form had a significantly greater intercanine width (P = 0.006) and a smaller intercanine depth (P = 0.024) than the tapered one. It also had a significantly greater intermolar width than both the tapered and ovoid arch forms (P < 0.0001 and P = 0.001, respectively). In the mandible, the tapered arch form had a significantly greater intercanine depth than the ovoid one, which was in turn greater than that of the square arch form. As in the maxilla, the mandibular square arch form had a significantly greater intercanine width than the tapered one, and a significantly greater intermolar width than both the tapered and ovoid arch forms (P < 0.0001 and P = 0.003, respectively).

The analyses of overjet in each arch-form type demonstrated that tapered and ovoid arches had homogeneous anterior and posterior overjets from 2.24 to 2.59 mm and from 1.86 to 2.18 mm, respectively. However, in the square arch form, there was a significant difference in overjet among different areas (P < 0.0001); the incisors showed a significantly greater overjet than did the posterior teeth, and the canines showed a significantly smaller overjet (2.14 mm) than did the central incisors (2.67 mm) (Table IV).

When we compared overjet among the 3 arch forms, ANOVA showed that it was significantly different in all areas except at the lateral incisor. The multiple comparison tests showed that the tapered arch form had a greater overjet than the ovoid one at the canine and posterior areas, and greater than the square one at the canine and premolar areas (Table IV).

DISCUSSION

The proper selection of the arch-form type during treatment has become increasingly emphasized to achieve better posttreatment stability as preformed superelastic wires have gained popularity. A recent study found that the maxillary arch form has become significantly narrower after extraction treatment than before and suggested that tapered archwires might be applied after extraction of premolars in patients with Class I crowding.29 Furthermore, tapered archwires were recommended for patients with narrow arch forms and gingival recession, and square archwires for maintaining the width after rapid maxillary expansion.30

The horizontal distance between the maxillary and mandibular teeth has been calculated and predicted through mathematic and geometric models.14,15,31 This amount of overjet might be connected to labiolingual or buccolingual tooth dimension, torque, and marginal ridge relationships.32,33 However, most studies limited their analyses to the anterior overjet and overlooked the posterior segment and arch type.14,15,31,34

No study has yet attempted to evaluate anterior and posterior overjets by arch-form type to accurately coordinate the maxillary and mandibular arches. Previous reports used incisal edges and cusp tips or indirect clinical bracket points on 2-dimensional photocopies.14-19,23-25
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However, they often lacked accuracy in identification of arch forms and interarch relationships because they failed to take advantage of FA points that are known to show a direct representation of clinical archwire shape. As expected, the tapered and square arch-form types demonstrated many significant differences in arch dimensions. However, with the exception of the mandibular intercanine depth and width-depth ratio, the ovoid arch form was not significantly different from the tapered and square arch forms. For example, its intercanine width was only 0.3 mm smaller than the square arch form. The tapered arch form was reported frequently in Asians, who have a higher proportion of the square arch form. The tapered arch form was shown to be 8.8% in a normal occlusion sample according to Nojima et al. Therefore, it was difficult to acc

### Table III. Comparison of arch-dimension variables among arch-form types

<table>
<thead>
<tr>
<th>Variable</th>
<th>Macilla</th>
<th>Mandible</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tapered</td>
<td>Ovoid</td>
</tr>
<tr>
<td>Intercanine width (mm)</td>
<td>37.21</td>
<td>37.89</td>
</tr>
<tr>
<td>Intermolar width (mm)</td>
<td>56.59</td>
<td>57.49</td>
</tr>
<tr>
<td>Intercanine depth (mm)</td>
<td>9.02</td>
<td>8.45</td>
</tr>
<tr>
<td>Intermolar depth (mm)</td>
<td>30.17</td>
<td>29.28</td>
</tr>
<tr>
<td>Canine W/D ratio</td>
<td>4.15</td>
<td>4.53</td>
</tr>
<tr>
<td>Molar W/D ratio</td>
<td>1.88</td>
<td>1.97</td>
</tr>
</tbody>
</table>

ANOVA with Scheffe multiple comparison.

<sup>*P <0.05; <sup>1</sup> P <0.01; <sup>2</sup> P <0.001. O, Ovoid; S, square; T, tapered.</sup>

### Table IV. Comparison of overjet among tapered, ovoid, and square arch-form types

<table>
<thead>
<tr>
<th>Overjet</th>
<th>Tapered n = 40</th>
<th>Ovoid n = 50</th>
<th>Square n = 106</th>
<th>Total</th>
<th>P value of arch-type comparison</th>
<th>Multiple comparison among arch types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor area</td>
<td>2.49</td>
<td>2.09</td>
<td>2.67&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.001&lt;sup&gt;T&lt;/sup&gt; S &gt; O</td>
</tr>
<tr>
<td>Lateral incisor area</td>
<td>2.56</td>
<td>2.18</td>
<td>2.44&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.033</td>
</tr>
<tr>
<td>Canine area</td>
<td>2.59</td>
<td>2.13</td>
<td>2.14&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.23&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.76&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.005&lt;sup&gt;T&lt;/sup&gt; T &gt; O and S</td>
</tr>
<tr>
<td>First premolar area</td>
<td>2.54</td>
<td>2.06</td>
<td>2.03&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.15&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.67&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.001&lt;sup&gt;T&lt;/sup&gt; T &gt; O and S</td>
</tr>
<tr>
<td>Second premolar area</td>
<td>2.45</td>
<td>1.99</td>
<td>2.04&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.11&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.63&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.001&lt;sup&gt;T&lt;/sup&gt; T &gt; O and S</td>
</tr>
<tr>
<td>First molar area</td>
<td>2.24</td>
<td>1.87</td>
<td>2.00&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.02&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.65&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.009&lt;sup&gt;T&lt;/sup&gt; T &gt; O</td>
</tr>
<tr>
<td>Second molar area</td>
<td>2.25</td>
<td>1.86</td>
<td>1.97&lt;sup&gt;e&lt;/sup&gt;</td>
<td>2.01&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.75&lt;sup&gt;e&lt;/sup&gt;</td>
<td>0.045&lt;sup&gt;T&lt;/sup&gt; T &gt; O</td>
</tr>
</tbody>
</table>

ANOVA with Scheffe multiple comparison.

<sup>*P <0.05; <sup>1</sup> P <0.01; <sup>2</sup> P <0.001. O, Ovoid; S, square; T, tapered. Means with the same letter are not significantly different among tooth areas according to the Scheffe grouping test.</sup>

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the ovoid and square arch forms, except at the central incisor area. This was due to the difference between the maxillary and mandibular intermolar widths, which were 5.1 mm in the tapered and 4.6 mm in the ovoid arch forms. The square arch form had the largest overjet of 2.7 mm at this area; this might be explained because it had the largest difference between maxillary and mandibular intercanine depths compared with the tapered and ovoid arch forms.

Considerations of differences between anterior and posterior overjet is essential for preadjusted bracket systems. Conventionally, it was proposed to be approximately 3 mm at all the areas. However, a recent study concluded that it was 2.3 mm at the central incisor with a tendency to decrease posteriorly to 2 mm at the second molar. Our results showed that there was a much greater difference between the anterior and posterior segments. This difference in findings might be due to the small sample size of the previous article that was not classified by arch-form type. Therefore, tapered and ovoid archwires might require a more homogenous overjet, and square archwires might need to be narrower in the posterior segment. The tendency of overjet to decrease posteriorly might be because the sample was not classified into different arch-form groups.

Our results regarding the transverse relationship seem to have clinical value in modern orthodontics in designing preformed superelastic archwires. This is because commercial archwires do not emulate arch forms, and some modification is almost always necessary. Therefore, it might be desirable to develop better coordinated preformed superelastic archwires according to the different arch types.

Figure 5 illustrates the coordinated arch forms for each group. Overjet in the anterior area of the square arch form is increased compared with the posterior area but still larger than that of the anterior areas of the tapered and ovoid arch forms. In contrast, tapered and ovoid arch forms have homogenous anterior and posterior overjets. In addition, the figure demonstrates the similarity in intermolar width between the tapered and ovoid arch forms.

Figure 6 shows that the ovoid arch form has an intercanine width close to that of the square form, and its intermolar width is similar to that of the tapered. In earlier studies, only the 8 points that represent the clinical bracket points from first premolar to first premolar on the arch-form curve were matched to arch-form templates to classify the samples. However, this was selected without scientific validation. Therefore, this research included a verification test of the minimum posterior extension required for accurately typing the arch form into tapered, ovoid, and square. The difference in the correctness of matching between the 3 posterior extensions was statistically insignificant, and there was a significant difference in correct identification among arch types (Table II). This implies that the precision of the matching process was not affected by whether the arch form is extended to the first premolar, the second premolar, or the first molar. This is also supported by the absence of significant differences in intermolar widths between the ovoid and
tapered arch forms. Moreover, the panel mismatched the square and ovoid arch-form types 33 times of 53 incorrect matches. These observations indicated that the templates were too similar between the square and ovoid types. This was our first attempt to evaluate the minimum posterior extension to determine arch types. However, we used only 2 arch forms from each type and limited them to the OrthoForm template. Therefore, further research with more arch-type images and other templates might be worthwhile. Also, this study focused on the dental arch forms in a sample with normal occlusion, but consideration of the dimensions of the basal arch form might deserve some attention because cone-beam computerized tomography is now readily available.

CONCLUSIONS

Application of FA points identified by 3D virtual models is valuable for determining clinical bracket position.

The tapered arch form had a greater overjet compared with the ovoid and square ones, except at the incisors. A significant difference in overjet among different areas was found in the square arch form only.

Therefore, it might be beneficial to consider more coordinated preformed superelastic archwires according to the variations in overjet of the different arch types.

The ovoid arch-form dimensions were similar to those of tapered and square arches.

The extension to the first premolar was sufficient to classify the arch-form type with the OrthoForm template. A considerable overlap in identification of mandibular arch-form types by the template was found.

Therefore, a new arch-form classification system that considers both form and size of the dental arch anteri-orly and posteriorly, and with more distinctive borders between groups, might be required.

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