Torque control in lingual orthodontics with lever arm mechanics: A case report

M. Aravind, MDS¹
G. Shivaprakash, MDS²
G.C. Ramesh, MDS³

The aim of this report is to illustrate treatment mechanics for torque control in lingual mechanotherapy using a lever arm and transpalatal arch (TPA) tab system during en masse retraction of anterior teeth. An 18-year-old female with bimaxillary dentoalveolar proclination with crowding was treated with a lever arm-TPA tab system. The retraction tabs bent into the TPA placed across the maxillary second molars were used as anchorage. The retraction force on the maxillary anterior teeth was applied using lever arm hooks soldered between the lateral incisors and canines on a lingual mushroom archwire. By applying a retraction force to the lever arm hooks, the maxillary anterior teeth experienced greater palatal root movement as compared to the conventional retraction forces applied at the crown level. The tabs, placed high in the TPA, produced a distal tipping moment on the maxillary second molars, reinforcing their anchorage. The retraction force applied to the long lever arm hooks from the TPA tabs at the level of center of resistance (CRes) of anterior and posterior teeth is advantageous mainly in two aspects. First, it reinforces the anchorage, and second, it favors the palatal root movement of anterior teeth, thus obtaining better control over the torque during en masse retraction.

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Understanding and applying basic biomechanical principles in treatment improves the efficiency of appliance systems and simplifies the treatment with minimal side effects. Bodily translation for anterior retraction is achieved either by directly applying a moment and force to an edgewise bracket or by using lever arm mechanics to change the point of force application so that the force passes closer to the center of resistance (CRes).¹,²,³ Retraction of incisors represents a fundamental and critical stage in orthodontic treatment. One of the most difficult challenges to overcome in lingual orthodontics is torque control of the anterior teeth during retraction.¹,⁴,⁵ Other common problems encountered are the vertical bowing effect and the transverse bowing forces during space closure.⁶,⁷

In a lever arm system, the desired tooth movement is achieved by adjusting the length of the lever arm and the point of force application, which is difficult with a labial appliance because of the oral anatomy.¹ However, with a lingual appliance, the lever arm system can ideally be located closer to the center of resistance of the maxillary anterior teeth because of the width and depth of the palate.⁸ Various types of dental micro or mini screw implants have been used...
for anchorage. However, this article describes an approach that uses a lever arm and transpalatal arch (TPA) tab system. This approach is simple to use and provides excellent maxillary anterior torque control compared to conventional methods, in which the moment and force are applied directly to lingual brackets.

Smith and Kurz et al 8,9 reported twelve keys to success in lingual orthodontic therapy: (1) patient selection, (2) bracket placement accuracy, (3) indirect bonding, (4) vertical and transverse control of buccal segments, (5) double over-ties on anterior teeth, (6) buccal and lingual molar attachments, (7) correcting rotations, (8) arch form and archwire sequence, (9) arch wire stiffness and torque control, (10) en masse retraction, (11) light resilient wire for detailing, and (12) gnathological positioner and retention. Other key factors to success include the interbracket distance, the retraction force vector with respect to the CRes of the maxillary anterior segment, the inclusion of second molars into the treatment mechanics, establishing torque before space closure, and segmental mechanics to correct the crowding.10,11

### CASE REPORT

An 18-year-old female patient’s chief concern was maxillary and mandibular anterior crowding with incompetent lips. The cephalometric analysis showed that she had a Class II skeletal pattern with maxillary and mandibular dentoalveolar proclination. The maxilla was slightly prognathic, with an SNA angle of 85°. The mandible was slightly retrognathic, with an SNB angle of 78° and an ANB angle of 7°, exhibiting Class II skeletal pattern (Table 1). The patient had a mesiofacial pattern; she had average vertical facial dimensions, with an FMA of 27°. The upper and lower lip length was normal.

Intraorally, the patient had a Class I malocclusion (Figs 1 and 2) with bimaxillary dentoalveolar proclination. The maxillary and mandibular anteriors showed a crowding of 3 mm and 4 mm, respectively. This crowding was hereditary. The overjet and overbite were both 3 mm.

<table>
<thead>
<tr>
<th>Table 1 Cephalometric measurements</th>
<th>Norms</th>
<th>Pretreatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA</td>
<td>82</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>SNB</td>
<td>80</td>
<td>78</td>
<td>77</td>
</tr>
<tr>
<td>ANB</td>
<td>2</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>N.L point A</td>
<td>0 ± 2 mm</td>
<td>2 mm</td>
<td>1.5 mm</td>
</tr>
<tr>
<td>N.L pog</td>
<td>0 to -4 mm</td>
<td>-11 mm</td>
<td>-12 mm</td>
</tr>
<tr>
<td>FMA</td>
<td>25</td>
<td>27</td>
<td>29</td>
</tr>
<tr>
<td>SN – Go-Gn</td>
<td>32</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>Max 1 – NA</td>
<td>4 mm</td>
<td>10 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td>Max 1 – SN</td>
<td>102</td>
<td>115</td>
<td>101</td>
</tr>
<tr>
<td>Mand 1– NB</td>
<td>4 mm</td>
<td>11 mm</td>
<td>7 mm</td>
</tr>
<tr>
<td>Mand 1– Go-Gn</td>
<td>95</td>
<td>110</td>
<td>101</td>
</tr>
</tbody>
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In order to correct the crowding and improve the facial profile, a removable appliance was selected to maintain the torque control. The appliance was designed to provide a bodily movement of the maxillary anteriors and to correct the overjet and overbite. The patient was also instructed on proper dental hygiene and the importance of continuous wear of the appliance to achieve optimal results.
TREATMENT OBJECTIVES

Seven treatment objectives were identified: (1) decrowding of the maxillary and mandibular anterior teeth; (2) correction of the proclined maxillary and mandibular anterior teeth to achieve lip competency; (3) achieving proper axial inclination of maxillary and mandibular anterior teeth; (4) maintaining the
transverse arch width; (5) maintaining vertical dimensions of face, class I canine, and molar relationships; (6) achieving a stable result; and (7) maintaining esthetics during the treatment.

TREATMENT PLAN

Extraction of all the first premolars was planned to meet the space requirements. As esthetics were of prime concern, lingual mechanotherapy was chosen. Second molar inclusion into the appliance was considered to reinforce the anchorage and to counteract the transverse bowing effects of retraction forces. Initially, segmental mechanics was performed, followed by alignment and leveling with continuous mechanics. Use of long lever arms extending gingivally and soldered to a stainless steel mushroom archwire was designed to increase the counterclockwise moment, thereby achieving maximum torque control of maxillary anterior teeth.

TREATMENT PROGRESS

After completion of laboratory procedures for indirect bonding using the Hiro system, 7th generation Kurz lingual brackets were indirectly bonded to all the permanent teeth except the left maxillary central incisor. This incisor was planned to be included in the appliance at the end of segmental mechanics, after creating space for its alignment. All the first molars were consolidated with second molars using a buccal sectional 0.019 × 0.025-inch stainless steel wire with an omega loop incorporated into it. This reinforced the anchorage and counteracted the undesirable rotation couple that may be generated on the first molar when the retraction forces are applied from the lingual surface of first molars.

To relieve the crowding, individual segmental canine retraction was carried out in the maxillary and mandibular arches with a 0.016-inch stainless steel mushroom archwire (Fig 3). After the initial decrowding of anterior teeth, four months into the treatment, leveling and aligning in both the arches was carried out by continuous mechanics using 0.016-inch followed by 0.017 × 0.025-inch nickel titanium (Ni-Ti) mushroom archwires. After a period of four weeks with
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0.017 × 0.025-inch stainless steel mushroom archwires, en masse retraction was started in both the arches. In the mandibular arch, conventional retraction mechanics was used. In the maxillary arch, lever arm mechanics was planned to control the inclination of anterior teeth during en masse space closure. A lateral cephalogram was taken at the end of the alignment phase with the lever arms soldered to the archwire and tabs bent into the TPA. The lever arms were soldered to the maxillary stainless steel mushroom archwire between the lat-
The length of the lever arm was adjusted to the level of the CRes of the maxillary anterior segment, based on the biomechanical principles involved in managing the retraction force vector (Fig 5e). The retraction tab were bent into the TPA fixed across the maxillary second molars, at the level of molar furcation. Retraction force was applied with an elastomeric chain from the tabs to the lever arms. The retraction force was applied such that the force vector passed through the CRes of the maxillary anteriors and canines on both sides (Fig 4). The length of the lever arm was adjusted to the level of the CRes of the maxillary anterior segment, based on the biomechanical principles involved in managing the retraction force vector (Fig 5e). The retraction tab were bent into the TPA fixed across the maxillary second molars, at the level of molar furcation. Retraction force was applied with an elastomeric chain from the tabs to the lever arms. The retraction force was applied such that the force vector passed through the CRes of the maxillary
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Fig 6  Finishing and detailing.

anterior teeth and at the furcation area of the first maxillary molars. At the end of space closure, some amount of lateral bowing effect on the buccal segment was observed in both the arches. Therefore, finishing and detailing were done with 0.017 × 0.025-inch TMA mushroom archwire with first and second order bends (Fig 6). Later, 0.016-inch Ni-Ti archwires were placed and composite buttons were bonded onto the buccal surfaces of all the canines and second premolars for settling the occlusion with “M” elastics. On completion of treatment, the lingual fixed appliance was debonded and a fixed lingual retainer was bonded from the left second premolar to the right second premolar in both the arches. The duration of treatment was 19 months.

TREATMENT RESULTS

Maxillary and mandibular anterior crowding was relieved by segmental canine retraction. The bimaxillary dentoalveolar proclination was corrected with optimum inclination of maxillary and mandibular incisors, with an interincisal angle of 134 degrees. The use of long lever arm mechanics gave good control over the torque of the maxillary anterior teeth. Competency of the lips was achieved. The maxillary and mandibular arch widths were maintained. The cephalometric measurement showed that the FMA increased by 2 degrees, which was not clinically significant. Clinically Class I canine and molar relationships were maintained post treatment (Figs 7 and 8).

DISCUSSION

One of the most difficult problems to overcome in lingual orthodontics has been the torque control of anterior teeth during retraction. There is a great amount of variation in the type of tooth movement obtained as the positioning of brackets is changed from labial to lingual surface of the teeth. As the occluso-gingival height of force application for en masse space closure is changed, the resultant relationship between the force vector and the CRes of the anterior teeth also changes. When a given amount of retraction and intrusion force is applied to the incisors in labial and lingual systems, the resultant force in the lingual mechanotherapy is pointed further away lingually from the CRes of maxillary incisors when compared with labial mechanotherapy. The retraction force, when applied at the level of lingual brackets, produces a large moment. This results in uncontrolled tipping of maxillary incisors as compared to space
closure with a labial fixed appliance. These limitations can be effectively overcome by making use of lever arm mechanics for space closure and known locations of the C Moody of maxillary anteriors.
Bulcke MMV et al., Yoshida N et al., Pendersen et al., and Aravind M et al. have shown that the instantaneous CRes of the maxillary anterior segment is located 7 mm apical to the interproximal bone level or around 13 mm from the incisal edge of maxillary anteriors in optimal biological conditions (palatal and labial alveolar bone height, root morphology, and other factors). The position of the retraction tabs in the TPA depends on the intrusion or extrusion required in the anterior segment.

The biomechanical response and displacement of six maxillary anterior teeth to a retraction force largely depends on the relationship between the line of action of force and the CRes of the maxillary anterior teeth segment en masse. A force acting through the CRes of the maxillary anterior segment produces a translatory en masse movement of teeth (Fig 5d to 5f). The force not acting through the CRes creates a moment that results in tipping of the anterior teeth segment around the CRot (Fig 5j to 5l). To obtain a translatory movement during retraction, the optimal lever arm-TPA mechanics should be determined.

The point of force application and the line of action of the retraction force are planned using a lateral cephalogram (Fig 4 and 5). By adjusting the length of the lever arm and the position of the retraction tabs in the TPA, the desired line of action of the retraction force with respect to the CRes of the maxillary anterior segment can be established.

The schematic diagram (Fig 5) explains the different combinations of lever arm and TPA systems in the maxillary arch expected during space closure using lingual mechanotherapy. In cases where the retraction is to be performed by translation and simultaneous intrusion, the force is redirected through the CRes of the maxillary anterior teeth segment and tabs in the TPA as close as possible to the palatal plane, away from the CRes of the molar anchoring TPA (Fig 5a and 5d). The retraction force vector is directed towards the occlusal plane as the force vector moves posteriorly. Fig 5c and 5f show a configuration that will result in a translation of maxillary anterior teeth during retraction with an added tendency for extrusion. The correct design of the lever arm-TPA system is chosen based on the needs of the clinical situation.
A lever arm of required length, bent in 0.9 mm stainless steel wire, is soldered onto the mushroom archwire made of 0.017×0.025-inch stainless steel wire between the lateral incisors and canines. The position of tabs in the TPA will depend on the anchorage requirements and the desired direction of the retraction force vector. In this case, lever arm TPA tab mechanics was planned for bodily movement of anterior teeth without any extrusive or intrusive mechanics (Fig 5e). The torque of the maxillary anterior teeth was well controlled with the use of lever arm mechanics, as shown in Table 1. As the anchorage preparation plays a vital role in lever arm TPA mechanics, lingual brackets with sheaths for the TPA can be placed on either maxillary first molars or second molars. When placed on second molars, posterior teeth should be engaged with a sectional rigid wire, and the second molar should be tied to an omega loop. This serves to avoid an undesirable rotation couple that may be generated on the first molar and a transverse bowing effect of the arch wire on the buccal segment during space closure. Further studies are required to determine the efficiency of lever arm mechanics over loop mechanics in controlling the torque of anterior teeth during en masse retraction.

Although lever arm mechanics finds its application mainly in sliding mechanics for en masse space closure, it has other uses also. It can be used for segmental canine retraction with the lever arm bonded onto the canines, to add additional moment in the case of space closure using looped archwires, in patients with generalized marginal bone loss, and for regaining torque in anterior teeth if lost after space closure.

CONCLUSIONS

Optimum control over the anterior torque during en masse space closure or regaining torque at the end of space closure is an important part of orthodontic therapy. Careful consideration of the relative positions of the lever arm and the TPA tabs in relation to the CRes of the anterior teeth is imperative for developing a plan that will minimize the likelihood of negative treatment consequences (torque loss). This case report demonstrates the difficulties encountered in controlling the torque with the conventional retraction mechanics in lingual orthodontics and the solution, in the form of a lever arm TPA tab system. Lever arm TPA mechanics for space closure helped to execute a treatment plan that resulted in a successful esthetic and functional outcome.

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REFERENCES