Poster teeth angulation in non-extraction and extraction treatment of anterior open-bite patients

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Abstract

Background: This study cephalometrically evaluated the posterior teeth angulation changes of anterior open-bite non-extraction and extraction treatment in the permanent dentition, with anterior vertical elastics.

Methods: The sample consisted of initial and final lateral headfilms of 60 patients divided into 2 groups: Group 1 consisted of 30 patients treated with non-extraction with an initial mean age of 15.26 years and treated with fixed appliances for a mean period of 2.46 years. Group 2 consisted of 30 patients treated with extractions, with an initial mean age of 14.03 years, and treated with fixed appliances for a mean period of 2.49 years. Within-group treatment changes were evaluated with paired t tests. Results were considered statistically significant at P < 0.05.

Results: The mandibular posterior teeth were significantly uprighted in both groups with both treatment protocols.

Conclusions: Correction of anterior open bite with either non-extraction or extractions with continuous archwires and vertical anterior elastics uprights the mandibular posterior teeth.

Background

Open-bite treatment should ideally be performed during the deciduous or mixed dentition, when stability of the results is very high [1–3]. When performed during the permanent dentition, treated whether with non-extraction, with extractions, or even orthodontic surgically, there are varying degrees of clinically significant relapse [4–8].

Generally, open-bite malocclusions have some skeletal involvement, presenting divergence of the palatal and mandibular planes [9–13]. Regarding the dentoalveolar characteristics, Kim [14] suggested that the posterior teeth are more mesially angulated in open-bite patients and developed the multiloop edgewise archwire technique, which incorporates distal tip-back bends to the posterior teeth in order to upright them. Anterior vertical intermaxillary elastics are also used to provide the vertical forces to close the anterior open bite [14].

An alternative method to upright the posterior teeth, instead of incorporating tip-back bends on the archwires, is to mesially angulate the posterior teeth accessories and use continuous archwires associated with anterior vertical intermaxillary elastics [14–17]. This procedure may simplify the orthodontic mechanics and provide more patient comfort. It is also speculated that the procedure of uprighting the posterior teeth will provide more treatment stability [14, 17].

Although the principle of intentionally uprighting the posterior either with tip-back bends on the archwires or by mesially angulating the posterior teeth accessories has been developed some time ago, this principle was not generally used [14, 17]. The most common procedure to close anterior open bite, before mini-implant [18–20] and mini-plate [21–23] development, was to use anterior vertical intermaxillary elastics, especially in non-extraction protocols [14–17]. However, it is quite obvious that some uprighting of the posterior teeth may occur even if no tip-back bends are incorporated or the accessories of the posterior teeth are not mesially tipped, due to the action of the elastic forces on these teeth [15–17, 24].

Therefore, the objective of this study is to investigate whether the posterior teeth are able to be uprighted even when no tip-back bends are incorporated or the
accessories of the posterior teeth are not mesially tipped, in non-extraction and extraction open-bite treatments.

**Methods**

This study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo, Brazil.

The study comprised 60 open-bite treated patients of both sexes, selected from the files of the Orthodontic Department at Bauru Dental School, University of São Paulo, divided into two groups: Group 1 consisted of 30 (12 male; 18 female) patients treated with non-extraction, with mean pre- and posttreatment ages of 15.26 (SD = 3.99) and 17.73 (SD = 4.16) years, respectively, and an initial mean open bite of 1.47 mm. Ten patients presented with Class I, 18 with Class II, and 2 with Class III malocclusions. Ten patients underwent maxillary expansion either with hyrax or Haas appliances to correct posterior crossbites or to provide space in the maxillary arch [25, 26]. Group 2 included 30 patients (11 male; 19 female), treated with extractions, with mean pre- and posttreatment ages of 14.03 (SD = 2.70) and 16.53 (SD = 3.12) years, respectively, with an initial mean open bite of 1.93 mm. Fourteen patients presented with Class I, 15 with Class II, and 1 with Class III malocclusions. Twenty-seven were treated with four first premolar extractions, 2 were treated with two first maxillary premolar extractions, and 1 was treated with two first mandibular premolar extractions. Seven underwent maxillary expansion either with hyrax or Haas appliances to correct posterior crossbites or to provide space in the maxillary arch. The main selection criterion was that the patients should present initially an anterior open bite clinically greater than or equal to 1 mm (Fig. 1). Additional criteria were the presence of all maxillary and mandibular teeth up to the first molars and that the patients had been treated non-extraction and with extractions with Edgewise appliances.

In the non-extraction group, treatment was conducted with the standard Edgewise technique, which is characterized by the use of 0.022 x 0.028-in. conventional brackets. For leveling and alignment, the usual wire sequence begins with a 0.015-in. twist-flex or a 0.016-in. nickel-titanium wire, followed by 0.016, 0.018, and 0.020-in. stainless steel round wires. Vertical anterior elastics to correct the open bite usually began to be used when at least an 0.018-in. stainless steel round archwire was inserted. The elastics were used until a positive overbite was obtained. Myofunctional therapy was recommended to correct tongue posture and function, when necessary. The mean treatment time was 2.46 years.

In the extraction group, the appliances used were similar to the non-extraction group. After the extractions, if there were anterior crowding, the canines were initially retracted until the anterior teeth could be aligned. Thereafter, leveling and alignment progressed as in the non-extraction group until a rectangular wire was inserted. Vertical anterior intermaxillary elastics were usually used after insertion of a 0.018-in. round stainless steel archwire. The elastics were used until a positive overbite was obtained. Maxillary and mandibular anterior retraction were performed on the rectangular archwires with elastic chains. Anchorage reinforcement was provided with an extraoral headgear in the maxillary and a lip bumper in the mandibular arch, when necessary. The retention procedures were similar to the non-extraction group. Myofunctional therapy was recommended to correct tongue posture and function, when necessary. The mean treatment time was also 2.49 years.

Two lateral cephalometric headfilms were obtained from each patient at the pre- (T1) and posttreatment (T2) stages. The cephalometric tracings and landmark identifications were performed on acetate paper by a single investigator (M.R.) and then digitized with a DT-11 digitizer (Houston Instruments, Austin, TX). In total, 128 landmarks were identified and 30 measurements were performed (Table 1 and Figs. 2, 3, 4, and 5). These data were stored in a computer and analyzed with Dentofacial Planner 7.0 (Dentofacial Planner Software, Janson et al. Progress in Orthodontics (2017) 18:13 Page 2 of 7
Toronto, Ontario, Canada), which corrected the image magnification factors of the groups. The magnification factors varied from 6 to 10.94%, because the radiographs were taken on different X-ray machines.

Error study
Thirty randomly selected radiographs were retraced, redigitized, and remeasured by the same examiner (M.R.) after a 30-day interval. The random errors were calculated according to Dahlberg’s formula \( (\text{Se}^2 = \Sigma d^2/2n) \) [27], where \( \text{Se}^2 \) is the error variance and \( d \) is the difference between two determinations of the same variable and the systematic errors with dependent \( t \) tests, at \( P < 0.05 \) [28–30].

Statistical analyses
Normal distribution of the variables was evaluated with Kolmogorov–Smirnov tests. Results of this test demonstrated that all variables were normally distributed. Therefore, paired \( t \) tests were used for intra-group comparison to evaluate the treatment changes within each group.

Results were regarded as significant at \( P < 0.05 \). These analyses were performed with Statistica software (Statistica for Windows 10.0; Statsoft, Tulsa, OK).

Results
No significant systematic errors were detected, and the random errors varied between 0.16 (OB) and 4.29 (Mx7.Md7) degrees.

In the non-extraction group, the maxillary second molar was significantly mesially angulated in relation to the BOP. The mandibular premolars and molars were significantly distally angulated with treatment, regarding BOP and the mandibular plane. There were significant

| Maxillomandibular relationship | SNB (*) | SN to NB angle |
|--------------------------------|---------|----------------|
| ANB (*) | NA to NB angle |

Growth pattern

| SN.PP (*) | SN to palatal plane angle |
| SN.GoGn (*) | SN to Go–Gn angle |
| PP.MP (*) | Angle between palatal plane(ANS/PNS) and mandibular plane( go–gn) |
| FMA (*) | Frankfurt horizontal to mandibular plane angle |
| Gonial angle (*) | Ar–Go to Go–Gn angle |

LAFH (mm) Lower anterior face height: distance from ANS to menton

Dental relationship

| Overbite (mm) | Distance between the maxillary and mandibular incisor borders. |

Maxillary teeth mesio-distal angulations

| Mx4.BOP (*) | Long axis (apex to tip) of maxillary 1st premolar to bisected occlusal plane (BOP) |
| Mx5.BOP (*) | Long axis (apex to tip) of maxillary 2nd premolar to bisected occlusal plane (BOP) |
| Mx6.BOP (*) | Long axis (furcation to center of the crown) of maxillary 1st molar to bisected occlusal plane (BOP) |
| Mx7.BOP (*) | Long axis (furcation to center of the crown) of maxillary 2nd molar to bisected occlusal plane (BOP) |

Mx4.PP (*) | Long axis (apex to tip) of maxillary 1st premolar to palatal plane(ANS–PNS) |
| Mx5.PP (*) | Long axis (apex to tip) of maxillary 2nd premolar to palatal plane (ANS–PNS) |
| Mx6.PP (*) | Long axis (furcation to center of the crown) of maxillary 1st molar to palatal plane (ANS–PNS) |
| Mx7.PP (*) | Long axis (furcation to center of the crown) of maxillary 2nd molar to palatal plane (ANS–PNS) |

Mandibular teeth mesio-distal angulations

| Md4.BOP (*) | Long axis (apex to tip) of mandibular 1st premolar to bisected occlusal plane (BOP) |
| Md5.BOP (*) | Long axis (apex to tip) of mandibular 2nd premolar to bisected occlusal plane (BOP) |
| Md6.BOP (*) | Long axis (furcation to center of the crown) of mandibular 1st molar to bisected occlusal plane (BOP) |
| Md7.BOP (*) | Long axis (furcation to center of the crown) of mandibular 2nd molar to bisected occlusal plane (BOP) |

Md4.MP (*) | Long axis (apex to tip) of mandibular 1st premolar to mandibular plane (Go–Gn) |

Md5.MP (*) | Long axis (apex to tip) of mandibular 2nd premolar to mandibular plane (Go–Gn) |
| Md6.MP (*) | Long axis (furcation to center of the crown) of mandibular 1st molar to mandibular plane (Go–Gn) |
| Md7.MP (*) | Long axis (furcation to center of the crown) of mandibular 2nd molar to mandibular plane (Go–Gn) |

Interdental angulations

| Mx4.Md4 (*) | Long axis (apex to tip) of maxillary and mandibular 1st premolars |
| Mx5.Md5 (*) | Long axis (apex to tip) of maxillary and mandibular 2nd premolars |
| Mx6.Md6 (*) | Long axis (furcation to center of the crown) of maxillary and mandibular 1st molars |
| Mx7.Md7 (*) | Long axis (furcation to center of the crown) of maxillary and mandibular 2nd molars |

Table 1 Cephalometric variables

| Table 1 Cephalometric variables (Continued) |
| Md4.MP (*) | Long axis (apex to tip) of mandibular 1st premolar to mandibular plane (Go–Gn) |

Table 1 Cephalometric variables (Continued)

| Md5.MP (*) | Long axis (apex to tip) of mandibular 2nd premolar to mandibular plane (Go–Gn) |
| Md6.MP (*) | Long axis (furcation to center of the crown) of mandibular 1st molar to mandibular plane (Go–Gn) |
| Md7.MP (*) | Long axis (furcation to center of the crown) of mandibular 2nd molar to mandibular plane (Go–Gn) |

Interdental angulations

| Mx4.Md4 (*) | Long axis (apex to tip) of maxillary and mandibular 1st premolars |
| Mx5.Md5 (*) | Long axis (apex to tip) of maxillary and mandibular 2nd premolars |
| Mx6.Md6 (*) | Long axis (furcation to center of the crown) of maxillary and mandibular 1st molars |
| Mx7.Md7 (*) | Long axis (furcation to center of the crown) of maxillary and mandibular 2nd molars |
increases in the interfirst and intersecond premolars and interfirst molar angles (Table 2).

In the extraction group, all maxillary posterior teeth were significantly mesially angulated and the mandibular posterior teeth were significantly distally angulated. Only the maxillary second premolar was not significantly mesially angulated regarding the BOP. There was a significant increase in the intersecond premolar and a significant decrease in the intersecond molar angle (Table 3).

The power of the tests was based on the results of intragroup comparisons of the current investigation. With a standard deviation of 7.94 for the Md6.BOP variable, and a minimum difference of 4.2° to be detected, with 30 subjects in the group, the test power was of 80%.

**Discussion**

**Sample selection and study design**

The specific criterion for sample selection in this study was that the patients presented an open bite of at least 1 mm, which is similar to other investigations [6–8, 13, 31]. No effort was made to include only open bites with predominant skeletal features. Therefore, the mean characteristics of the groups represent the predominant type of patient in an orthodontic practice, and the results are mostly adequate for these patients.

The random errors ranged from 0.16 (over-bite) to 4.29 (Mx7.Md7). The random errors do not significantly compromise the validity of this work, since four landmarks are needed to obtain these angles and some of these landmarks are subjective [32–34]. Therefore, a few random errors of greater magnitude were expected. Similar studies do not mention the random error magnitude [16, 24]. Therefore, probably, they would be similar for the mentioned reasons.

The decision to use non-extraction and extraction patients was because there are some differences in treatment
mechanics between these groups [14–16, 24, 31]. Basic-
ally, when treating non-extraction, the open bite is closed 
only consequent to the anterior vertical intermaxillary 
elastics [13, 14, 16, 35, 36]. In the extraction group, be-
sides the elastics, the open bite is also closed through the 
drawbridge principle and by some mesialization of the 
posterior teeth [35, 37]. Therefore, there was a need to 
know whether these procedures would influence the an-
gulation of the posterior teeth.

Posterior teeth angulation

In the non-extraction group, the treatment changes 
caused a significant mesial angulation of the maxillary 
second molar in relation to BOP (Table 2). This is con-
trary to what would be expected [13, 14]. The explana-
tion may be based on its eruption orientation. Before 
eruption, the second molar crown is usually distally 
angulated, and after eruption, as the teeth occlude, the 
apex moves distally, uprighting it [38, 39]. The patients 
began treatment at a mean age of 15.26 years, in which 
the second molars are still more distally angulated than 
their final position [38, 39]. As the teeth are leveled and 
aligned, it was uprighted by these procedures [15, 16, 24].

In the mandibular arch, all posterior teeth were signifi-
cantly distally angulated with treatment (Table 2). This 
shows that even without intentionally trying to distally 
tip these teeth with tip-back bends in the archwires or 
by mesially angulating the posterior teeth accessories, it 
is possible to upright, at least, the mandibular posterior 
teeth. If uprighting the posterior teeth actually leads to 
more stability, as speculated [13, 14, 16, 17, 24], this may 
have contributed to it in an earlier study with some of 
these patients [6]. Therefore, the principle of uprighting the 
posterior teeth can be partially accomplished even 
without the mentioned procedures [13–16, 24]. This 
uprighting may also be seen as a necessary dentoalveolar 
change to compensate for the divergent palatal and 
mandibular planes that are usually associated with open-
bite characteristics [40].

The mandibular premolars distal tipping significantly 
increased the interpremolar and interfirst molar angles 
(Table 2). However, the mandibular second molars distal
Interdental angulations

Mandibular teeth mesio-distal angulations

Maxillary teeth mesio-distal angulations

Conclusions

The conclusions are the following:

Clinical implications

This study showed that posterior teeth uprighting is usually obtained when using continues archwires and anterior vertical elastics to close anterior open bite, especially in the mandibular arch. However, uprighting of the posterior maxillary teeth is more difficult, primarily in extraction cases. Therefore, mechanical procedures such as the multiloop edgewise archwire technique [13, 14] or mesially angulating the posterior teeth accessories with continuous archwires [15–17, 24] are recommended to increase the possibility of actually uprighting the posterior teeth. If, in fact, this mesial angulation increases treatment stability, this will be a contributing factor. Nevertheless, despite some clinical evidence that uprighting the posterior teeth will increase treatment stability, this has yet to be investigated.

The conclusions are the following:

Premolar and molar mesial tipping and significantly increased the intersecond premolar and intersecond molar angles, respectively (Table 3). However, the mandibular first molars distal tipping was not enough to overcome the maxillary first molars mesial tipping and significantly increase the intermolar angles.

Clinical implications

This study showed that posterior teeth uprighting is usually obtained when using continuous archwires and anterior vertical elastics to close anterior open bite, especially in the mandibular arch. However, uprighting of the posterior maxillary teeth is more difficult, primarily in extraction cases. Therefore, mechanical procedures such as the multiloop edgewise archwire technique [13, 14] or mesially angulating the posterior teeth accessories with continuous archwires [15–17, 24] are recommended to increase the possibility of actually uprighting the posterior teeth. If, in fact, this mesial angulation increases treatment stability, this will be a contributing factor. Nevertheless, despite some clinical evidence that uprighting the posterior teeth will increase treatment stability, this has yet to be investigated.

Conclusions

The conclusions are the following:

Tipping was not enough to significantly increase the intersecond molar angles.

In the extraction group, the treatment changes caused significant mesial angulation of all the maxillary teeth (Table 3). This is most likely due to the extraction mechanics that may have allowed some mesialization of these teeth, through mesial tipping [41]. Additionally, for the second molars, the eruption orientation may have also contributed to a certain amount, as explained for the non-extraction group.

In the mandibular arch, all posterior teeth were significantly distally angulated with treatment (Table 3). The same explanation given to the non-extraction group applies here. Additionally, it has to be emphasized that despite some tendency that the posterior teeth have to mesially tip during space closure [41], the mechanics with vertical elastics was able to overcome it and distally tip them.

The mandibular second premolar and molar distal tipping was able to overcome the maxillary second premolar and molar mesial tipping and significantly increased the intersecond premolar and intersecond molar angles, respectively (Table 3). However, the mandibular first molars distal tipping was not enough to overcome the maxillary first molars mesial tipping and significantly increase the intermolar angles.

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The mandibular second premolar and molar distal tipping was able to overcome the maxillary second premolar and molar mesial tipping and significantly increased the intersecond premolar and intersecond molar angles, respectively (Table 3). However, the mandibular first molars distal tipping was not enough to overcome the maxillary first molars mesial tipping and significantly increase the intermolar angles.

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The mandibular second premolar and molar distal tipping was able to overcome the maxillary second premolar and molar mesial tipping and significantly increased the intersecond premolar and intersecond molar angles, respectively (Table 3). However, the mandibular first molars distal tipping was not enough to overcome the maxillary first molars mesial tipping and significantly increase the intermolar angles.
• Correction of anterior open bite with either non-extraction or extractions with continuous archwires and vertical anterior elastics uprights the mandibular posterior teeth.
• However, there is also mesial angulation of the maxillary posterior teeth with this mechanics.
• Therefore, additional mechanical procedures should be used to increase posterior teeth uprighting in open-bite treatment, especially in the maxillary arch.

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Authors’ contributions
MR contributed to the data collection, statistical analyses, and manuscript draft. GJ is the research supervisor, contributed to the statistical analyses and English revision, and is the project idealizer. VL and FV contributed to the writing of the discussion. DG contributed to the data checking, manuscript draft, and corrections. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Ethics approval and consent to participate
This study was approved by the Ethics in Research Committee of Bauru Dental School, University of São Paulo.

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