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An Improved Transpalatal Bar Design. Part I. Comparison of Moments and Forces Delivered by Two Bar Designs for Symmetrical Molar Derotation

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ABSTRACT

Moments and forces delivered during symmetrical derotation of upper molars by 10 Goshgarian-type (GTPB) and 10 Zachrisson-type transpalatal bars (ZTPB) were measured in laboratory experiments using a computer-based strain gauge. The bar passivity in sagittal, transverse, and vertical planes was first assessed at the measurement apparatus. Then each end of the 20 passive bars was symmetrically activated by 10 mm in the sagittal plane using a template. The activated bars were placed into lingual attachments of the measuring apparatus, and three consecutive measurement steps were done for each bar. Measurements were made when the attachments were at 0°, 5°, and 10° of deactivation. The mesiodistal (sagittal) forces, the horizontal forces, and the moments of rotation at the right and left attachments were measured at each step. The horizontal forces and the moments of rotation of the two designs had statistically significant differences. Greater moments of rotation were produced by the GTPB. The ZTPB produced significantly lower contractive horizontal forces than did the GTPB at 5° and 10° of deactivation.

KEY WORDS: Zachrisson-type transpalatal bar, Goshgarian-type transpalatal bar, Symmetrical derotation of molars.

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INTRODUCTION Return to TOC

Transpalatal bars are routinely used in orthodontics in both permanent and mixed dentition treatments to establish and maintain arch widths,[1] to derotate unilaterally or bilaterally rotated molars,[1–5] to control upper molar eruption,[1,4] to increase posterior anchorage,[6] to correct unilateral crossbites,[7,8] for maxillary expansion and buccal root torque of upper molars,[9–11] and to correct mesiodistal asymmetries.[12] Different designs of transpalatal arches exist. The original and still most commonly used transpalatal bar designed by Goshgarian (Goshgarian-type transpalatal bar [GTPB]) is bent from a 0.036-inch (0.9 mm) stainless steel wire with or without a central loop. The loop is oriented either mesially or distally. The traditional form can be bent directly by the clinician or used prefabricated in different lengths (GAC International Inc, Central Islip, NY). These bars are most commonly used with prefabricated lingual attachments welded to the molar bands or soldered directly onto the bands.[1] Variations of the traditional transpalatal bar are the quad-helix appliance,[11] Burstone's precision lingual arches with hinge cap attachment,[13–15] Wilson 3D lingual appliances,[16] NiTi palatal expander,[17] and NiTi molar rotator.[17,18] A recently introduced design variation is the Zachrisson-type transpalatal bar (ZTPB).[19,20] The clinical application of the ZTPB appears satisfactory, but the forces and moments produced have not been assessed. The aim of this study was to measure the forces and moments produced by the ZTPB using a computer-based strain gauge system and to compare these forces and moments with those of the GTPB.

MATERIALS AND METHODS Return to TOC

Ten ZTPBs, handmade from 0.036-inch Blue Elgiloy wire (Rocky Mountain/Orthodontics, Denver, Colo), were compared with 10 prefabricated 0.036-inch stainless steel GTPBs (GAC International) (Figure 1). Both types of bars measured 53 mm between the ends. The ZTPB has three loops (Figure 1). The central loop is larger and longer than the single round loop of the GTPB bar. Two distally directed smaller loops are symmetrically positioned on either side of the central loop. Ten ZTPBs were made from a 0.036-inch Blue Elgiloy wire by one investigator. The extended length of the bar except for the ends was 89 mm. The size of the central loop was nine mm, and the width from the two farthest points was 12 mm. The size of the two smaller loops was five mm, and the width was four mm. The ends of the bar are longer than the standard GTPBs for an improved engagement in the lingual attachments (Figure 1). The size of the middle loops of the GTPB was seven mm, and the width was six mm. The extended length of the bar except for the ends was 61 mm.

The ZTPBs and the prefabricated GTPBs were bent to be passive in horizontal, vertical, and sagittal planes and adjusted to the same template by an experienced orthodontist to get the same conditions for feasible measurements (Figures 2 and 3). On the template, the intermolar distance was 34 mm, and the height of the palatal vault was 13 mm.

After the optimal shape was fabricated, the ZTPBs were stress-relieved for 15 seconds under a continuous current at level 5 using a Memory Maker (Forestadent, Pforzheim, Germany). Before activation of the bars, their passivity was measured at 0° of inclination of the attachments in the measuring apparatus (Figure 4). Even though they were adjusted to be passive, the measured maximum moments were ~200 cN mm and maximum forces were ~10 cN. The bars were therefore readjusted and measured until they were totally passive. Then each end of the 20 passive bars was symmetrically activated by 10 mm in the sagittal plane using a millimeter template (Figure 3). The fully activated bars were inserted into the vertically positioned lingual attachments of the measuring apparatus (Figure 4), and three consecutive measurement steps were performed on each bar. The first measurement was taken at 0° deactivation, where the vertically positioned lingual attachments were parallel to each other (Figure 4). After manually altering the inclination to 5° in a clockwise direction at the right attachment (mesial out, distal in) and 5° in an anticlockwise direction at the left attachment (mesial out, distal in), the second measurement was taken (5° of deactivation). The third measurement was taken in the same way at 10°. After the third measurement, the bar was removed from the attachments, and the same method was implemented for the other bars.

The measuring apparatus, a computer-based strain gauge system, consisted of two units representing the left and right first molars of the upper arch (Figure 4). To simulate the clinical scenario, lingual attachments were placed on both units. The distance between the lingual attachments on the measuring apparatus was 34 mm. The attachments were fastened to the movable clutches, which had strain gauge sensors. The attachments were placed vertically, parallel, and facing each other on the same plane. The inclinations of the attachments were manually changed to the desired degree at each step of measurement, and it was possible to read the degree of this change from a scale connected to the clutches on both the left and right units (Figure 4). The sagittal (mesiodistal) and horizontal forces were measured by means of four force recorders, and the moments were measured in their corresponding planes by means of two moment recorders. After each measurement, the analog signals recorded by the measuring amplifiers were digitized. Forces and moments were read into a computer.

In the computer assessment, moments in the clockwise direction were read as plus (+), moments in anticlockwise direction as minus (−), palatal-directed contractive horizontal forces as (−), buccal-directed expansive horizontal forces as (+), mesial-directed sagittal forces as (−), and distal-directed sagittal forces as (+).

Statistical methods

Statistical analysis included calculation of means and standard deviations for forces and moments for both types of transpalatal bars at each angle of deactivation. Analysis of variance (ANOVA) tests were performed to analyze the influence of the type of bar and the extent of deactivation on the forces and moments of rotation measured. *t*-Tests were used to verify significant differences between the ZTPB and the GTPB as well as between the different degrees of deactivation.

RESULTS Return to TOC

The two-way ANOVA tests showed a significant influence of the design of the transpalatal bars as well as the extent of deactivation on the horizontal forces and the moments of rotation. However, the sagittal forces did not differ. A one-way ANOVA test showed a highly significant influence of the extent of deactivation on the horizontal forces and moments of rotation for both bar designs.

t-Tests performed between the ZTPB and the GTPB for each angle of deactivation measured (0°, 5°, and 10°) showed that at 0° of deactivation, the moments at either side differed significantly ($P = .02$). However, at 5° of deactivation only the moment at the right side differed significantly (*P* = .04). The horizontal forces at either side differed highly significantly (*P* < .01) at 5° and 10° of deactivation.

Both types of bars produced the largest moments at full activation (0°). The moments produced by the GTPB were larger than those produced by the ZTPB at full activation and at 5° of deactivation. At full activation, the ZTPB showed statistically insignificant expansive horizontal forces. With increasing deactivation, both types of bars showed significantly increasing contractive forces between 0° and 10° of deactivation, but those of the ZTPB were statistically significantly lower. The variability of the sagittal (mesiodistal) forces of the GTPB was higher than those of ZTPB at each angle of deactivation (Table 1).

DISCUSSION Return to TOC

According to Newton's first law of biomechanics a body will remain at rest or continue to move at a constant velocity unless acted on by some force. This states that the body is in equilibrium under these conditions. In an orthodontic system, according to this law, the sum of all forces and moments must be zero.[21]

Burstone[22] categorizes the force system acting on the individual teeth into six geometries, by dividing the entire arch into two-tooth segments. Symmetrically mesial-in, distal-out rotated left and right upper molars are acting as in geometry 6: same degree of angulation in contrary directions. If the central loop of the bar and the related horizontal forces are not considered, during derotation of symmetrically rotated left and right molars by using transpalatal arches, equal and opposite moments of rotation will be produced without creating sagittal (mesiodistal) forces (Figure 5a) as in the sixth geometry of Burstone. If the moments on both sides are not exactly the same, equal and opposite sagittal forces will be produced as in Burstone's geometry 5. The sagittal force will be mesial where the moment of derotation for mesially rotated molars is larger (Figure 5b).

As the result of some asymmetric adjustment of the transpalatal bar, it is impossible to produce equal moments in clinical practice, even if the molars are symmetrically rotated. Unequal moments will create some sagittal forces in the contrary direction as explained above. Although the bars were adjusted on a template to be totally passive in all three planes by an experienced clinician in our study, small, but presumably clinically significant, moments and forces were measured, confirming other studies on transpalatal bars.[3,9,23]

The optimal moments of rotation individually depend on the root surface area and conditions of the tooth-supporting tissues. Small, continuous forces and a large working range may be desired during orthodontic treatment. Stainless steel and heat-treated Elgiloy wires are comparable materials with similar modulus of elasticity.[24,25] By changing the elastic properties of the bars, smaller moments and a larger working range can be achieved. Increasing the length of the wire will decrease its strength, whereas its springiness will increase as the cubic function of the ratio of the length, and its range will increase as the square of the ratio of the length. This will lower the load-deflection rate and make the forces more constant and precise.[26] The extended length of wire of the GTPB in this study was 30% shorter than that of the ZTPB. The ZTPB produced lower and more constant moments of derotation. Both types of bars showed their largest moments at full activation.

One of the undesired side effects of symmetrical derotation of upper molars by using transpalatal bars is contraction produced by palatally directed horizontal forces.[2,3] At the beginning of the derotation (0° of deactivation), when both bars are at the full activation in the attachments, the mesially directed central loop of each bar opens itself. By following derotation of the molars (5° and 10° deactivation) the central loops close themselves ~ one mm. As a result of this change at the central loop, the initial horizontal forces are expansive, and the magnitude of contractive forces increases with increasing deactivation. The two small, distal-directed loops of the ZTPB give the bar obvious flexibility, which makes the engagement into the attachments easier with less activation loss. At the beginning of derotation, these small loops show less closure; however, during derotation, when the central loop is closing, each loop opens itself ~ 0.5–1 mm. This enables the ZTPB to produce less contractive forces during derotation of molars. In our measurements, the measured horizontal forces produced by the ZTPB were statistically significantly less contractive at 5° and 10° of deactivation than those produced by the GTPB. At full activation of the bars (0° of deactivation), the ZTPB produced low expansive forces, which were not statistically significant. At 10° of deactivation, where each end of the bars was parallel to the inclination of the attachments into which they were inserted, the most contractive forces were produced. This result indicates that control appointments are required during derotation of upper molars, and the bars should be removed and made passive as soon as the molars are derotated. To compensate for contraction during derotation of molars by transpalatal bars, mesially directed loops should be used, and some expansive force may be bent into the transpalatal bar depending on the transverse relationship of the upper and lower molars in each clinical situation.

CONCLUSION Return to TOC

Compared with the conventional GTPB, the ZTPB seemed to show some clinically relevant advantages. The lower load-deflection rate permits lower initial moments at full activation and less or no reactivation during derotation. The developing horizontal contractive forces produced during deactivation were lower. Thus, less compensation is needed. Eventual mesial forces that occur can be effectively counteracted by the simultaneous use of a high-pull headgear. Part II of this study shows the clinical efficiency of the ZTPB.

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TABLE 1. Mean Values of the Measured Moment at Left and Right Attachments, Horizontal Forces at Left and Right Attachments, and *P* Values. Three Consecutive Measurement Steps Were Done When the Attachments Were at 0°, 5°, and 10° of Deactivation

	Moment Left (cN mm)[a]			Moment Right (cN mm)			Horizontal Force Left (cN)			Horizontal Force Right (cN)		
	ZTPB	GTPB	*P*	ZTPB	GTPB	*P*	ZTPB	GTPB	*P*	ZTPB	GTPB	*P*
At 0° of deactivation	−2322	−2976	.02	2381	2917	.02	19	−7	NS[b]	23	2	NS
At 5° of deactivation	−1373	−1566	NS	1344	1701	.04	−5	−55	<.01	−4	−51	<.01
At 10° of deactivation	−370	−368	NS	316	552	NS	−28	−87	<.01	−28	−86	<.01

[a] In the computer assessment, moments in the clockwise direction were read as plus (+), moments in anti clockwise direction as minus (−), palatally directed contractive horizontal forces as (−) and buccally directed expansive horizontal forces as (+).
[b] NS indicates Not significant where $P \geq .05$.

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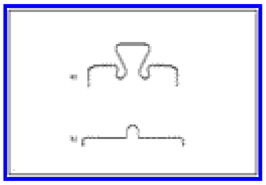
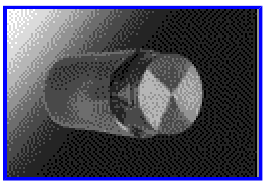


Click on thumbnail for full-sized image.

FIGURE 1. a.) Occlusal view of a Zachrisson-type transpalatal bar. The bar is hand made from a 0.036-inch (0.9 mm) Blue Eligiloy wire, has longer double wire ends to secure improved engagement to the lingual sheaths and has three loops: one, a mesially directed larger and longer central loop and two small, distally directed loops on either side of the central loop. b.) The prefabricated Goshgarian-type transpalatal bar is made from 0.036-inch stainless steel. It has one mesially directed central loop. For this study, the distance between the ends was 53 mm for both bar designs



Click on thumbnail for full-sized image.

FIGURE 2. The same adjustment was made to each of the bar designs by the use of a template with an intermolar distance of 34 mm and a palatal vault height of 13 mm.

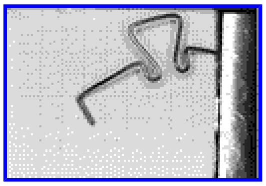


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FIGURE 3. Each end of the bars was symmetrically activated by 10 mm.

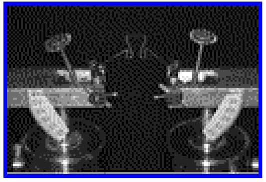

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FIGURE 4. The measuring apparatus, a computer-based strain gauge system, measures the forces and moments produced at left and right lingual attachments during deactivation of the transpalatal bars.

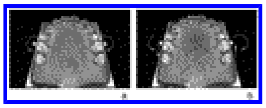

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FIGURE 5. Model showing equal but opposite moments produced during derotation of symmetrically rotated molars. No sagittal forces are produced (a). Model showing equal, but opposite, sagittal forces produced during derotation of asymmetrically rotated molars or as a side effect of asymmetrically bent transpalatal bar. The sagittal force will be mesial on the side with the larger derotation moment (b)

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