Ocular correction effects on EMG activity of stomatognathic muscles in children with functional mandibular lateral-deviation: a case control study

A. MONACO, R. CATTANEO, A. SPADARO, P. D’ANDREA*, G. MARZO, R. GATTO

ABSTRACT. Aim This study was conducted in order to determine the ocular correction effects on electromyography activity of anterior temporal, masseter, sternocleidomastoid and anterior digastric muscles in children with functional mandibular lateral-deviation. Methods This study was performed on 32 subjects, aged between 8 and 12 years with functional lateral deviation of mandible and oculo-extrinsic muscular tone disorders. After complete ophthalmologic evaluation and ocular correction prescription, the children were randomly divided into two groups: study and control. In the study group (16 subjects) EMG activity at rest was recorded in the following conditions: with eyes closed; with eyes open; with ocular correction modified through electromyographic control. In the control group (16 subjects) EMG activity at rest was recorded in the following conditions: with eyes closed; with eyes open; with conventional ocular correction. Data were acquired in 15-seconds trial using a SEMG K7 (Myotronic Inc., Seattle, USA), while the subjects maintained rest dental position. Results/Statistics Both groups presented a significative correlation between value of lateral-deviation and the degree of oculo-extrinsic muscular tone disorders (r=0.69). In addition, a significant statistical increase of EMG activity at rest with eyes open in both groups was observed in the anterior temporal left and right. A significant decrease of EMG activity with open eyes was observed only with ocular correction upon electromyographic control (study group). The findings, expressed as Symmetry Index, showed a significant increase of muscles imbalance right/left with conventional methods of ocular correction (p<0.0001). Conclusion The significant worsening in EMG activity, mainly observed with conventional “corrective” lenses, could have an important consequence in clinical diagnostic and therapeutic behaviour because anterior temporal muscles are important in postural position of the mandible. Instead EMG corrective lenses could improve tonus and balance of stomatognathic muscles and, therefore, support the functionality of orthodontic treatment. Moreover, the data suggest an interesting new tool in order to reach an interdisciplinary approach to complex growth disorders represented by functional lateral deviation of mandible and oculo-extrinsic muscular tone disorders.

KEYWORDS: Visual input, Lateral deviation, Masticatory muscles, Postural muscles, Electromyography.

Introduction

Stomatognathic apparatus is a component of the craniomandibular system representing an entrance of external stimuli. The relationship between occlusion, masticatory muscle system [Clark et al., 1993; Kiliaridis et al., 1995] and head posture [Lee et al., 1995; Sandikcioglu et al., 1994] have been recently confirmed. In this complex system, adaptative modifications can be induced by a sensorial dysfunction or by an inadapted stimulation deriving from a discrepancy of contiguous systems information [Oddsson, 1996].

The ocular system and the stomatognathic one are anatomically and physiologically connected. Vision plays an important role in the multi-sensorial process of postural stabilisation: among visual input, the postural one allows to draw a moving object [D’Andrea, 1996], ocular nuclei control the eye position in the orbit; they send fibres to nuclei which control neck and head movements and receive afferences from vestibular nuclei. It has been observed that a modification of ocular proprioception modifies head and body posture [Donaldson et al., 1991;
Ocular proprioception is linked with stomatognathic muscular system: neuromuscular spindles and myotendinous receptors [Rose et al., 1991; Lukas et al., 1994; Rose et al., 1975] of extraocular muscles send afferences to trigeminal and cuneate nuclei [Porter, 1986]. Moreover oculomotor, vestibular, trigeminal and accessorinal nerve nuclei are connected to each other trough the medial longitudinal fasciculus. The role of trigeminal afferences on tonic-postural regulation has been underlined too [Meyer et al., 1976].

Several studies supported anatomical linkage between stomatognathic and ocular systems. TMD patients showed more ocular convergence defects than normal individuals [Monaco et al., 2003]; a similar association has been found in patients with a mandibular functional lateral-deviation [Monaco et al., 2004]. It is also stated that in TMD subjects head rotation (as a compensatory adjustment for the eye dominance) is significantly associated to a mandibular shifting toward the contralateral side [Pradham et al., 1996]. These relationships, recorded by measuring transverse head postural change by means of temporary eye dominance change, have been confirmed [Lin et al., 1996]. Passive soft-tissue viscoelasticity and stretch reflexes in the jaw-closing muscles are involved in mandibular postural stability during locomotion as a consequence of the influence of head support and body posture on the mandibular rest position [Stanley et al., 2003].

Relationship between oculomotors and neck cephaloergic muscles have been reported by Meyer et al. [1976]. These authors showed that desmodontal receptors and temporo-mandibular joint, like sternocleidomatoid, trapezius and cervical muscles are connected with oculomotor muscles. A study confirmed that the alteration of dental occlusion can induce some fluctuations in visual focusing [Sharifi et al., 1998]. The visual input effect on the EMG activity of sternocleidomastoid and Masseter muscles at rest has been proved too [Miralles et al., 1998; Monaco et al., 2006]. Monaco et al. [2006] confirmed that myopic defects can induce some alterations on EMG activity of masticatory muscles.

Therefore, the aim of the present study was to evaluate in study and control group: electromyographic activity of stomatognathic muscles at rest with eyes closed and with eyes open; the effects of ocular correction on electromyographic activity and muscular balance. This knowledge could be clinically relevant in order to evaluate if in subjects with functional lateral deviation the ocular correction could contribute to variations of muscular tone and its symmetry.

**Materials and methods**

The study was performed at the Dental Center of the University of L’Aquila. This study included 32 subjects with functional lateral-deviated mandible selected among children with tooth midline deviation listed to paediatric dentistry clinic for dental care. All the patients presented natural dentition, observable deviation of mandibular and anterior tooth midlines on functional base diagnosed by clinical examination, frontal and basal tele-radiographs. The subjects were chosen according to the following parameters: at clinical examination, deviated chin from mid-sagittal plane (recognized by perpendicular line to horizontal bipupillary and bicommissural lines); at intraoral examination the lack of alignment of upper and lower labial frena, interincisive lines and molars/canine classes asymmetries; at functional examination the presence of deviation of incisor midline in maximal intercuspidation both in centric relation and at rest position, mandibular deviation during opening and noise and tenderness referred to TMJ. The frontal tele-radiograph, taken at open mouth, confirmed symmetry of maxillary and mandibular structures. In order to be considered for the study the following characteristics had to be present.

a) Negative history of orthodontic treatment.

b) Observable deviation of anterior tooth midlines >1.5 mm with alignment at mouth open.

c) Absence of skeletal asymmetry.

d) Absence of any anterior or posterior/lateral cross-bite.

e) Muscular ocular-extrinsic tone alteration.

At first visit all subjects underwent complete ophthalmological and orthoptical evaluation by the same ophthalmologist. The oculo-extrinsic muscular

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**Fig. 1 - Electromyographic control of a subject of the study group with ocular correction through lenses centered and balanced.**
Ocular correction effects on EMG activity of stomatognatic muscles

tone disorders were classified as eso (convergence latent strabismus) and exophorias (divergence latent strabismus) and measured by using cover test and Berens prisms. The values expressed as angle of deviation were measured in prismathic diottries (DP). Among all were selected 32 children with functional mandibular lateral deviation and muscular extrinsic ocular tone disorders, 19 girls and 13 boys, ranging from 8 to 12 years of age, with mean age of 10.1 (sd 1.1) in study group and 9.6 (sd 1.6) in control group (Table 1). No statistical differences were observed in the mean age for the two groups. Therefore all subjects received a prescription for their ocular alterations. The subjects were randomly divided into two groups: study and control. The study group received ocular correction that needed to be balanced upon EMG control at the next visit, the control group received a conventional ocular correction through lenses.

At second visit all subjects were investigated by surface EMG. Recordings were performed by placing bipolar surface electrodes (Instruments Co. Seattle) on the left and right anterior temporal, masseter, sternocleidomastoid and digastric muscles.

During the recordings, EMG was monitored using a system K7 (Myotronics Inc., Seattle, USA). Each subject underwent three recordings of the integrated EMG activity at rest, with eyes open and closed and after ocular correction.

During the first EMG recordings each child (n°32) was asked to keep their eyes closed. During the second EMG recordings each child was asked to keep their eyes open while looking straight ahead and to keep their lips in normal soft contact. During the third EMG recordings the control group children wore glasses for ocular correction through orthoptic examination only, while the study group children lenses centred and balanced through orthoptic evaluation integrated by means electromyographic control (Fig. 1).

Recordings were performed with previous instruction to the children. EMG recording time for each trial was 15 seconds.

Two-samples mean comparison test (t-test) was performed on EMG activity recorded at rest, with and without visual input and with ocular correction, for each muscle.

The EMG values are based on RMS measured in microvolt and using Symmetry Index (Table 1) (right-left / right+left) (SI). SI Values range from 0 to 1 (0 = perfect symmetry).

**EMG recording.** Each patient was seated in a wood chair with headrest in a comfortable stance, and their eyes were closed to avoid environmental input. EMG activity was recorded by K7 Myotronic Inc.–Seattle, Wash, using bipolar surface electrodes at single differential with interelectrode distance of 1 cm. The surface electrodes were affixed with adhesive tape to the skin over the superficial masseter (LMM,RMM), anterior temporal (LTA,RTA), anterior digastric (RDa, LDa) and sternocleidomastoid (LSC, RSC) bilaterally and parallel to the muscle fibers. Eight channel surface electromyographic equipment was used (Myotronics). The signal obtained were amplified, recorded and computed using a clinical aimed software (K7-Myotronics); the Root Mean Square (RMS), expresses in microvolts, was used as amplitude indicator of the signal. EMG of the subjects were examined by the same operator without knowledge of recording purpose.

**Experimental protocol.** The subjects of both groups were analysed with respect to the rate of lateral deviation from tooth midline and electromyographycally examined. Therefore the subjects of the study group wore lenses centred and balanced by means EMG, the control group wore lenses fabricated according to conventional orthoptic evaluation. The EMG values were compared and statistically analysed.

**Statistical analisys.** A paired t-test for independent samples was performed to obtain a comparison between mean and variance values of electromyographic data. Differences with a value of p <.05 and p<.01 were regarded as significant and highly significant. A correlation analysis was performed between the rate of lateral deviation and the DP rate. A correlation coefficient (r) equal or greater than 0.600 was considered significant. A linear regression statistics coefficient was performed between the rate of lateral deviation and the DP rate. To facilitate data introduction in statistic software all absolute values expressed in microvolts (RMS) were multiplied by 10.

**Results**

Table 1 shows the age and sex both in the study group and the control group. Comparison according to the age of the subjects showed no significant differences between groups (t = 1.43; p > 0.05).

Tables 2 and 3 show age, sex, value and direction of mandibular deviation and ocular-extrinsic muscular tone degree of 32 subjects divided in two groups. It is important to notice the significant correlation between value of lateral-deviation and degree of ocular-extrinsic disorders in both groups. In the study group the correlation coefficient was 0.74, in the control group it was 0.65. The two groups combined showed
**Table 1** - Characteristics of subjects in the study and the control groups.

<table>
<thead>
<tr>
<th>Study P. Sex</th>
<th>Age</th>
<th>Control P.</th>
<th>Sex</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Female</td>
<td>10</td>
<td>Female</td>
<td>11</td>
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<tr>
<td>2</td>
<td>Female</td>
<td>11</td>
<td>Male</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>11</td>
<td>Female</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Male</td>
<td>11</td>
<td>Female</td>
<td>8</td>
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<td>Male</td>
<td>10</td>
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<td>6</td>
<td>Female</td>
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<td>Male</td>
<td>9</td>
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<td>Male</td>
<td>10</td>
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<td>9</td>
<td>Female</td>
<td>8</td>
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<td>12</td>
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<td>12</td>
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<td>13</td>
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<td>9</td>
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<td>9</td>
<td>Female</td>
<td>11</td>
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<tr>
<td>15</td>
<td>Female</td>
<td>10</td>
<td>Female</td>
<td>8</td>
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<tr>
<td>16</td>
<td>Male</td>
<td>12</td>
<td>Male</td>
<td>9</td>
</tr>
</tbody>
</table>

**Table 2** - Rate of mandibular lateral deviation and oculo-extrinsic muscular tone defects: study group.

<table>
<thead>
<tr>
<th>Pat. Sex</th>
<th>Age</th>
<th>Lat. dev.</th>
<th>Prism.</th>
<th>Diot.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>9</td>
<td>1.5 mm</td>
<td>Dx</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>11</td>
<td>2.0 mm</td>
<td>Sx</td>
</tr>
<tr>
<td>B</td>
<td>F</td>
<td>11</td>
<td>2.0 mm</td>
<td>Sx</td>
</tr>
<tr>
<td>C</td>
<td>F</td>
<td>12</td>
<td>2.5 mm</td>
<td>Sx</td>
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<tr>
<td>D</td>
<td>M</td>
<td>11</td>
<td>2.5 mm</td>
<td>Sx</td>
</tr>
</tbody>
</table>

**Table 3** - Rate of mandibular lateral deviation and oculo-extrinsic muscular tone defects: control group.

<table>
<thead>
<tr>
<th>Pat. Sex</th>
<th>Age</th>
<th>Lat. dev.</th>
<th>Prism.</th>
<th>Diot.</th>
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<tbody>
<tr>
<td>A</td>
<td>F</td>
<td>12</td>
<td>1.5 mm</td>
<td>Dx</td>
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<td>12</td>
<td>M</td>
<td>9</td>
<td>1.5 mm</td>
<td>Sx</td>
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<td>B</td>
<td>F</td>
<td>11</td>
<td>1.5 mm</td>
<td>Sx</td>
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<tr>
<td>1</td>
<td>F</td>
<td>11</td>
<td>2.0 mm</td>
<td>Sx</td>
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<tr>
<td>C</td>
<td>M</td>
<td>12</td>
<td>2.5 mm</td>
<td>Sx</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>8</td>
<td>3.5 mm</td>
<td>Sx</td>
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</tbody>
</table>

The correlation coefficient is $r=0.69$. Tables 4 and 5 illustrate the mean values, in microvolts, of EMG activity at rest with closed eyes for the anterior temporal, masseter, sternocleidomastoid and anterior digastric muscles respectively of the study and control groups. Tables 6 and 7 show the mean values of EMG activity at rest for the anterior temporal, masseter, sternocleidomastoid and anterior digastric muscles with eyes open in the study and the control groups, respectively. Tables 8 and 9 report the mean values of EMG activity at rest for the anterior temporal, masseter, sternocleidomastoid and anterior digastric muscles with ocular correction in the study and the control group, respectively. Tables 10 and 11 compare the values with eyes closed and open with those of ocular correction and summarise the results of the statistical tests. EMG activity of the anterior temporal increased significantly in children with conventional ocular correction (control group) ($p<0.05$) (Table 11). In the study group children the ocular correction obtained by means
### Table 4 - Mean value and standard deviation of electromyographic activity at rest with eyes closed in the stomatognathic muscles of study subjects.

<table>
<thead>
<tr>
<th>LTA</th>
<th>LMM</th>
<th>RMM</th>
<th>RTA</th>
<th>LSC</th>
<th>LDA</th>
<th>RDA</th>
<th>RSC</th>
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</tr>
<tr>
<td>Mean</td>
<td>20.3</td>
<td>19.5</td>
<td>19.9</td>
<td>17.5</td>
<td>22.9</td>
<td>29</td>
<td>36.5</td>
</tr>
<tr>
<td>SD</td>
<td>(10.5)</td>
<td>(13.0)</td>
<td>(13.7)</td>
<td>(6.7)</td>
<td>(6.4)</td>
<td>(18.1)</td>
<td>(22.7)</td>
</tr>
</tbody>
</table>

LTA = Left Temporalis Anterior; LMM = Left Masseter; RMM = Right Masseter; RTA = Right Temporalis Anterior; LSC = Left Sternocleidomastoid; LDA = Left Digastric; RDA = Right Digastric; RSC = Right Sternocleidomastoid

### Table 5 - Mean value and standard deviation of electromyographic activity with eyes closed in the stomatognathic muscles of control patients.

<table>
<thead>
<tr>
<th>LTA</th>
<th>LMM</th>
<th>RMM</th>
<th>RTA</th>
<th>LSC</th>
<th>LDA</th>
<th>RDA</th>
<th>RSC</th>
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<tr>
<td>Mean</td>
<td>20.5</td>
<td>13.6</td>
<td>11.6</td>
<td>18.9</td>
<td>18.0</td>
<td>17.9</td>
<td>19.4</td>
</tr>
<tr>
<td>SD</td>
<td>(9.4)</td>
<td>(7.0)</td>
<td>(5.1)</td>
<td>(8.0)</td>
<td>(10.9)</td>
<td>(8.6)</td>
<td>(8.2)</td>
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</table>

LTA = Left Temporalis Anterior; LMM = Left Masseter; RMM = Right Masseter; RTA = Right Temporalis Anterior; LSC = Left Sternocleidomastoid; LDA = Left Digastric; RDA = Right Digastric; RSC = Right Sternocleidomastoid

### Table 6 - Mean value and standard deviation of electromyographic activity with eyes open in the stomatognathic muscles of study patients.

<table>
<thead>
<tr>
<th>LTA</th>
<th>LMM</th>
<th>RMM</th>
<th>RTA</th>
<th>LSC</th>
<th>LDA</th>
<th>RDA</th>
<th>RSC</th>
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</tr>
<tr>
<td>Mean</td>
<td>24.5</td>
<td>19.5</td>
<td>18.1</td>
<td>27.9</td>
<td>22.5</td>
<td>30.7</td>
<td>30.6</td>
</tr>
<tr>
<td>SD</td>
<td>(12.4)</td>
<td>(12.3)</td>
<td>(13.2)</td>
<td>(15.1)</td>
<td>(8.5)</td>
<td>(21.5)</td>
<td>(18.5)</td>
</tr>
</tbody>
</table>

LTA = Left Temporalis Anterior; LMM = Left Masseter; RMM = Right Masseter; RTA = Right Temporalis Anterior; LSC = Left Sternocleidomastoid; LDA = Left Digastric; RDA = Right Digastric; RSC = Right Sternocleidomastoid

### Table 7 - Mean value and standard deviation of electromyographic activity with eyes open in the stomatognathic muscles of control patients.

<table>
<thead>
<tr>
<th>LTA</th>
<th>LMM</th>
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</tr>
<tr>
<td>Mean</td>
<td>25.3</td>
<td>13.6</td>
<td>12.0</td>
<td>27.9</td>
<td>19.4</td>
<td>19.4</td>
<td>19.9</td>
</tr>
<tr>
<td>SD</td>
<td>(12.7)</td>
<td>(6.3)</td>
<td>(5.2)</td>
<td>(15.1)</td>
<td>(10)</td>
<td>(8.9)</td>
<td>(8.1)</td>
</tr>
</tbody>
</table>

LTA = Left Temporalis Anterior; LMM = Left Masseter; RMM = Right Masseter; RTA = Right Temporalis Anterior; LSC = Left Sternocleidomastoid; LDA = Left Digastric; RDA = Right Digastric; RSC = Right Sternocleidomastoid

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EMG did not show an increase of muscular values of TA (Table 10).
Table 12 and 13 showed the SI values in the two groups. SI values indicate a less homogeneous behaviour of control group after conventional ocular correction, compared to study group.

**Conclusion**

This study shows the role that visual input plays on the stomatognathic system through its influence on EMG activity.

The significant increase of EMG activity at rest observed in the temporal anterior muscles in 32
subjects of two groups with eyes open compared to eyes closed agrees with previous studies that found a similar effect [Kawamura et al., 1967; Miralles et al., 1998; Monaco et al., 2006; Shahani et al., 1976]. The different pattern of EMG activity of temporal anterior with respect to masseter, sternocleidomastoid, and anterior digastric observed at rest upon variation in the visual input, suggests a differential innervation of stomatognathic muscles. In fact sternocleidomastoid and digastric anterior are innervated by spinal and hypoglossal (XI and XII), while masseter and anterior temporal by trigeminal (V) nerves.

In this experimental study both groups presented a worsening of symmetry with eyes open. In the control group this worsening was significant with the conventional ocular correction (p<0.005). In the study group the use of EMG controlled correction allowed to maintain the right/left balance of closed eyes condition.

These results underline that:

a a change in the visual input induces a modification in the stomatognathic muscles system base tone;
b the correction of ocular proprioceptive defects is often accompanied by a modification of the muscular right/left balance.

Masticatory muscles activity, controlled by trigeminal nerve, is regulated by several inputs coming from proprioception of neuromuscular spindles. These inputs have an important role in the maintenance and modifications of muscular basal tone.

Proprioceptive messages coming from the muscles of the neck are integrated in the central nervous system and they contribute to control the balance and body orientation in the space-time surrounding it [Kavououdias et al., 1999]. Centripetal impulses from the neck proprioceptors muscles cooperate with the labyrinth impulses to promote the oculomotor muscular activity through the cervical-vestibular-ocular reflex [Shinsuke et al., 1995].

Some important encephalic nuclei (trigeminal nuclei, oculomotor nuclei, vestibular nuclei, accessorio nerve nuclei) are integrated in the medial longitudinal fasciculus. Moreover ocular proprioceptive receptors send afferences to trigeminal and cuneate nuclei.

This study confirms the physiologic links of these anatomical structures: a modification of the proprioceptive ocular afferences can be reflected on the stomatognathic one. The three EMG evaluations originated different RMS values as a consequence of the proprioceptive input change. Particularly, the improvement in balancing of extraocular muscle activity often implies a better balance in masticatory muscles tone. The results of the symmetry index confirm this idea, and suggest that conventional ocular correction ignoring the relationship between stomatognathic and oculomotor system fails to give a good head and neck muscular balance, while the use of EMG could increase the integration of the two systems. The significant change in EMG activity, mainly observed after ocular correction, suggests that visual input variations by inadequate lenses could be associated to a worsening of tone and symmetry of stomatognathic muscles, with clinical consequences in both diagnosis and treatment of children with functional asymmetry of the mandible, whose treatment is generally difficult.

The EMG controlled ocular correction in young people with mandible lateromediation could reduce the above mentioned symptoms and be an interesting perspective of our future research.

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subjects and in patients with myogenic cranio-cervical-
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