Effects of maxillary molar intrusion with zygomatic anchorage on the stomatognathic system in anterior open bite patients

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SUMMARY The aim of this study was to evaluate the effects of intrusion of the maxillary posterior teeth with zygomatic anchorage on the dentofacial system, on electromyographic (EMG) activity of the masticatory muscles, and on vibration of the temporomandibular joint. The study sample consisted of 19 subjects (13 females, 6 males) with a mean age of 17.7 years. Lateral cephalometric and posteroanterior (PA) radiographs, EMG, and electrovibratographic (EVG) records were obtained before (T0) and after (T1) intrusion. Paired t- and Wilcoxon signed ranks tests were used for statistical evaluation. Maxillary molar intrusion of 3.37 ± 1.21 mm was obtained with a force of 400 g in an average period of 6.84 ± 1.64 months. At T1, all measurements showed that facial growth direction, ANB angle, convexity, and overjet were decreased (P < 0.05). SNB angle, facial depth, and overbite were significantly increased (P < 0.05). Upper lip-E plane distance was increased (P < 0.05). Evaluation of the PA radiographs showed that the right and left molar reference angles were unchanged. EMG and EVG analysis showed that the stomatognathic system at T0 was maintained at T1. Intrusion of the maxillary posterior teeth with zygomatic anchorage is an effective treatment alternative for anterior open bite correction.

Introduction

An open bite is one of the main symptoms of an overall dentofacial deformity. Most subjects with an anterior open bite (AOB) are characterized by overeruption of the maxillary molars (Schudy, 1965). When orthodontic or surgical intrusion of the overerupted maxillary teeth is performed, the mandible rotates, resulting in open bite closure (Bell, 1980).

Intrusion of the molar teeth with traditional orthodontic mechanics is difficult. The multiloop edgewise archwire has been recommended for open bite closure in non-growing patients, but with this approach, the correction is achieved mainly through extrusion of the incisors without skeletal change (Kim, 1987; Kim et al., 2000).

Until recently, there was no orthodontic approach for predictable intrusion of the maxillary posterior teeth in non-growing patients. Skeletal anchorage has been suggested for the orthodontic movement of teeth (Ödman et al., 1988; Costa et al., 1998; Kokich, 2000).

Due to increased interest in the functional aspects of the stomatognathic system, diagnosis of malocclusion and evaluation of the results of orthodontic treatment should not be restricted only to clinical and cephalometric evaluation. Facial musculature is directly and intimately related to the development of malocclusions; its correct functioning is fundamental in obtaining equilibrium of the stomatognathic system and treatment planning.

Electromyographic (EMG) analysis of the masticatory muscles, which has good reproducibility, provides useful data regarding the functional impact of morphological discrepancies and permits functional evaluation of treatment of occlusal relationships (Ferrario et al., 1999; Alarcón et al., 2000). Currently, many areas of health care, such as medicine, physiotherapy, and speech therapy include superficial EMG examinations to assist in diagnoses, establishing a more accurate prognosis and accompanying muscular performance during various types of treatment. Despite its usefulness, no studies have evaluated the behaviour of these muscles in patients with an AOB treated with intrusion of the maxillary posterior teeth with zygomatic anchorage.

With developing technology, orthodontists must evaluate more than subjective findings (e.g. palpation and auscultation) when evaluating the temporomandibular joint (TMJ). There is a need to objectively assess the patient’s joint health and document both pre-treatment conditions and the response to treatment.

Electrovibratography (EVG) is a method to objectively evaluate the TMJs and identify vibration patterns that help to distinguish primary TMJ dysfunction from other painful conditions. This method is the electronic recording of TMJ sounds that has a high specificity. TMJ sounds are frequently found among temporomandibular joint dysfunction (TMD) patients (Ishigaki et al., 1992; Mazzetto et al., 2008). It has been reported that certain groups of TMD patients show a higher incidence of TMJ sounds (Agerberg and Carlsson, 1975; Mazzetto et al., 2008), and it is important to demonstrate the diagnostic specificity and sensitivity of these sounds (Elfving et al., 2002).
The aim of this study was to evaluate the effects of intrusion of the maxillary posterior teeth with zygomatic anchorage on the dentofacial system, on EMG activity of the masticatory muscles, and on joint vibration analysis of the TMJ in AOB patients.

Subjects and methods

This research was approved by the ethics committee of Hacettepe University (LUT 06/90-4).

Subject selection

This study included 19 patients (13 females, six males) with a mean age of 17.7 years (range: 13.1–25.9 years). Eight patients who had Class I occlusions were treated with upper first premolar extractions and the 11 subjects with a Class II malocclusion with a non-extraction treatment approach. Treatment commenced with intrusion mechanics. At the end of intrusion, brackets were immediately bonded and fixed orthodontic therapy was initiated. At the start of treatment, all patient had an AOB greater than 1 mm; a mean of \(-3.21 \pm 1.37\) mm. Lateral cephalograms and posteroanterior (PA) radiographs were taken before (T0) and after (T1) intrusion. Treatment of the patients and manual tracing of the cephalograms was performed by one author (SA). Twenty-six measurements were made on each lateral cephalogram to assess the dental, skeletal, and soft tissue changes and two measurements on the PA radiographs to assess buccal tipping of the maxillary molars (Figures 1–5).

Surgery

Placing of the miniplates was conducted by the same surgeon (AA). After rinsing the mouth for 1 minute with 0.2 per cent chlorhexidine gluconate, local anaesthetic was infiltrated bilaterally at the zygomatic process areas. A 1 cm vertical incision was made along the zygomatic buttress ending at the mucogingival junction. Using blunt dissection, the zygomatic process of the maxilla was totally exposed. An ‘I’ shaped titanium miniplate (Bollard Zygoma Anchor: Surgi-Tec, Bruges, Belgium, Figure 6) was adjusted to fit the contour of the lower face of each zygomatic process and fixed by two or three bone screws (length 5 or 7 mm) with the long arm exposed to the oral cavity from the incised wound. The wound was closed and...
Figure 3 Measurements used for evaluation of maxillo-mandibular and dental changes. 1-SNA: angle formed by SN and NA, 2-SNB: angle formed by SN and NB, 3-ANB: angle formed by NA and NB, 4-convexity: distance from point A perpendicular to N-Pg, 5-facial depth: angle formed by N-Pg and FH, 6-maxillary depth: angle formed by NA and FH, 7-saddle angle: angle formed by SN and Sar, 8-wits appraisal: the distance between points A perpendicular to OP and B perpendicular to OP, 9-overbite depth indicator (ODI: ‘PD-FH’+‘AB-MD’) ‘PD-FH: angle formed by ANS-PNS and FH’, 10-AB-MP: angle formed by AB and MP, 11-overbite: distance between U1i and L1i in the horizontal plane, 12: overjet: distance between U1i and L1i in the vertical plane.

Figure 4 Measurements used for evaluation of dentoalveolar changes. 1-U1-SN: angle formed by the axial inclination of the maxillary incisor and SN, 2-U1-FH: angle formed by the axial inclination of the maxillary incisor and FH, 3-IMPA: angle formed by the axial inclination of the mandibular incisor and MP, 4-FMIA: angle formed by the axial inclination of the mandibular incisor and FH, 5-U1-HRL: perpendicular distance between U1 and the HRL plane, 6-L1-MD: perpendicular distance between L1 and the MP, 7-U6-HRL: perpendicular distance between U6 and the HRL plane, 8-L6-MD: perpendicular distance between L6 and the MP.

Figure 5 Measurements used for evaluation of buccal tipping changes of the maxillary molar. 1-right molar reference angle: angle formed by right zygomaticofrontal suture (ZR) and right molar reference, 2-left molar reference angle: angle formed by left zygomaticofrontal suture (ZL) and left molar reference.
sutured. During the healing period, instructions were
given to the patients on how to clean the wound area.
Seven days later, the sutures were removed and force was
applied to the miniplates.
When oral hygiene was poor, swelling and cheek irritation
were experienced but recovered following recommendations
for brushing of the miniplate and the surrounding mucosa.
No miniplate failure was observed during treatment. In
those patients that required fixed orthodontic therapy with
maximum anchorage, the miniplate was left in situ until the
end of treatment as anchorage. Otherwise, the miniplate
was surgically removed at the end of intrusion, and fixed
orthodontic treatment was commenced.

Orthodontic treatment and fabrication of the appliance
All patients received a standard, bondable fixed intraoral
appliance constructed from 0.9 mm stainless steel round
wire and adapted 3 mm away from the palate. To serve as a
reference indicator on the radiographic records, a 0.5 mm
stainless steel wire was placed in the acrylic plate (Figure 7).
The intraoral appliance was bonded on the occlusal surfaces
of the maxillary posterior teeth. A 9 mm nickel titanium
closed coil spring (GAC International Inc., Bohemia, New
York, USA) with an intrusive force of 400 g/per side was
applied.

Evaluation of TMJ and masticatory muscles
To evaluate masticatory muscle activity during rest,
maximum clenching and swallowing, EMG records were
obtained with BioPAK records (version 2.03, BioResearch
Associates Inc., Milwaukee, Wisconsin, USA) at T0
and T1.

The environment in which EMG and EVG recordings
were obtained was calm, quiet, and semi-dark. The patients
were seated in a comfortable upright position on an office
chair, with the Frankfort plane parallel to the floor, with
their feet on the floor, and arms resting on their thighs.

Single use bipolar surface electrodes and BioEMG 8
channel amplifier were used to obtain the EMG records
during physiological rest (for 10 seconds), maximum
clenching, and swallowing of saliva. Before placing the
electrodes, the patient’s skin was cleaned with alcohol to
eliminate any grease or other residue. The reference
electrode was positioned over the clavicle and active
differential electrodes on the belly of the masseter (MM),
temporalis anterior (TA), digastricus anterior (DA), and
sternocleidomastoid (SCLM) muscles on both the right
and left sides (Figure 8A). The position of the electrodes
was determined by palpation, and maximum voluntary
contraction was performed to ensure that the muscles were
accurately located. Muscle contractions, recorded during
physiological activity using surface electrodes placed
bilateral, were measured in microvolts (µV). Calibration
values adjusted in the programme (20 µV for rest position
and 200 µV for functional records) were not changed while
taking the EMG records. Differences during function
between the left and right muscle groups were checked and
changes at T0 and T1 were evaluated.

TMJ vibrations were evaluated by EVG at T0 and T1
using the BioJVA system (BioResearch Associates Inc.).
This system, which has piezoelectric accelerometer sensors
that were attached to the right and left TMJs, includes an
amplifier to transfer and record the collected data (Figure 8B).
After positioning the sensors, the patients were asked to
open their mouths as wide as possible and maximum
vertical opening was calculated by subtracting the amount
of the AOB from the distance between the incisal edges of
the upper and lower central incisors. The patient was asked
to open and close their mouth, synchronized with a
metronome working as the opening/closing time circle at
1.5 seconds on the computer screen. Measurements during
opening and closing movements were undertaken separately
for each EVG record. Three regions were selected on the
vibration curve during both opening and closing movement.
The average value was defined as the mean frequency of
these three regions. The results were recorded as total
integral (i), which is the total amount of energy in the
vibration, integral below 300 Hz (i < 300 Hz)above 300 Hz
(i > 300 Hz).

Figure 6 Schematic view of the zygomatic anchorage miniplate used in
the study.

Figure 7 Intraoral appliance used in study for intrusive force application.
Statistical analysis

The cephalometric variables, EMG, and EVG data were analysed using the Statistical Package for Social Sciences, version 16 (SPSS Inc., Chicago, Illinois, USA). The mean, standard deviation, minimum and maximum values were given as descriptive statistics. Normal distribution of permanent variables was investigated using the Shapiro–Wilk test. Variables with a normal distribution were evaluated using paired $t$-tests and those not normally distributed by Wilcoxon signed ranks test. $P < 0.05$ was accepted as statistically significant.

To determine the method error of the radiographic measurement, 10 randomly selected lateral cephalograms and PA radiographs were remeasured by the same author (SA) after 2 weeks. To evaluate the method error, the formula of Dahlberg and intraclass correlation coefficients ($r$) were calculated. The method errors ranged from 0.4 to 0.7 mm for linear measurements and from 0.6 to 0.9 degrees for angular measurements. Intraclass correlation coefficients showed that the lowest correlation (0.867) was for maxillary depth and the highest (0.982) for U1-SN for angular measurements. For linear measurements, the lowest rate was 0.996 for overjet and the highest rate 0.927 for L6-MD.

Results

The AOB was corrected in all patients. This was achieved by counter clockwise rotation of the mandible (on average 4.16 degrees, $P < 0.05$) and maxillary molar intrusion (on average 3.37 mm, $P < 0.05$, Figure 9). Measurements on the PA radiographs showed that the maxillary molars were tipped slightly buccally, which was statistically insignificant (Table 1).

Comparison of the EVG records of the right and left TMJs while opening and closing the mouth at T0 and T1 is shown in Table 2. There were no significant differences between T0 and T1 ($P > 0.05$). Evaluation of EMG rest measurements showed that there was no significant change in the investigated muscles between T0 and T1 ($P > 0.05$; Table 2).

Table 2 shows the comparison of EMG measurements of the muscles at T0 and T1, during clenching. A statistically significant decrease was found only for MM left measurement ($P < 0.05$).

At T0 and T1 during swallowing, both the left and right TA, MM, SCLM, and DA muscle groups showed no significant difference ($P > 0.05$) (Table 2).

Discussion

Skeletal anchorage allows management of some dentofacial deformities. Miniplates that can serve as absolute anchorage for the intrusion of overerupted teeth have been recommended (Costa et al., 1998; Daimaruya et al., 2001; Erverdi and Acar, 2005).

When segmental intrusion is required, the teeth can be grouped using segmental archwires or acrylic blocks which surround the crowns of the teeth. The intraoral appliance used in this study was made of two stainless steel bars with an acrylic block. It was hypothesized that the acrylic block would work as a bite block and thus some of the masticatory muscles would contribute to intrusion (Iscan and Sarisoy, 1997).

Applying an apically directed force to intrude maxillary posterior teeth will tip the molars buccally and impede intrusion. As a lingual force component must be applied to avoid this, two transpalatal bars made of 0.9 mm rigid wire were added to the intraoral appliance in this research. It has been hypothesized that an intrusion appliance that includes a transpalatal arch passing 3–5 mm away from palatal mucosa, similar to that used in the present study, has the additional advantage of an intermittent intrusive force of the tongue on the posterior teeth (McLaughlin and Bennett, 1991) and avoids irritation of the palatal mucosa (Erverdi et al., 2004; Park et al., 2005; Kravitz et al., 2007; Xun et al., 2007) during intrusion.

When evaluating intrusion, an adequate plane of reference is important because changes in these planes during treatment can clinically alter perception of the intrusion obtained (Kiliaridis et al., 1989). A line 7 degrees below the sella–nasion (SN) plane was defined as the horizontal reference line and amount of molar intrusion was measured from U6 to this line. This line helps simulate natural head position and is minimally affected by treatment.

Park et al. (2003), who used an intrusion force of 200–300 g to the upper molars, observed no root resorption. Yao et al. (2004) applied a force of 150–200 g to each tooth during intrusion of the maxillary first and second molars.
molars. Erverdi et al. (2006) and Sugawara and Nishimura (2005) applied a 400 g intrusive force to the posterior segments which they blocked with acrylic. In the present study, similar to other investigations (Sugawara and Nishimura, 2005; Erverdi et al., 2006), an intrusive force of 400 g was used on each maxillary posterior tooth segment.

Approximately 3.4 mm of molar intrusion was achieved in this study in approximately 6.8 months. Sherwood et al. (2002) achieved 2 mm of maxillary molar intrusion in 5.5 months and Erverdi et al. (2004) and Erverdi et al. (2007) 2.6 mm in 5.1 months and 3.6 mm in 9.6 months, respectively.

In the present study, GoGnSN angle was decreased by a mean of 3.8 degrees, FMA angle by a mean of 3.8 degrees, total face height angle by a mean of 3.9 degrees, ANS–Me distance by a mean of 2.8 mm, and upper face height angle by mean of 4.2 degrees ($P < 0.05$). Thus mandibular autorotation occurred due to intrusion of the maxillary posterior teeth. As a result of mandibular anterior rotation, a 2.0 degree increase in SNB ($P < 0.05$) and a 2.4 degree decrease in ANB ($P < 0.05$) were observed. Overbite increased by 4.8 mm ($P < 0.05$) and overjet decreased by 1.7 mm ($P < 0.05$). Similar to other studies (Sherwood et al., 2002; Erverdi et al., 2004), statistically significant decreases were found in wits appraisal, facial depth angle, and convexity.

Posteroanterior cephalometric analysis showed that there were no significant differences between T0 and T1 in right and left side measurements, indicating that use of an intraoral appliance prevents buccal tipping of the posterior teeth.

Many researchers have stated that joint differences should be evaluated in an open bite malocclusion subject even when there are no clinical TMD symptoms (Schellhas, 1989; Castelo et al., 2005). The major problem in treating AOB patients is the loss of centric occlusion of the anterior teeth (Koak et al., 2000). For this reason, anterior mandibular movement guidance is lost and an increasing rate of TMD frequently occurs because of interference from the posterior teeth (Kerstein and Farrell, 1990).

Tanaka et al. (2003) stated that there are dysfunctions in masticatory muscles and TMJs in most of open bite cases and that an unstable occlusion negatively affects stomatognathic system functions. Kuroda et al. (2007) reported successful treatment of a patient with a severe skeletal AOB and TMD by intruding the mandibular molars with titanium screw anchorage. Those authors suggested that molar intrusion with skeletal anchorage decreases...

**Figure 9** Bar charts showing the changes in (A) facial growth direction, (B) dentoskeletal, (C) dental, and (D) soft tissue measurements.
might be a useful treatment option to improve function, occlusion, and facial aesthetics in patients with a severe AOB and TMD.

EMG and EVG analysis permits evaluation of joint behaviour and muscle activity under various clinical conditions, as well as after skeletal dental alterations resulting from intrusion of the maxillary posterior teeth. There are some studies (Umemori et al., 1999; Erverdi et al., 2002, 2004, 2006; Sherwood et al., 2002; Park et al., 2004; Yao et al., 2005; Seres and Kocsis, 2009) that showed intrusion of the maxillary posterior teeth, but the functional effects of this therapy were not considered.

Sounds of TMJ could be the precursor of dysfunction in joints and muscles (Elfving et al., 2002). Different disorders result in different vibration patterns (Oster et al., 1984). It has been reported that subjects with TMJ disorders have a higher vibration energy level compared with healthy subjects of all frequency ranges and when intracapsular disorders in the TMJ develop this become symptomatic, \( i > 250-300 \) Hz of energy increase (Hutta et al., 1987; Kiliaridis et al., 1989; Ishigaki et al., 1993). Mazzetto et al. (2008) stated that individuals with a normal condyle-disc relationship show low vibration energy and underlined that evaluation of joint noises using EVG is important for diagnosis and treatment planning. Christensen and Orloff (1992) reported that repeatability of EVG records is high.

In the present study, it was observed that energy values \( i < 300 \) Hz were significantly higher than those at T0 of \( i > 300 \) Hz. As the study group comprised clinically asymptomatic individuals in terms of TMD, the low frequency energy value at T0 was not unexpected.

After intrusion of the maxillary posterior teeth, differences in total integral, \( i < 300 \) Hz and \( i > 300 \) Hz were significantly higher than those at T0 of \( i < 300 \) Hz and \( i > 300 \) Hz. As the study group comprised clinically asymptomatic individuals in terms of TMD, the low frequency energy value at T0 was not unexpected.

Without considering aetiology, dysfunctions in masticatory muscles such as muscle activity and unbalanced coordination are mostly observed in patients with an open bite (Lowe, 1980), but the relationship between occlusion and muscle functions has not yet been clarified (Lowe, 1980).

The effects of intrusion of the maxillary posterior teeth with zygomatic anchorage on the masticatory muscles were evaluated in this study using surface EMG which has been

### Table 1  Comparison of cephalometric measurements before (T0) and after (T1) intrusion (n=19).

<table>
<thead>
<tr>
<th>Measurement</th>
<th>T0</th>
<th>T1</th>
<th>Difference</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNA angle†</td>
<td>79.32 ± 4.04</td>
<td>79.00 ± 3.59</td>
<td>−0.32 ± 0.88</td>
<td>0.119</td>
</tr>
<tr>
<td>SNB angle†</td>
<td>74.21 ± 5.35</td>
<td>76.21 ± 4.40</td>
<td>2.00 ± 1.91</td>
<td>0.001*</td>
</tr>
<tr>
<td>ANB angle†</td>
<td>5.11 ± 2.81</td>
<td>2.79 ± 2.85</td>
<td>−2.42 ± 1.30</td>
<td>0.001*</td>
</tr>
<tr>
<td>Convexity (mm)††</td>
<td>4.68 ± 3.83</td>
<td>3.21 ± 4.28</td>
<td>−1.47 ± 1.47</td>
<td>0.001*</td>
</tr>
<tr>
<td>Facial depth angle††</td>
<td>83.84 ± 4.51</td>
<td>84.95 ± 4.47</td>
<td>1.11 ± 1.76</td>
<td>0.014*</td>
</tr>
<tr>
<td>Maxillary depth angle†</td>
<td>38.52 ± 3.81</td>
<td>88.00 ± 3.45</td>
<td>−52.52 ± 1.31</td>
<td>0.088</td>
</tr>
<tr>
<td>Saddle angle††</td>
<td>122.31 ± 6.42</td>
<td>121.74 ± 5.89</td>
<td>−0.58 ± 3.25</td>
<td>0.448</td>
</tr>
<tr>
<td>Overbite depth indicator (ODI)††</td>
<td>69.74 ± 4.84</td>
<td>69.16 ± 5.54</td>
<td>0.58 ± 2.43</td>
<td>0.314</td>
</tr>
<tr>
<td>Wits (mm)††</td>
<td>1.89 ± 3.86</td>
<td>0.01 ± 3.68</td>
<td>−1.89 ± 1.94</td>
<td>0.001*</td>
</tr>
<tr>
<td>Overbite†</td>
<td>−3.21 ± 1.37</td>
<td>1.58 ± 1.35</td>
<td>4.79 ± 1.36</td>
<td>0.001*</td>
</tr>
<tr>
<td>Overjet†</td>
<td>5.37 ± 3.53</td>
<td>3.68 ± 2.31</td>
<td>−1.68 ± 2.00</td>
<td>0.002*</td>
</tr>
<tr>
<td>GoGnSN angle††</td>
<td>45.58 ± 7.33</td>
<td>41.79 ± 7.29</td>
<td>−3.79 ± 1.87</td>
<td>0.001*</td>
</tr>
<tr>
<td>FMA angle††</td>
<td>36.32 ± 7.03</td>
<td>33.05 ± 6.91</td>
<td>−3.26 ± 1.56</td>
<td>0.001*</td>
</tr>
<tr>
<td>Total face height†</td>
<td>71.84 ± 7.25</td>
<td>67.89 ± 6.34</td>
<td>−3.94 ± 1.54</td>
<td>0.001*</td>
</tr>
<tr>
<td>Lower face height††</td>
<td>57.05 ± 4.92</td>
<td>52.84 ± 4.63</td>
<td>−4.16 ± 1.71</td>
<td>0.001*</td>
</tr>
<tr>
<td>ANS-Me (mm)††</td>
<td>82.22 ± 3.33</td>
<td>79.44 ± 3.38</td>
<td>−2.82 ± 0.07</td>
<td>0.001*</td>
</tr>
<tr>
<td>Maxillary height†</td>
<td>63.16 ± 4.63</td>
<td>63.58 ± 4.40</td>
<td>0.42 ± 0.21</td>
<td>0.714</td>
</tr>
<tr>
<td>U1-SN angle††</td>
<td>106.21 ± 6.34</td>
<td>106.68 ± 6.03</td>
<td>0.47 ± 3.17</td>
<td>0.523</td>
</tr>
<tr>
<td>U1-FH angle†</td>
<td>113.11 ± 8.93</td>
<td>114.95 ± 6.09</td>
<td>1.84 ± 6.77</td>
<td>0.252</td>
</tr>
<tr>
<td>IMPA†</td>
<td>86.63 ± 7.23</td>
<td>87.89 ± 6.88</td>
<td>−0.74 ± 2.86</td>
<td>0.448</td>
</tr>
<tr>
<td>FMA†</td>
<td>55.74 ± 9.72</td>
<td>57.79 ± 9.09</td>
<td>2.05 ± 3.41</td>
<td>0.017*</td>
</tr>
<tr>
<td>U1-HRL (mm)††</td>
<td>81.89 ± 3.41</td>
<td>81.95 ± 3.39</td>
<td>0.05 ± 1.02</td>
<td>0.826</td>
</tr>
<tr>
<td>L1-MD (mm)††</td>
<td>43.47 ± 3.34</td>
<td>43.74 ± 3.19</td>
<td>0.26 ± 0.56</td>
<td>0.059</td>
</tr>
<tr>
<td>U6-HRL (mm)††</td>
<td>74.68 ± 4.41</td>
<td>71.32 ± 4.20</td>
<td>−3.37 ± 1.21</td>
<td>0.001*</td>
</tr>
<tr>
<td>L6-MD (mm)††</td>
<td>32.05 ± 3.29</td>
<td>31.21 ± 3.33</td>
<td>0.16 ± 0.83</td>
<td>0.429</td>
</tr>
<tr>
<td>Upper lip-E plane (mm)†</td>
<td>−2.26 ± 3.29</td>
<td>−3.00 ± 3.25</td>
<td>−0.74 ± 1.05</td>
<td>0.011*</td>
</tr>
<tr>
<td>Lower lip-E plane (mm)†</td>
<td>−0.05 ± 3.59</td>
<td>−0.47 ± 3.17</td>
<td>−0.42 ± 1.17</td>
<td>0.135</td>
</tr>
<tr>
<td>Right molar reference angle††</td>
<td>73.79 ± 12.05</td>
<td>74.42 ± 11.22</td>
<td>0.63 ± 6.38</td>
<td>0.671</td>
</tr>
<tr>
<td>Left molar reference angle††</td>
<td>75.53 ± 12.85</td>
<td>73.37 ± 13.37</td>
<td>−1.16 ± 7.79</td>
<td>0.526</td>
</tr>
</tbody>
</table>

†Tested with Wilcoxon test.
††Tested with paired \( t \)-test.
*\( P < 0.05\).
shown to be a repeatable method (Burdette and Gale, 1990; Ferrari et al., 1991). Rest EMG values for the MM of 0.5–1.4 μV and for TA of 1.0–1.9 μV are quoted for healthy individuals (BioPak; Ferrari et al., 1993). Normal values stated for DA and SCLM muscles range between 1.0 and 1.5 μV (BioPak). For the participants in the present study, resting EMG values for all muscles at T0 and T1 were higher than these normal values. There were no statistically significant differences between T0 and T1 for DA and SCLM muscles.

There is a converse relationship between vertical dimension and elevator muscle activity (Proffit and Fields, 1983). In open bite cases, muscle activity is expected to decrease because of growth in the vertical direction (Proffit and Fields, 1983; Bakke et al., 1990). However, weak muscle activity may also cause an open bite (Kiliaridis et al., 1989); so an increase of masticatory muscle activity will contribute to long-term stability. The zygomatic anchorage plate and intraoral appliance combination used in this study had a decreasing effect (although not significant) on masticatory muscle activity. Long-term stability and masticatory muscle activity should be evaluated.

It has been stated that TA shows 161.7–181.9 μV and MM 156.8–216.2 μV electric activity when clenching in healthy individuals (Ferrario et al., 1993). In the current research, EMG values of TA and MM muscles were found to be lower than these amounts during clenching. After treatment, except for a slight increase in the right DA muscle, all muscle activity was found to be generally decreased; however, these decreases were not statistically significant. Treatment mechanics and more importantly the
acrylic block included in the intraoral appliance used could have affected muscle activity.

Non-significant changes in EMG activities were also found during swallowing. During swallowing, except for the left TA, all the muscle activity was decreased. In normal individuals, TA and MM work bilaterally during swallowing, with the MM muscle being the most active (BioPak). Because the mouth is closed while swallowing, DA is minimally active (BioPak). In this study, in agreement with the data, TA and MM muscles worked symmetrically, whereas the DA muscle demonstrated high activity, contrary to the literature. This may be due to the decrease in swallowing activity of the tongue during the 6 months of treatment with acrylic blocks. In individuals with an open bite, the tongue is trying to make an oral seal by using the teeth while swallowing. It is accepted that this activity of the tongue in individuals with an open bite causes abnormal swallowing patterns (Stormer and Pancherz, 1999).

There are a number of limitations in the present study: the sample size was small with a large age range, the surface electrodes can detect only myoelectrical activity near the electrode and cannot measure actual physical force production of the muscles, and joint vibration analysis can be affected by external vibrations. However, as EMG and EVG analysis application were non-invasive, patient compliance was good.

Conclusions

Cephalometric measurements showed that the vertical dimension was decreased on average by 3.37 mm due to maxillary molar intrusion. In addition, an average of 4.16 degrees of mandibular anterior autorotation was achieved after intrusion of the maxillary posterior teeth. Intrusion of the maxillary posterior teeth using zygomatic bone anchorage and an intraoral appliance is a successful treatment alternative for open bite correction and has, within the limitations of the recording system used, no recordable effects on the TMJs and masticatory muscles.

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