Assessment of Transpalatal Arch Activations: A Comprehensive Review of In Vitro Studies

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Abstract: The biomechanical understanding of the removable transpalatal arch (TPA) is complex because it represents a two-bracket system that is constrained at both ends. This system is defined as statically indeterminate because some of the unknown forces and moments cannot be calculated from the force and moment equilibrium formula. No previous studies reviewed this aspect. The aim of this comprehensive review was to assess different activation of transpalatal arch in vitro studies.

A review of the literature was carried out using the following electronic databases: MEDLINE via PubMed, EMBASE via Ovid, LILAC, Scopus and Web of Science (ISI).

A total of 205 papers were selected if they reported analysis of transpalatal arch activation. A final number of 7 studies met the inclusion criteria and were included for analysis. The types of activation with the transpalatal arch evaluated in the studies were: torque, derotation and expansion.

The torque and expansion activations were shown in two studies, whereas the derotation activation was described in four studies in the literature. The results indicated that the transpalatal arch activations cannot be accurately evaluated, because of several consistent biases showed in the methodology and results reported in the included studies, as well as the different type of stainless steel and the wideness, height, length of the transpalatal arch. Thus, further research with more homogeneous inclusion criteria and type of activations is needed in next studies.

Keywords: Transpalatal arch, stainless steel, in vitro studies, activation, torque, derotation, expansion.

1. INTRODUCTION

The transpalatal arch (TPA) is an orthodontic appliance mainly used in non-extraction treatment to relieve crowding through molar derotation along with mild transversal dental expansion, inducing an increase of both arch widths and perimeter [1-3]. The TPA is usually made of 0.036-inch stainless steel archwire with a mesially directed loop in the middle [4]. The biomechanical understanding of the removable TPA is complex. It can be compared to a two-bracket system constrained at both ends, thus the same principles of biomechanics regarding the force system delivered by a segment of a 0.016-inch stainless steel wire into two brackets with varying mutual angulations may be considered [5]. The palatal arch is well cinched into the molar lingual sheaths on both right and left sides with elastomeric or stainless steel ligature ties so that the wire can move neither in nor out of the sheaths [4]. Constraining forces that cannot be intuitively predicted are introduced into the system due to the rigidity and fixed length of the TPA [6]. The additional contributions of these forces on the global force system applied may affect tooth movement in such a way as to alter the anticipated tooth response. However, it is difficult to accurately account for all of these contributions that can only be discussed in certain instances. Differently to the one-bracket systems, which deliver clinically measurable forces, the two-bracket systems are defined as “statically indeterminate” because they include some incalculable forces and moments with the equilibrium formulas [5,7]. Static analysis still provides a clinically useful prediction of direction and relative magnitude of the TPA system before the tooth movement beginning.

To define forces and moments of the system, the six geometries described by Burstone and Koenig are used [7-9]. Such measurements represent little more than a so-called pseudoscience, since they will not predict the expected biologic response and the nature of the tooth movement in vivo [7]. The six geometries can only describe the initial force system when the wire
is inserted into the lingual sheaths. Then, the force system will immediately change after the tooth movement beginning. Anyhow, the system of forces applied to the teeth will not radically change, direction and versus remaining fairly similar to the initial situation with the exception of particular cases [10].

The six geometries have been used by Burstone to describe the forces acting when a 0.016-inch round-section wire is placed in two non-lined up sheaths [7] but the general knowledge of these geometries allows for a better understanding of induced movements and treatment achievements with a TPA treatment too. The force systems were analyzed considering the connection between the TPA loop and the lingual sheath not rigid [10-12]. The two molars and the palatal archwire together cannot be considered independent from each other, thus the action on one molar causes an action in the same sense on the other molar with a 50% of the intensity [4].

If the bond were rigid, action on one molar would induce on the contralateral molar an action equal not only in versus, but also in intensity. The problem in calculating the intensity of forces and their moments should not induce to ignore the only calculation that yields an unquestionable result. For instance, the sum of the forces and the moments of a system is always zero, as expressed by statics equations. This means that the system must always reach equilibrium. The equilibrium is obtained directly if the force system acting on the TPA is composed of equal and opposite moments. In the other cases, equilibrium is indirectly reached through the developing of a couple of forces generating a moment which brings the sum of forces and moments composing the system back to zero. This couple of forces can generally be considered as sagittal in the case of rotation, vertical in the case of torque activation, and transversal in presence of expansion, but the activation can include more than one movement, and this should be previously expected in the orthodontic treatment with TPA. The purpose of this comprehensive review was to assess the main different types of activation of the TPA evaluated in vitro, thus to clarify some of the biomechanical aspects regarding the TPA clinical application.

2. MATERIALS AND METHODS

A literature search was conducted to identify studies with the evaluation in vitro of the main activations performed with TPA orthodontic appliance.

The web search was carried out using MEDLINE via PubMed, EMBASE via Ovid, LILAC, Scopus and Web of Science (ISI). The research has been done with the following search terms: transpalatal bar, transpalatal arch, transpalatal [All Fields] AND (bar [All Fields] OR arch), (transpalatal [All Fields] AND bar [All Fields]) AND ("evaluation studies" [Publication Type] OR "evaluation studies as topic" [MeSH Terms] OR "quantitative evaluation" [All Fields]). phy" [Mesh] AND "Humans" [Mesh]. Additional studies were taken from reference lists of previous review articles, and citations of relevant original articles were screened. The "related articles" tool was used to improve the study on PubMed, and references of included studies were checked by a research librarian. Unpublished studies, gray literature or studies not published in the English language were excluded. The last search was performed on February 21, 2018.

2.1. Inclusion Criteria and Data Extraction

Two reviewers performed the literature search. A full-text version was obtained for the studies considered adequate on the basis of the abstract and for those articles where the abstract was inconclusive. All the manuscripts were then independently assessed by the two reviewers. Studies were selected if they reported a quantitative analysis of TPA activation evaluated with in vitro methods (Table 1).

Studies that did not match the inclusion criteria in this second selection phase were excluded. Any disagreement on the eligibility of included studies was resolved through consensus.

To compare the quantitative evaluation of the different type of activation, we tried to uniform the type of TPA considered, choosing appliances with a similar design, length, height and wideness. Also, the center of resistance reported in the studies was considered and reported in Table 1 to evaluate the different forces reported taking into account this important parameter too.

To compare the forces measured for the three types of activation considered (torque, derotation, expansion) we uniformed the different unit of measure choosing one of the variables used and converting all the others. Moreover, to assess the amount of activation, we have converted all the different activation and considered a standard of 10° activation (Table 2).
Table 1: Characteristics of Included Studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Provenience</th>
<th>Type of Movement</th>
<th>Measure Method</th>
<th>Arch Design</th>
<th>Arch Material</th>
<th>Diameter</th>
<th>Width</th>
<th>Height</th>
<th>Length</th>
<th>Distance Center of Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baldini &amp; Luder</td>
<td>1982</td>
<td>Switzerland</td>
<td>Symmetrical buccal Root torque</td>
<td>Torque gauge</td>
<td>Gosgharian-type TPA with a U middle loop</td>
<td>Stainless steel</td>
<td>0.9 mm</td>
<td>32.2 mm</td>
<td>17.6 mm</td>
<td>NS</td>
<td>8 mm</td>
</tr>
<tr>
<td>Ingervall et al.</td>
<td>1996</td>
<td>Switzerland</td>
<td>Symmetrical derotation</td>
<td>Computer-based strain-gauge measuring system</td>
<td>GAC prefabricated TPA with a middle loop</td>
<td>Stainless steel</td>
<td>0.036 inches (0.91 mm)</td>
<td>NS</td>
<td>NS</td>
<td>53 mm</td>
<td></td>
</tr>
<tr>
<td>Hoederath</td>
<td>2001</td>
<td>Germany</td>
<td>Symmetrical expansion - Symmetrical distal rotation - Unilateral distal tipping - Symmetrical buccal root torque</td>
<td>Orthodontic Measurement and Simulation System (OMSS)</td>
<td>Gosgharian-type TPA with MIA palatal arch system (3M Unitek®)</td>
<td>Stainless steel</td>
<td>0.036 inches</td>
<td>30 mm</td>
<td>18 mm</td>
<td>NS</td>
<td>6.5 mm</td>
</tr>
<tr>
<td>Gündüz et al.</td>
<td>2003</td>
<td>Austria</td>
<td>Symmetrical molar derotation and distalization</td>
<td>Computer-based strain gauge</td>
<td>Prefabricated GTPAs (GAC) with a middle loop (height 7 &amp; width 6 mm)</td>
<td>Stainless steel</td>
<td>0.036 inches</td>
<td>NS</td>
<td>NS</td>
<td>53 mm</td>
<td></td>
</tr>
<tr>
<td>Whichchaus et al.</td>
<td>2003</td>
<td>Switzerland</td>
<td>Transversal expansion without torque - Transversal expansion with torque - Rotation</td>
<td>Six-components measuring sensors</td>
<td>Gosgharian-type transpalatal arch</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Geramy &amp; Etezadi</td>
<td>2013</td>
<td>Iran</td>
<td>Unilateral molar rotation</td>
<td>Finite Elements</td>
<td>TPA handmade using a template and a model with bands and lingual sheaths</td>
<td>Stainless steel</td>
<td>0.032 inches</td>
<td>33 mm</td>
<td>13 mm</td>
<td>46 mm</td>
<td></td>
</tr>
<tr>
<td>Sakima et al.</td>
<td>2017</td>
<td>Brazil and Denmark</td>
<td>Symmetrical mesiobuccal + mesiolingual rotations - Asymmetric mesiobuccal + mesiolingual rotations</td>
<td>Force System Identification Machine</td>
<td>TPA handcrafted using a template and a model with bands and lingual sheaths</td>
<td>Stainless steel</td>
<td>0.032 inches</td>
<td>33 mm</td>
<td>13 mm</td>
<td>46 mm</td>
<td></td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

After the search strategies, 105 articles were identified through database searching. 62 were primarily excluded after reviewing the abstracts. 43 full-text were assessed for eligibility, and after screening full texts, 36 were excluded. 7 articles [13-19] were included in the review process. Characteristics and data of the included studies are reported in Table 1 and Table 2.

3.1. Torque

The torque activation was evaluated in 2 studies [13, 15]. In both studies a symmetrical buccal root torque was evaluated; this is a geometry VI according to Burstone and it is the most frequent activation. When activations on the TPA terminal loops are symmetric, with moments equal in intensity but opposite in versus, similar moments will act on the molars, so that the system reaches equilibrium without the developing of vertical forces. In the study of Baldini et al. [13] a Gosgharian-type transpalatal arch with a wideness of 32.2 mm, a height of 17.6 mm and a center of resistance with a distance of 8 mm from the molar attachment was used, while in the study of Hoederath et al. [15] a Gosgharian-type transpalatal arch with a wideness of 30 mm, a height of 18 mm and a center of resistance with a distance of 6.5 mm was considered. The torque moment produced with a buccal activation of 10° was of 0.039 Nmm in the study of Baldini et al. [13] and of 0.0135 Nmm in the study of Hoederath et al. [15]. This difference might be explained by the different position of the center of resistance.
3.2. Derotation

The derotation was evaluated in 5 studies [14, 15, 18-20]; in three of these, the activation was symmetrical [14-16], whereas it was unilateral in two studies [18, 19]. The symmetrical bilateral derotation is the geometry VI of Burstone and it allows obtaining mesiobuccal rotation of both molars without sagittal side effects.

In the study of Ingervall et al. [14] we consider round GAC prefabricated stainless steel TPA for symmetrical derotation of molars. The arch had a diameter of 0.036 inches (0.91 mm) with a middle loop, an arch length of 53 mm and the moment delivered with an activation of 10° was 0.0047 Nm. In this study, for the expansion of 4 mm, a force of expansion of 4.4 N was measured.

In the study of Hoederath et al. [15], Goshgarian-type arch, with a height of 18 mm, a width of 30 mm and a center of resistance at 6.5 mm from attaches of the MIA system showed a moment of 0.026 Nm. In this study, for the expansion of 4 mm, a force of expansion of 4.4 N was measured.

In the study of Gündüz et al. [16], the Goshgarian-type arch was made from 0.036-inch stainless steel and his length was 53 mm; the moment delivered during symmetrical derotation of upper molars was 0.0046 Nm. In the study of Geramy et al. [17], a three-dimensional finite element model was produced with an activation of 1 mm and a moment of 0.026 Nm and horizontal forces of 0.69 N. In the study of Sakima et al. [19] handmade 0.032-inch stainless steel TPA using a specific template and a structured model with bands and welded lingual sheaths was used. The geometry considered is geometry VI according to Burstone, with a moment of 0.0354 Nm and a mesio-distal force of 0.19 N.

3.3. Expansion

The expansion was evaluated in two studies [15,17]. In the study of Hoederath et al. [15] a symmetrical expansion was evaluated using Goshgarian-type transpalatal arches with MIA palatal arch system (3M Unitek®). The arches were made of stainless steel of 0.036 inches in diameter, a wideness of 30 mm and a height of 18 mm: the distance of the center of resistance was assumed at 6.5 mm. In this study, for the expansion of 4 mm, a force of expansion of 4.4 N was measured.

In the study of Wichelhaus et al. [17], a trasversal expansion without torque was evaluated. In this study, the authors used Goshgarian-type transpalatal arch with 5 mm of activation that generated a force of 8 N on the unloading curve.

CONCLUSIONS

The present comprehensive review evaluated studie describing the TPA activation in vitro. The transpalatal arch can be used as an anchorage device as well as an active device for tooth movements. While the forces developed in the different activation are well understood, too many differences regarding the methods of measurements and the evaluation machine, the shape and characteristics of the arch, have to be considered. Thus, many selection and methodological biases may have affected the results because they are relevant when evaluating the quantitative aspects of the forces delivered. Finally,
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further research is needed considering more homogeneous inclusion criteria and type of TPA activations to get more evidence-based results.

AUTHOR’S CONTRIBUTIONS

FdA and MV made contributions to acquisition and analysis of data. RC and ML performed interpretation of data. AJ and VG conceptualized and designed the study and revised the manuscript. All authors read and approved the final version of the manuscript.

REFERENCES


