

## Forces and Moments Generated with Various Incisor Intrusion Systems on Maxillary and Mandibular Anterior Teeth

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### ABSTRACT

**Objective:** To evaluate the comparative intrusive forces and torquing moments in the sagittal plane generated during anterior intrusion using different incisor intrusion mechanics in the maxillary and mandibular anterior teeth.

**Materials and Methods:** Five wire specimens were used for each of the following intrusive arches: non-heat-treated, 0.016 × 0.016-inch blue Elgiloy utility arch, 0.017 × 0.025-inch TMA utility arch, and 0.017 × 0.025-inch TMA Burstone intrusion arch. The wires were constructed according to the specifications given by their inventors and were inserted on bracketed dental arches on Frasaco models, segmented mesial to the canines. Simulated intrusion from 0.0–1.5 mm was performed on the Orthodontic Measurement and Simulation System (OMSS), and forces and moments were recorded at 0.1 mm vertical displacement increments. All measurements were repeated five times for each specimen, and maximum values recorded at 1.5 mm for all wires were used for all statistical evaluations. The data were analyzed with two-way analysis of variance (ANOVA) with forces and moments serving as the dependent variables, separately, and wire type and jaw as the independent variables. Post hoc multiple comparisons were performed using the Tukey test (.05 error rate).

**Results:** The 0.017 × 0.025-inch TMA Burstone intrusion arch exerted the lowest intrusive forces, followed by the 0.017 × 0.025-inch TMA utility and the 0.016 × 0.016-inch blue Elgiloy utility arch. The lowest anterior moment in the sagittal plane in this experiment was generated from the 0.017 × 0.025-inch TMA Burstone intrusion arch.

**Conclusions:** The intrusive forces, as well as the generated moments, were always higher in the mandible, where significant differences were observed among the configurations tested. (*Angle Orthod.* 2009;79:928–933.)

**KEY WORDS:** Intrusion; Burstone arch; Utility; TMA; Moments

### INTRODUCTION

Two major orthodontic intrusion techniques for the anterior dentition have been developed: the segment-

ed arch<sup>1–3</sup> and the bioprogressive<sup>4,5</sup> techniques. Both use intrusion arches with anchorage on posterior teeth but have fundamental biomechanical differences in their construction/use and consequently in their mode of action.<sup>6</sup> The first is a determinate one-couple force system, with moments and forces that can readily be discerned, measured, and evaluated. The utility intrusion arch is a two-couple system, created by tying the rectangular wire into the incisor brackets; in this manner the precise magnitude of forces and couples cannot be known, especially if torque bends or cinch back are incorporated in the archwire.<sup>7</sup> The Burstone intrusion arch does not require a cinch, since the incisor inclination can be controlled by the contact point of the incisor tie.<sup>6</sup>

Most of the published clinical studies about these two techniques concerned the extent of root resorption<sup>8–11</sup> or their side effects on the posterior part of the

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dentition.<sup>12-13</sup> The force magnitude<sup>14</sup> and the application point of the intrusive force<sup>15</sup> were also clinically evaluated for the segmented arch technique. Also, a limited number of studies dealt with the comparison of the segmented<sup>16</sup> or the Ricketts technique<sup>17</sup> with a continuous archwire technique, whereas one study focused on incisor intrusion in patients with marginal bone loss using both techniques.<sup>18</sup> The differential effect of the intrusion techniques on each jaw is not clear. Goerigk et al<sup>11</sup> evaluated the segmented arch technique and found a similar rate of intrusion in both jaws, but the extent of the intrusive movement and the percentage of root resorption were larger in the mandible.<sup>13</sup> McFadden et al evaluated the bioprogressive technique and found lesser root shortening in the mandible.<sup>9</sup> Greater intrusion in mandibular incisors was reported by Otto et al using the bioprogressive technique<sup>8</sup> and by Weiland et al<sup>16</sup> using the Burstone technique. However, comparison of the results of these studies is complex because of the variation in the methods used.

The aim of this study was to evaluate comparatively the intrusive forces and torquing moments generated during anterior intrusion between the two intrusion techniques in both jaws.

## MATERIALS AND METHODS

### Experimental Apparatus and Configuration

The Orthodontic Measurement and Simulation System (OMSS) was used for the *in vitro* evaluation of the different intrusion mechanics.<sup>19</sup> The OMSS is based on the principle of the two-tooth model and allows the measurement of all forces and moments acting on two regions simultaneously. For this purpose, the OMSS has two stepping motor-driven positioning tables equipped with force/moment transducers, monitored by a personal computer that controls the measurements. Absolute measurements were recorded of the forces/moments generated by an orthodontic appliance, when the positioning tables are moved along a specified path.<sup>20</sup>

An acrylic Frasaco model was constructed for each jaw, with an ideal, leveled, and aligned, dental arch. The first and second molars on the model were bonded with 0.018-inch slot tubes with 0° angulation/torque/distal offset, and 0.018-inch slot brackets were placed on the rest of the teeth (Forestadent, Pforzheim, Germany). Each model was split into two segments after bracket placement: the anterior segment, which included the four incisors and the posterior segment, which included the teeth from the canine to the second molar. An appropriate adaptor was fixed on each of these model segments to make them mountable to the positioning tables of the OMSS (Figure 1). A straight

0.018 × 0.025-inch stainless steel archwire was subsequently ligated to the two segments, and they were both mounted on the positioning tables of the OMSS. An adjustment of the system was conducted with the straight wire in place and all forces/moments generated were nullified in this configuration.

In the absolute measurement mode, the dental arch was initially leveled. During the measurement procedure, the anterior segment was gradually extruded up to 1.5 mm and afterwards intruded to its initial position. The forces/moments generated in the anterior segment were measured in 0.1 mm steps, and the maximal values were evaluated statistically.

### Materials

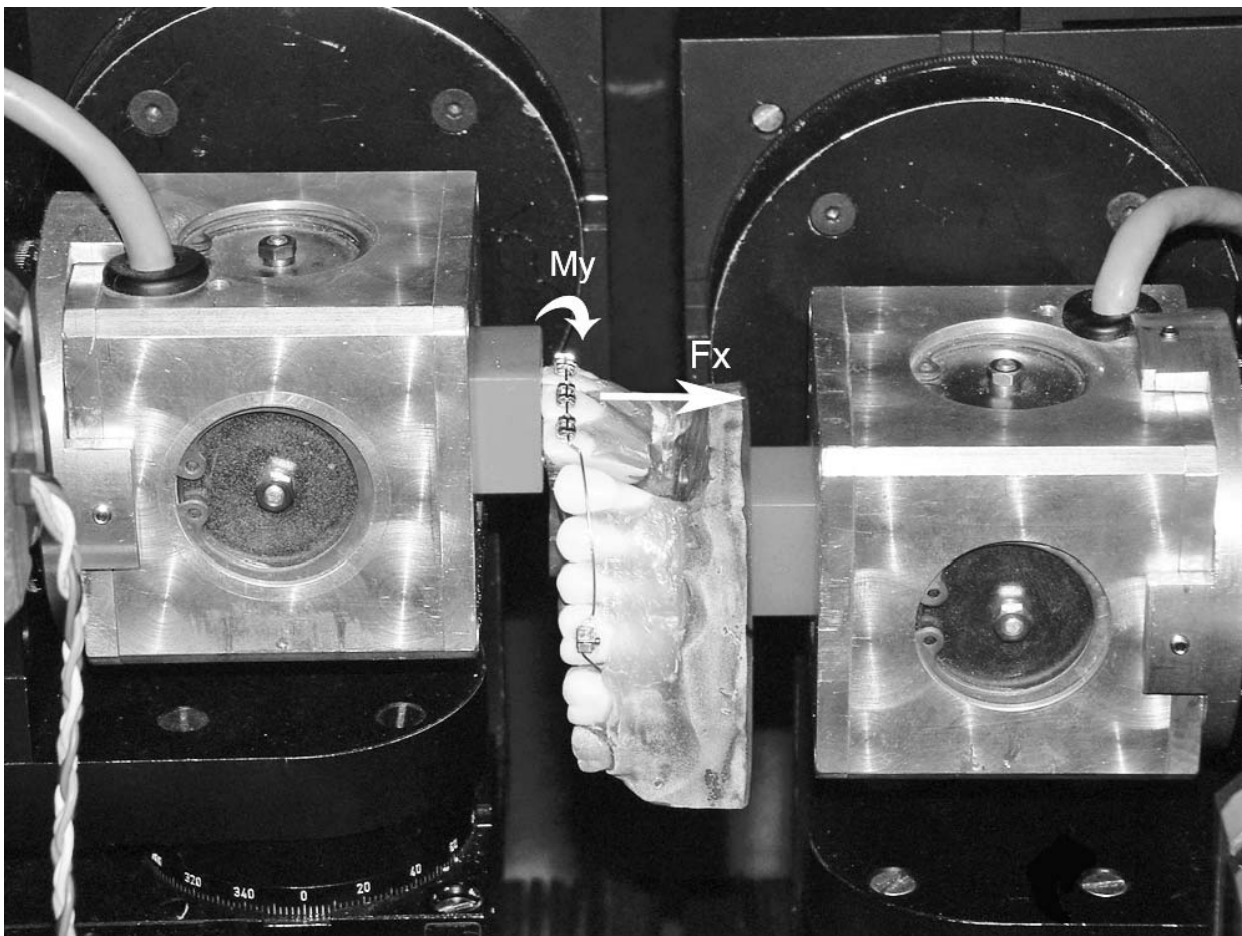
The following arches were evaluated with the absolute measurement system, with regard to the forces/moments generated in the anterior maxillary and mandibular segments:

- Utility arch 0.016 × 0.016-inch blue Elgiloy, non-heat-treated (Rocky Mountain Orthodontics, Denver, Colo).
- Utility arch 0.017 × 0.025-inch TMA (Ormco, Glendora, Calif)
- Burstone intrusion arch constructed with a 0.017 × 0.025-inch TMA (Ormco), ligated distal to the lateral incisors and gingivally of the anterior sectional wire.

Five utility and five Burstone intrusion arches were fabricated by the first author for each of the above-mentioned combinations and for each jaw. All measurements were performed in quintuplicate.

The segmented intrusion arches were constructed according to the specifications given by Burstone.<sup>3</sup> The 3-mm helix of the intrusion arch was wound and placed mesial to the molar tube. The diameter of the helix was measured with a measuring gauge, and a 45° molar tip-back was incorporated in the wire, whereas the intrusion arch was ligated gingivally to the anterior segmented arch. The posterior segment consisted of both molars and premolars on each side, which were stabilized with a sectional passive 0.018 × 0.025-inch stainless steel wire. An anterior, passive sectional arch from the same wire was fabricated for the stabilization of the incisors. A palatal/lingual arch was not deemed necessary since the posterior segments of the model were united. The utility arches were fabricated with 45° molar tip-back, as described by Ricketts,<sup>4,5</sup> without any molar rotation or buccal root torque incorporated in the wire, for simplicity. During the experimental intrusion, the helix of the Burstone archwires was ligated to the tube and the utility archwires were cinched back.

For the objectives of this study, which targeted the



**Figure 1.** The acrylic Frasaco model mounted to the positioning tables of the Orthodontic Measurement and Simulation System (OMSS).

pure intrusive and buccolingual torque components of the intrusion configurations, only the intrusive forces (Fx) and the moments (My; anterior buccolingual torque) were used for the final evaluations of simulated intrusion. The remaining force (Fy, Fz) and moment (Mx, Mz) components are greatly affected by factors such as proper adjustment of the anterior segment relative to the posterior segment, wire bending, proper archwire insertion, ligation, and activation. Because all of the aforementioned factors introduce unnecessary variability and confound the results that are of real interest during anterior maxillary intrusion, the components Fy, Fz, Mx, and Mz were adjusted to zero.

**Statistical Analysis**

The results of forces and moments were statistically analyzed separately by means of two-way analysis of variance (ANOVA). Forces and moments were the dependent variables and wire type and jaw were the independent variables. Post hoc multiple comparisons were performed using the Tukey test (.05 error rate). Statistical analysis was performed with Statistical

Package for Social Sciences (SPSS Inc, version 15.0, Chicago, Ill).

**RESULTS**

The Utility archwires recorded mean intrusive forces in the range of 1.33–1.71 N. The utility 0.016 × 0.016-inch blue Elgiloy exerted higher force than the utility 0.017 × 0.025-inch TMA. The recorded magnitudes for the Burstone 0.017 × 0.025-inch TMA intrusive arches were 0.99–1.25 N (Table 1). The analysis of

**Table 1.** Results of the Anterior Intrusion Forces at 1.5 mm for the Three Configurations Included in the Study

Wire Type	Intrusion Force, N	
	Maxilla	Mandible
	Mean* (SD)	Mean* (SD)
Burstone TMA (0.017 × 0.025)	0.99 <sup>b</sup> (0.11)	1.25 <sup>a</sup> (0.14)
Utility Elgiloy (0.016 × 0.016)	1.43 <sup>d</sup> (0.07)	1.71 <sup>c</sup> (0.10)
Utility TMA (0.017 × 0.025)	1.33 <sup>a</sup> (0.12)	1.54 <sup>e</sup> (0.13)

\* Means with same letters are not significantly different at the .05 level.

**Table 2.** Analysis of Variance (ANOVA) for Intrusion Force

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected model	7.719 (a)	5	1.544	139.598	.000
Intercept	283.873	1	283.873	25,669.680	.000
Wire	5.319	2	2.660	240.490	.000
Jaw	2.377	1	2.377	214.912	.000
Wire × jaw	0.023	2	0.012	1.050	.353
Error	1.592	144	0.011		
Total	293.185	150			
Corrected total	9.311	149			

variance indicated significant differences for both wire type and jaw variables, whereas the interaction term was insignificant (Table 2). Significant difference between the maxilla and the mandible was observed, and for the same wire type, the forces were always higher in the mandible.

The highest moment value was recorded for the lower utility 0.017 × 0.025-inch TMA (7.79 Nmm), and the lowest for the upper Burstone 0.017 × 0.025-inch TMA intrusion system (2.47 Nmm). Significant difference between the maxilla and the mandible was observed, and for the same wire type, the moments were always higher in the mandible (Tables 3 and 4).

**DISCUSSION**

Orthodontic intrusion of the incisors is indicated for the management of deep bite, especially in cases where bite opening with eruption of posterior teeth is contraindicated. The decision whether to intrude the maxillary or the mandibular anterior teeth is made by the functional evaluation of the upper gingival line in relationship with the upper lip.<sup>21,22</sup> The proper force magnitude for the four upper incisors was initially suggested by Burstone to be around 1 N<sup>3</sup>, and as the results of the present study indicate, a maxillary 0.017 × 0.025-inch TMA Burstone intrusion arch, exerted forces within this range. On the other hand, Ricketts<sup>5</sup> proposed a magnitude of 1.2–1.6 N, and the utility

**Table 3.** Results for the Anterior Moments at 1.5 mm for the Three Configurations Included in the Study

	Moment, Nmm	
	Maxilla	Mandible
	Mean* (SD)	Mean* (SD)
Burstone TMA (0.017 × 0.025)	2.47 <sup>b</sup> (1.44)	3.86 <sup>a</sup> (2.22)
Utility Elgiloy (0.016 × 0.016)	5.92 <sup>c</sup> (0.96)	7.02 <sup>cd</sup> (1.02)
Utility TMA (0.017 × 0.025)	7.31 <sup>d</sup> (1.28)	7.79 <sup>d</sup> (1.24)

\* Means with same letters are not significantly different at the .05 level.

**Table 4.** Analysis of Variance (ANOVA) for Moments

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected model	564.798 (a)	5	112.960	55.814	.000
Intercept	4919.559	1	4919.559	2430.782	.000
Wire	522.441	2	261.221	129.071	.000
Jaw	36.878	1	36.878	18.222	.000
Wire × jaw	5.478	2	2.739	1.353	.262
Error	291.436	144	2.024		
Total	5775.793	150			
Corrected total	856.233	149			

arches that were measured were in that range. With respect to the lower incisors, both authors agree that the force should be approximately half the amount used for the upper incisors.

Nevertheless, a recent clinical study demonstrated that 0.4 N of force could intrude the four maxillary incisors with the same rate as those of double the magnitude.<sup>14</sup> In light of this evidence, the force magnitudes of the biomechanical configurations tested in this experiment are exceedingly high. The lowest values were recorded for the upper 0.017 × 0.025-inch TMA Burstone intrusion arch, since the moduli of elasticity of beta-titanium wires are around 40% of that of stainless steel,<sup>23</sup> in contrast to Elgiloy wires, whose moduli of elasticity are similar to stainless steel.<sup>24</sup> Accordingly, beta-titanium wires deliver about half the amount of force compared with that of stainless steel<sup>25</sup> or cobalt-chromium wires<sup>23</sup> of comparable cross section and equal amounts of activation. Although a 3-mm helix was incorporated in the Burstone intrusion archwire, the 45° molar tip-back produced 0.99 N in the upper and 1.25 N in the lower anterior segment.

The 0.016 × 0.016-inch Elgiloy exerted about 10% more force than the 0.017 × 0.025-inch TMA. Generally, a 0.017 × 0.025-inch cantilever is about 86% stiffer than a 0.016 × 0.016-inch cantilever from the same material,<sup>26</sup> but in the case of a rectangular supported beam, its properties are primarily determined by the dimension in the direction of bending. Additionally, if the ends are tightly anchored, ie, not free to slide, the beam is stronger and less flexible.<sup>7</sup> In this simulation, the intrusive forces were always higher in the mandible, since the length of the buccal bridge of the mandibular utility arches, calculated as the distance between the anterior and posterior vertical steps, was 25 mm, 3 mm shorter than in the maxillary arches. For the same reason, the points of contact in the maxillary Burstone intrusive arches were more anteriorly located, in comparison to the mandibular arches. The length of the moment arm is of great impor-

tance for the determination of the force magnitude, and it is recommended to do initially as much retraction as possible to decrease this length.<sup>27</sup>

The results of this experiment encourage the use of a force gauge in order to evaluate the intrusive archwires used in clinical practice. This measurement reflects closely the intrusive force in case of a Burstone intrusive archwire. Additionally, the force magnitude of such an archwire for a given activation could be measured from the force-deflection graphs, provided for different arch lengths.<sup>3</sup> In a two-couple utility arch system, the load required to bring the incisor segment of the wire to the incisor brackets does not accurately reflect the intrusive/extrusive load acting at the teeth.<sup>6</sup> In this system, the torque bends or cinch back, which are probably required additionally to the activation bends, change the biomechanical geometry, and under these circumstances, it is difficult to be certain which of the moments will prevail or whether the intrusion force is appropriate.<sup>7</sup> According to the results of this experiment, a 45° molar tip-back in the mandibular intrusion arches tested, produces forces beyond the biologically sufficient level, especially in case of a utility arch.

The 0.017 × 0.025-inch TMA Burstone arch demonstrated the lowest values, since it was ligated distal to the lateral incisors and more closely to the center of resistance of the anterior segment. If the intrusive forces were applied in line with the center of resistance, no faciolingual moment would occur.<sup>15,27</sup> The moments produced by the 0.017 × 0.025-inch TMA utility arch were larger than those produced by the 0.016 × 0.016-inch blue Elgiloy utility arch, although the intrusive forces of these two archwires showed an inverse relationship. A 0.016 × 0.016-inch blue Elgiloy wire in a 0.018-inch slot has a torsional play of 27°, and consequently a 35°–48° of twist should be applied to get 20 Nmm of torsional moment.<sup>28</sup> TMA presents lower torsional stiffness values in comparison with blue Elgiloy, but, generally and if the wire material/manufacturer remain the same, the increase of the cross section from 0.016 × 0.016-inch to 0.017 × 0.025-inch reduces the slack by two thirds.<sup>29</sup> Moreover, the cinch of the activated utility wires introduces an additional force in the horizontal plane and a moment, which tends to counteract partially the faciolingual moments generated by the intrusive force,<sup>6</sup> and apparently Elgiloy wire exerted larger counteracting moments.

The clinical relevance of this experiment, as well as most in vitro investigations, cannot be drawn without skepticism. The OMSS is based on the principle of the two-tooth model and resembles closely the clinical situation but fails to take account of some factors that have additional influence in practice, such as intraoral

aging and saliva. Furthermore, it has not yet been possible to predict the center of resistance of the four incisors, and the intrusion of these teeth should be carefully monitored to avoid side effects.

## CONCLUSIONS

- The 0.017 × 0.025-inch TMA Burstone arch exerted the lowest forces, followed by the 0.017 × 0.025-inch TMA utility and the 0.016 × 0.016-inch non-heat-treated blue Elgiloy utility arch. According to recent clinical research, a 45° molar tip-back in the mandibular intrusion arches of rectangular cross section, produces forces beyond the biologically sufficient level, especially in case of a utility arch.
- The lowest anterior moment in the sagittal plane in this experiment was generated from the 0.017 × 0.025-inch TMA Burstone intrusion arch, followed by the 0.016 × 0.016-inch non-heat-treated blue Elgiloy utility and the 0.017 × 0.025-inch TMA utility arch.

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