Evaluation of the vertical forces generated by the cervical biteplate facebow

Stanley Braun, DDS, MME; Baxter E. Johnson, DDS, MS; William P. Hnat, PhD; Jaime A. Gomez

The biteplate facebow was introduced by Cerverva in 1967[1] for the treatment of Class II malocclusions with deep overbite. The facebow has been shown to be successful in selected types of Class II malocclusions; however, controversy still exists as to the precise biomechanical effects on the dentition.[2]

The biteplate facebow is similar in design to the conventional cervical facebow with the addition of a metal plate to the inner-anterior portion of the facebow, as seen in Figure 1.

When the rigid inner bow is engaged in 0.045 tubes attached to the maxillary first molars, the plate is presumed to exert an intrusive force on the maxillary incisors when the outer bow is activated by attachment of the cervical neck strap. The forces applied to the maxillary first molars are posterior and downward. The patient is unable to fully close when wearing this facebow, as the mandibular incisors impinge on the underside of the plate. This prevents full closure, disarticulates the occlusion, and acts like a biteplate. Hooks are incorporated on the inner bow for optional use of elastics across the labial surfaces

Abstract

The biteplate facebow has been recommended for use in the correction of Class II malocclusions with deep overbites. This facebow is similar in design to the conventional cervical facebow with the addition of an inner bow metal plate. The plate presses against the maxillary incisors and prevents the patient from fully closing, thus acting as a biteplate. A test apparatus was constructed to simulate the force system present during application of the facebow. In this study, high resolution force transducers were used to measure the intrusive forces on the maxillary and mandibular incisors. Static force analysis techniques were then used to calculate the vertical force component of the first molars. Analyses were performed using a wide range of relative bow angles, neck strap tensions of 200 grams and 400 grams, and various mandibular incisor occluding forces. The molar eruptive forces of the biteplate facebow are found to exceed those of the standard cervical facebow by a low of 158% to a high of 537%, depending on the neck strap tension and the inner bow/outer bow angle. While the intrusive forces on the maxillary incisors were excessive, no intrusion is anticipated because the biteplate disarticulates the posterior teeth and the eruption of the unopposed maxillary molars would likely cause the occlusal plane to tip in a counter-clockwise direction. Consequently, the overbite correction would be obtained through maxillary molar eruption accompanied by occlusal plane tipping. Before considering use of the biteplate facebow, a patient's anticipated growth pattern, the magnitude of the intrusive forces and the treatment objectives should be evaluated.

Key Words

Biteplate • Facebow • Inner bow metal plate • Intrusive forces

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Figure 1
Biteplate facebow

Figure 2
Biteplate facebow in position, showing dimensions used for this study

Figure 3
Free body diagram of a conventional cervical facebow

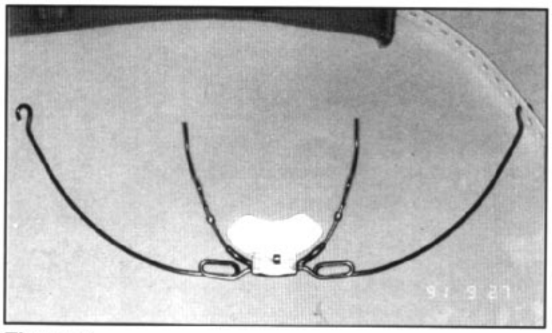

Figure 1

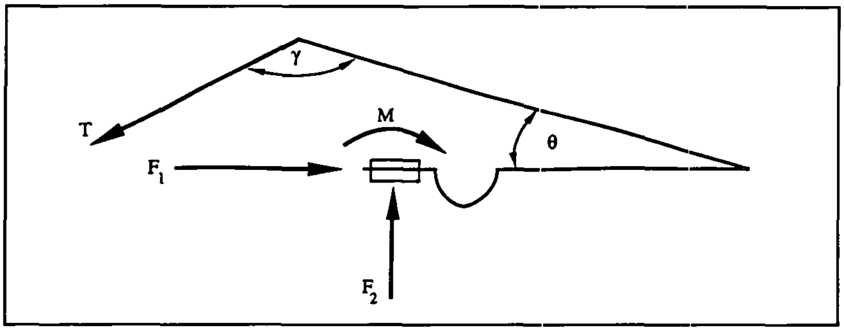

Figure 3

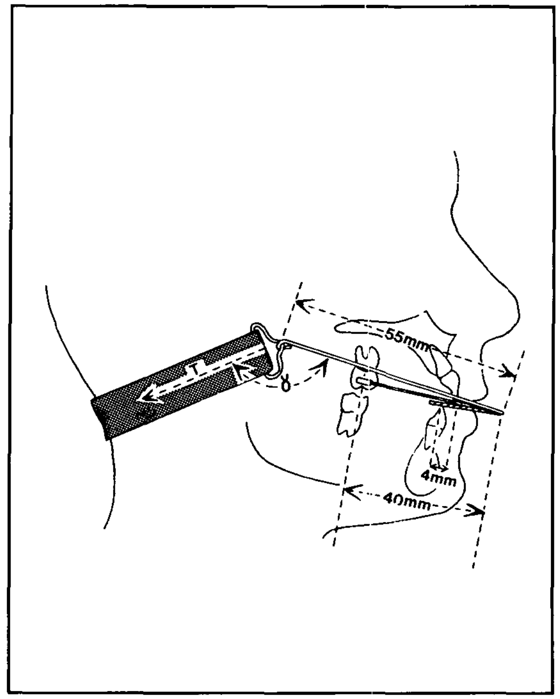

Figure 2

of the maxillary incisors. The object of the elastic is to prevent labial movement of the maxillary incisors since the force from the biteplate is anterior to the center of resistence of the maxillary incisors.

This *in vitro* study analyzes the intrusive forces on the incisors and the vertical, extrusive forces on the maxillary first molars. The effectiveness of these forces bears directly on overbite correction. Molar vertical force comparisons are also made to the conventional cervical facebow.

Force systems analysis has shown that the overbite correction seen in cases treated with this type of facebow occurs by extrusion of the molars and not by intrusion of the incisors as claimed by the manufacturer.[3] Opening the vertical in this manner can be considered adverse, especially in patients with insufficient compensatory skeletal growth. The resultant downward and backward rotation of the mandible is counterproductive in the correction of Class II relationships.

Materials and methods

The biteplate facebow is shown in position on a typical patient in Figure 2. The dimensions shown are also considered typical for this analysis. Force system analysis was done with cervical neck strap tensions of 200 grams and 400 grams, and with outer bow-to-inner bow angles of +30° to -5°, following engagement of the neck strap.

A positive angle indicates the outer bow is above the inner bow, and a negative angle indicates the outer bow is below the inner bow. Impingement of the mandibular incisors on the underside of the inner bow plate is not predictable, since it is a function of whether or not the patient actually brings the mandibular incisors into contact with the plate, to what degree he or she occludes, and the length of time in contact with the plate. An analysis is thus performed for several possibilities, namely: 0, 50, 100, 150, 200 and 500 grams of total mandibular incisor impingement. Overjet is highly variable and is assumed to be 4 mm for this study.

The maxillary molar vertical component of the force system induced by a conventional cervical facebow is calculated using static equilibrium analysis for comparison purposes. The equilibrium equation based on the free body diagram of Figure 3 is given by

$$F_2 = T \sin [180 - (\gamma + \theta)] \qquad (1)$$

where F_2 is the molar eruptive force, T is the neck strap tension, γ is the neck strap/outer bow angle following neck strap engagement, and θ is the inner bow/outer bow angle, following neck strap engagement.

When the maxillary and/or mandibular incisors impinge upon the biteplate, the number of indeterminants involved in the equilibrium equations exceed the number of independent variables. To resolve the molar eruptive force, F_2, a test apparatus which allows measurement of the mandibular and maxillary incisor forces was constructed. The neck strap force and the mandibular and maxillary incisor forces were measured

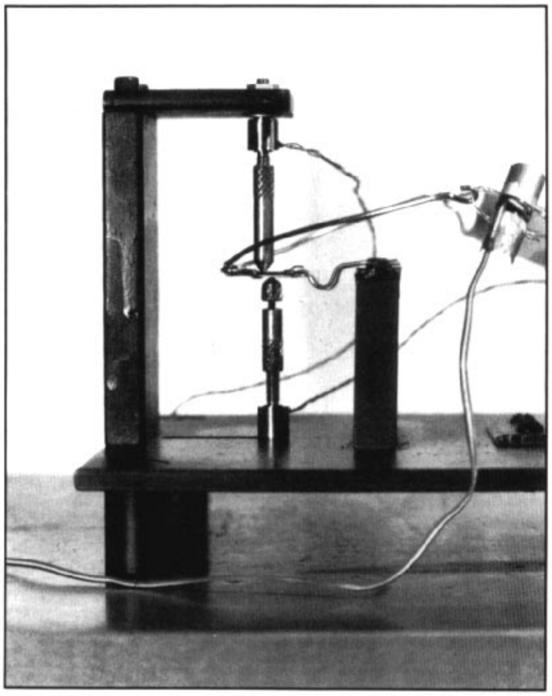

Figure 4

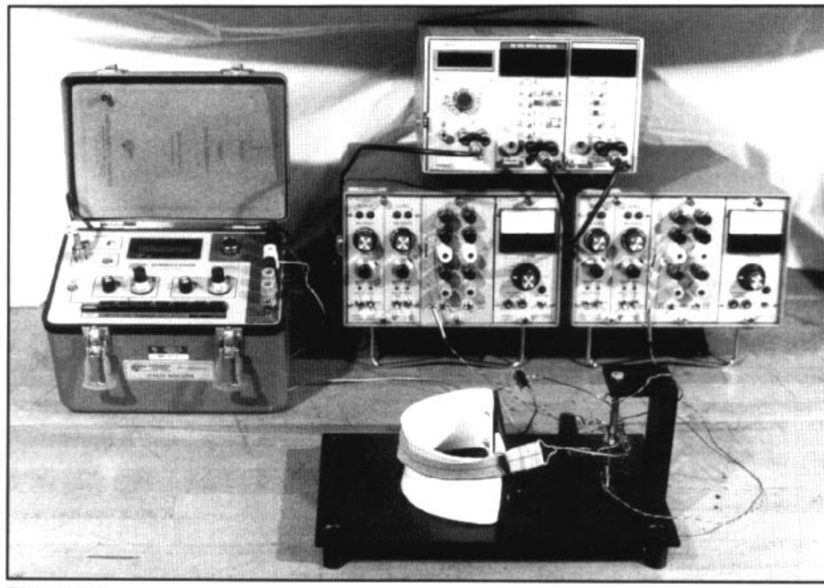

Figure 5

using high resolution strain gauge force transducers (Entran Model ELH-TC400-4). Figures 4 and 5 are photographs of the test apparatus and associated instrumentation. The spacial dimensions were the same as described earlier and are shown in Figure 2.

The molar eruptive force with no mandibular incisor force is calculated from the static force equilibrium equation based on the free body diagram of Figure 6.

$$F_2 = T \sin [180 - (\gamma + \theta)] + F_3 \qquad (2)$$

where F_3 is the total maxillary incisor force.

Results

For comparison purposes, the molar eruptive forces were calculated using Equation 1 for a standard cervical facebow with neck strap tensions of 200 grams and 400 grams and for inner bow/outer bow angles from +30° to -5°, in 5° increments. These angles were measured on patients following neck strap engagement. The negative angle refers to the outer bow in equilibrium below the inner bow. The calculated molar eruptive force as a function of the inner bow/outer bow angle is shown in Figure 7.

Molar eruptive forces of the biteplate facebow without mandibular incisor impingement were calculated using Equation 2 and force measurements of the maxillary incisor intrusive forces. The results are shown graphically in Figure 8 for neck strap tensions of 200 grams and 400 grams.

Total maxillary incisor intrusive forces obtained by direct force measurement for various inner bow/outer bow angles are shown graphically in Figure 9.

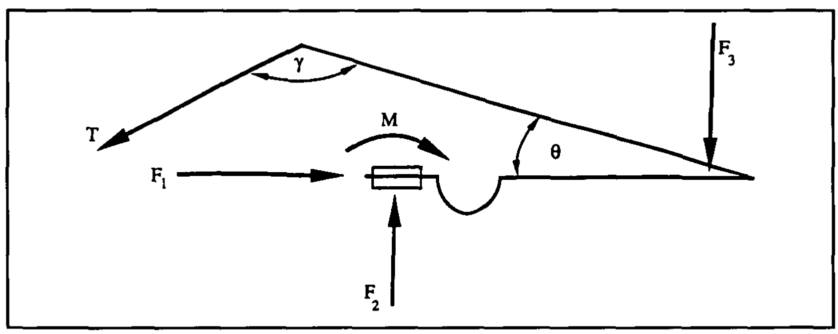

Figure 6

Figure 4
Experimental test apparatus

Figure 5
Experimental test apparatus and associated instrumentation

Figure 6
Free body diagram of biteplate facebow without mandibular incisor impingement force

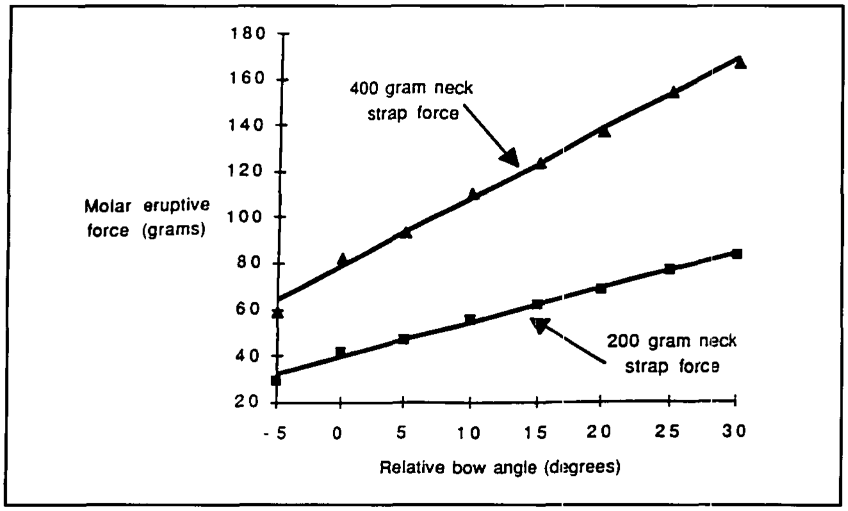

Figure 7

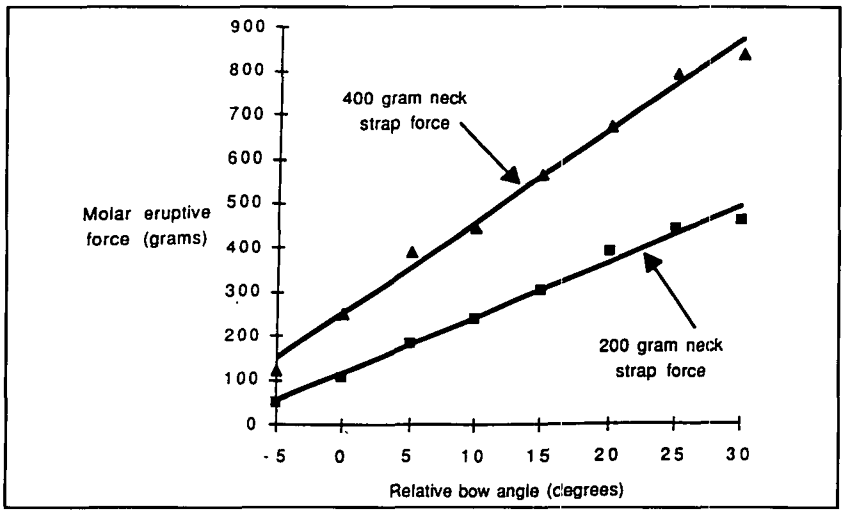

Figure 8

Figure 7
Calculated molar eruptive force for the standard cervical facebow

Figure 8
Molar eruptive force for the biteplate facebow without the mandibular incisor impingement force

Because mandibular incisor impingement is highly variable and unpredictable, molar eruptive forces were calculated using the measured maxillary incisor intrusive forces for applied mandibular total incisor intrusive forces of 500, 200, 150, 100, and 50 grams. Neck strap tensions of 200 grams and 400 grams and inner bow/outer bow angles between +25° and -5° were evaluated. The applicable free body diagram is shown in Figure 10. The applicable equilibrium equation is:

$$F_2 = T \sin [180 - (\gamma + \theta)] + F_3 - F_4 \qquad (4)$$

where F_4 is the total mandibular incisor force. The data is shown in Tables 1 and 2.

A comparison of molar eruptive forces between the standard cervical facebow and the biteplate facebow is shown in Figure 11.

Discussion

For the conventional cervical facebow with 400 grams neck strap tension, each molar is subjected to a maximal eruptive force of 166 grams when the outer bow is at 30°. This eruptive force diminishes almost linearly to 59 grams when the inner bow is at -5°. If the neck strap tension is reduced to 200 grams, the molar eruptive force is reduced proportionally to 83 grams at 30°, and 30 grams at -5° (see Figure 7).

In the case of the biteplate facebow, the molar eruptive force without mandibular incisor impingement is markedly increased throughout the range of inner bow/outer bow angles. At a 30° inner bow/outer bow angle with 400 gram neck strap tension, the molar eruptive force is 834 grams, a 502% increase over the molar eruptive force induced by a conventional cervical facebow. This increased molar eruptive force occurs throughout the range of inner bow/outer bow angles to a minimum increase of 256% at -5°.

When the neck strap tension is reduced to 200 grams, the molar eruptive force is 459 grams at 30°, and 40 grams at -5°. Comparing the molar eruptive forces to the conventional cervical facebow at 200 grams of neck strap tension, the values are 553% above the cervical facebow at 30° and 163% at -5°.

A review of the molar eruptive force equations for the conventional cervical facebow, $F_2 = T \sin [180° - (\gamma + \theta)]$, and the biteplate facebow, $F_2 = T \sin [180 - (\gamma + \theta)] + F_3$, reveals that the molar eruptive force is increased by the value F_3, the maxillary incisor intrusive force. The magnitude of F_3 was found to be significant and accounts for the large increases in the molar extrusive forces (see Figure 9).

During the time when a patient occludes, the range of molar eruptive forces is not changed materially within the range of occluding forces studied. This is irrespective of neck strap tensions and inner bow/outer bow angles (see Tables 1 and 2).

Total maxillary incisor intrusion without mandibular incisor impingement was found to be 1337 grams at +30° and 122 grams at -5° when the neck strap tension is at 400 grams. When the neck strap tension is at 200 grams, these values are 752 grams and 39 grams, respectively.

If the patient occludes on the inner bow plate, the maxillary incisor intrusive force does not change significantly at the upper range of inner bow/outer bow angles. At -5°, the total maxillary incisor intrusive forces are within the range of 87 grams to 302 grams, depending on the magnitude of mandibular incisor impingement.

Conclusions

It is apparent that the choice of neck strap tension and inner bow/outer bow angle are critical to the magnitude of the force system affecting the molars and maxillary incisors. The molar eruptive forces of the biteplate bow can be exceedingly high and may border on the non-physiologic at all values above 0° outer bow/inner bow angles. It is important to recognize that there are no counterbalancing molar occlusal forces since the inner bow plate acts as a biteplate. It is therefore likely that overbite correction would occur primarily by maxillary molar eruption. One may question if this is desirable, even in the most favorably growing patient, for if a deep overbite exists with a correlative curve of Spee, the resultant occlusal plane would be unfavorably tipped. If the neck strap tension is at 200 grams and the outer bow is adjusted below 0°, the molar eruptive force is less than 49 grams. This may be more acceptable with regard to patient comfort and will likely result in a more physiologic eruptive response, recognizing the absence of counter-balancing molar occlusion.

The total intrusive force that is imparted to the maxillary incisors at 400 grams of neck strap tension is considered non-physiologic[4], ranging from 1337 grams at 30° to 122 grams at -5°. It is probable that these intrusive forces would not be shared equally by the four incisors, as it is unlikely all of these teeth will be in equal simultaneous contact with the plate. When the strap tension is adjusted to 200 grams, the maxillary incisor intrusive forces decrease to 752 grams at 30° and to 30 grams at -5°. While the lower range of values may be more acceptable physiologically, the lack of continuous and constant maxillary incisor intrusive forces would likely make this an ineffective method of obtaining true intru-

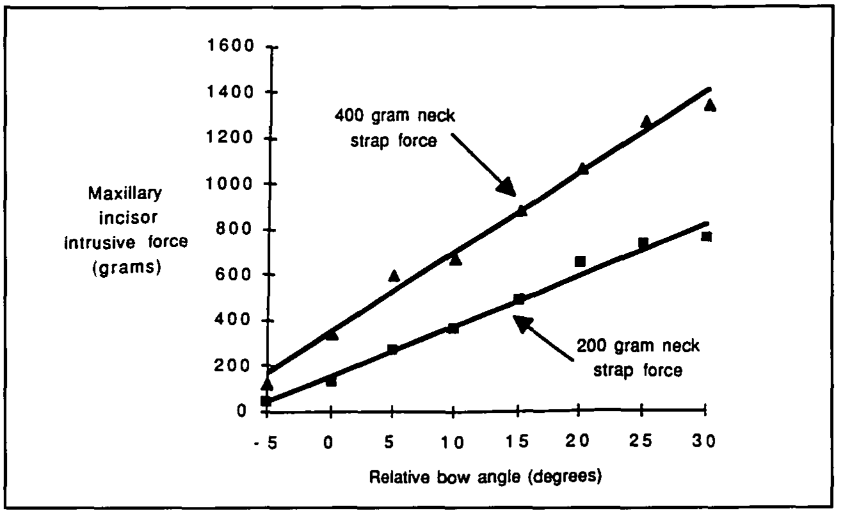

Figure 9

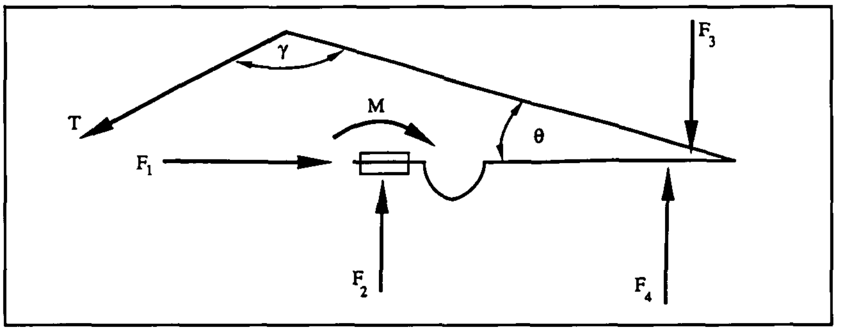

Figure 10

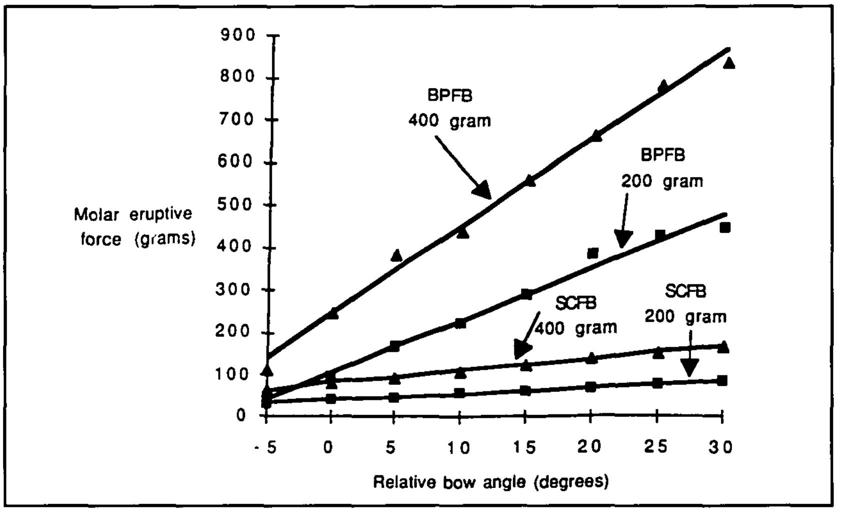

Figure 11

Figure 9
Total maxillary incisor intrusive force following neck strap engagement

Figure 10
Free body diagram of biteplate facebow with mandibular incisor impingement force

Figure 11
Comparison of the molar eruptive force between the standard cervical facebow (SCFB) and the biteplate facebow (BPFB)

Table 1
Molar and incisor vertical forces for various mandibular impingements for the biteplate facebow

Neck Strap Tension at 200 Grams

Inner bow/outer bow angle θ (degrees)	Total mandibular incisor force (grams)	Total maxillary incisor intrusive force (grams)	Molar eruptive force (grams)
25	50	770	398
20	50	695	354
15	50	522	269
10	50	404	201
5	50	312	151
0	50	182	83
-5	50	78	31
25	100	817	395
20	100	740	352
15	100	572	267
10	100	449	202
5	100	358	152
0	100	229	81
-5	100	129	28
25	200	903	390
20	200	828	348
15	200	667	199
10	200	544	196
5	200	454	147
0	200	313	78
-5	200	223	22
25	500	1168	375
20	500	1115	339
15	500	925	247
10	500	810	181
5	500	726	133
0	500	584	70
-5	500	525	25

sion in the correction of deep overbites.

When the neck strap tension is 400 grams, the data reveal that the maxillary incisor intrusive forces remain relatively high and are not affected in any significant way by the magnitude of mandibular incisor impingement. If the neck strap tension is reduced to 200 grams, the total maxillary incisor intrusive force is above those commonly accepted values as physiologic. The increased risk of root resorption for intrusive forces beyond 25 to 30 grams per incisor is significant.[5]

Summary

Maxillary molar extrusive and maxillary incisor intrusive forces that occur from the use of the biteplate facebow were studied via static equilibrium analysis and force measurement. Neck strap tensions of 200 grams and 400 grams in combination with various inner bow/outer bow angles and mandibular incisor occluding forces were

Table 2
Molar and incisor vertical forces for various mandibular impingements for the biteplate facebow

Neck Strap Tension at 400 Grams			
Inner bow/outer bow angle θ (degrees)	Total mandibular incisor force (grams)	Total maxillary incisor intrusive force (grams)	Molar eruptive force (grams)
25	50	1315	786
20	50	1112	668
15	50	925	561
10	50	710	440
5	50	649	393
0	5	388	252
-5	50	173	121
25	100	1341	774
20	100	1154	664
15	100	968	558
10	100	761	441
5	100	687	387
0	100	422	244
-5	100	220	119
20	150	1200	662
15	150	1016	557
10	150	808	439
5	150	730	383
0	150	467	242
-5	150	248	108
20	200	1238	565
15	200	1058	553
10	200	850	435
5	200	778	382
0	200	512	338
-5	200	302	110

evaluated with regard to the correction of deep overbites. For most of the facebow adjustments, the molar eruptive forces were excessive. The maxillary incisor intrusive forces were also found to be excessive and highly variable.

This study revealed that the correction of deep overbites is more likely to occur through maxillary molar extrusion than by maxillary incisor intrusion. Under most circumstances, the molar extrusive forces were found to be excessive, particularly since no counter-balancing occlusion exists. The resultant occlusal plane may also be unfavorably tipped.

In light of these findings, it would be of additional value to evaluate the biteplate facebow in a clinical study.

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