Effect of the Enveloppe Linguale Nocturne on atypical swallowing: surface electromyography and computerised postural test evaluation

**Introduction**

Swallowing is a neuromuscular mechanism regulated by many nervous reflex arcs. Persistence of child swallowing at the end of dental eruption is called atypical swallowing (AS). This condition is related to a dysfunction of vertical maxillary growth called open bite. The authors treated this malocclusion with the “Enveloppe Linguale Nocturne” (ELN), or tongue positioner, created by Dr. Bonnet. The aim of this work is to evaluate the effect of ELN on swallowing and the postural variation obtained by its use.

**Materials**

Seven patients affected by AS were evaluated. Surface Electromyography (sEMG) testing was performed on each patient with different tongue positions, and swallowing was evaluated with and without the ELN. A surface Electromyograph (Biopack) with 8 channels was used (4 channels for the right muscles and 4 for the left) on 4 groups of muscles: temporals, masseters (MM), submental (SUB) and sternocleidomastoids. On each patient a postural test using a computerised Postural test (Lizard) was also performed.

**Results**

All seven subjects had different results in the sEMG and footrest tests. The sEMG test results indicated that muscle activation and swallowing duration varied greatly with the use of ELN, with a reduction of time of swallow act (p = 0.002) and variation in contraction of muscles. Mean MM activation was higher without ELN than in tests performed with the appliance (p = 0.002). Mean SUB activation was higher with than without ELN (p = 0.0033). ELN has a therapeutic effect on posture too. Computerised postural test without device showed in all patients an alteration of barycentre as well as an elevated oscillatory record (A mmq; V mms). With ELN footrest test shows that ELN induces a Mm activation reduction compared to swallowing test without ELN (P = 0.002) and an increase of SUB activation (P = 0.0033). In the same way with ELN there is a significant reduction of time of swallowing (c.f. oral phase) (P = 0.002). Patients with ELN changed their posture with a complete modification of barycentre (Footrest unbalancing kg P = 0.0110), oscillatory movement area (Footrest Area difference P = 0.0102), and oscillatory Velocity (Footrest Velocity oscillation difference P = 0.0102). These data suggest that this appliance has a function in the rehabilitation of atypical swallowing. ELN produces a physiologic neuromuscular mechanism that induces the correction of tongue position.

**Conclusion**

With ELN the tongue reaches the physiologic position during the swallowing and it is possible to have a low dental contact without tongue interference. ELN has no dental retention or contact. For this reason sEMG swallowing test shows that ELN induces a Mm activation reduction and a great reduction in respect to patients record without ELN. Oscillatory Area (P = 0.0102) and velocity of oscillation (P = 0.0102) presented a great reduction in respect to patients record without ELN. ELN has a therapeutic effect on swallowing and the postural variation obtained by its use.

**Keywords:** Atypical swallowing; Surface electromyography; Oral appliance.

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Materials and methods

Seven patients affected by AS have been evaluated. Additional inclusion criteria were absence of temporomandibular joint disorders, the presence of healthy periodontal ligament, Angle’s first molar class, good dental arch symmetry and anterior open bite. The sEMG test performed intended to find a possible correlation between tongue posture (TP) in atypical swallowing patients (ASP) and head and neck muscle function. Each patient received a complete sEMG and postural evaluation. The sEMG test was performed on each patient with different tongue positions and swallowing, evaluated without and with the ELN. First of all it was necessary to build an ELN for all patients, so impressions were taken and given to the dental technician for fabrication of the appliances.

The ELNs were made in acrylic resin with no dental retention and contacts. Its function is determined by an inclined plane of 60° ending with a hole near palatal wrinkle. The ELN were made with two steel wire positioning guides (0.8 mm) inside the resin. The two guides did not have dental retention function but allowed the correct oral tongue position to be obtained in swallowing. Sometimes an upper medial standard steel screw was added to the appliance to slowly expand the maxilla (Fig. 1).

The sEMG test were shown on 5 window displays on the computer screen and were calculated in micro volts (µV). From these windows it is possible to see the activity level of each monitored muscle. Each column of numbers represents the average muscle activity (microvolts) throughout a marked region, and the time for the muscle to exceed the activity level (measured in milliseconds relative to the earliest muscle). Electromyography gives the operator the effective RMS (Root Mean Squared) value. The Average EMG display shows a corrected average of the muscle signals that are contained within the zoom cursor. The height of the graph represents the activity of the muscle averaged every 25 milliseconds. The numbers below represent the average firing strength of each muscle (microvolts). The EMG test was performed in a darkened room at 26 °C. The patients were lying down, and their body temperature was taken. The room was free of interferences and distractions. A surface electromyograph (Biopack) with 8 channels was used (4 channels for the right muscles and 4 for the left) on 4 groups of muscles: temporals, masseters (MM), submental (SUB) and sternocleidomastoids. Facial points for the positioning of electrodes were identified by asking the patients to close their mouth and clench their teeth; then these points were wiped with alcohol and the electrodes were applied. The specific electrode positions were as follows: two electrodes were placed on both sides at the mandibular angle to record masseters activity; two electrodes were placed on both sides 2 centimetres above the eyebrows to record the temporals activity; two electrodes were placed under the chin to record submental muscles; two electrodes were placed on the right and left side of the neck to record the sternocleidomastoids activity. Another earth electrode was positioned in the centre of the forehead.

All tests were performed for 15 seconds. Before the tests, the jaw of the patients was in resting position, and during recording they were asked to swallow.

After the sEMG test, each patient was submitted to a computerized postural test (Lizard). The test was performed in two conditions: with and without the ELN. Patients were then asked to stand some seconds on a footrest to record their postural situation. A mirror was also positioned in front of the footrest in order to find the natural head position. The stabilometry test gives...
information on barycentre, oscillatory movement and pressure on the patient's feet. The footrest was connected to a computer that recorded all posture variations, floowed by an analog-to-digital conversion in numerical signals. All patients were positioned barefoot on the footrest and were asked to place their feet along the marked lines. The tests were performed for 60 seconds on each patient, in a closed room, with and without the ELN. The footrest contains strength receptors, which give information about the exact position of the centre of plantar pressure, and sensors that record the patient's oscillation in all directions. From this information, parameters of balance (width, frequency, surface, length and speed of moving) were calculated. Statistical analysis was done using the Graph pad Instat 3 both for sEMG activity and for computerised postural analysis.

Results

The duration of the reflex phase of muscle activity during saliva swallowing (Maximum Time Contraction, MTC) in ASP without ELN was 2.193 s, while in the same patients with ELN this value was 0.750 s. The difference between the two means was 1.443 (p = 0.002). There were significant differences in MM electric activity. The sEMG evaluation showed that the mean MM electric activity was higher without the ELN (34.940 µV mean) than when the device was present (11.438 µV mean). The difference between the two means was 23.502 µV (p = 0.002). The mean SUB electric activity without ELN was 10.209 µV, and 26.931 µV with ELN (p = 0.0033). Pairing of electric activity means showed different muscle activation in the two performed tests. With the ELN SUB activation was about 50%-70% higher than the MM activity (26.931 µV mean SUB; 11.438 µV mean MM) while in swallowing tests without ELN the opposite values were found, and mean MM activity was higher than the mean SUB activity (M MM: 34.940 µV; SUB: 10.209 µV). This data suggest that with the ELN the neuromuscular activation is different, and with this type of appliance swallowing of saliva is faster with low dental contact.

The first effect of the ELN is its efficacy on swallowing. The sEMG showed a significant difference in muscle activation with and without ELN. The ELN allowed normal dental contact and correct tongue position which may have a beneficial effect on posture. Infact, the computerised postural test showed therapeutic effect of ELN. Without ELN all patients showed alteration of the barycentre as well as an elevated oscillatory record (A mm2; V mm/s). However, for the tests done with the ELN these values changed. Barycentre, oscillatory movement area (i.e. trace Area valued in mm²), oscillatory velocity (OV calculated in mm/s), and foot pressure (i.e. Kg distribution variation) became normal. The comparison of these tests showed that with the ELN were obtained the best postural modifications and the best results for equilibrium, barycentre and foot pressure. Significant difference in Kg body distribution on the feet was evaluated. In tests without the ELN patients showed a mean imbalance of 3.029 Kg, whereas with the ELN patients' mean imbalance was 0.7714 Kg. The difference between the two means was 2.257 Kg (p = 0.0110). The oscillatory movement (i.e. trace Area valued in mm²) and oscillatory velocity (calculated in mms) showed great variation with the use of ELN. In tests performed without the ELN the mean oscillatory movement was 66.614 mm², in tests with the ELN the oscillatory movement mean was 20.529 mm² with a difference of 46.086 (P = 0.0102). The computerized posture program showed a reduction of OV in the two situations. Without the ELN OV was 5.257 mm/s mean while with the ELN OV the mean was 3.200 mm/s with a difference between the two tests of 2.057 (P = 0.0102) (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SEM</th>
<th>Median</th>
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<th>Max</th>
<th>95 % CI</th>
<th>p-Value (pairing means Test)</th>
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<tr>
<td>MTC (sec.)</td>
<td>without ELN 2.193</td>
<td>0.2227</td>
<td>2.300</td>
<td>1.350</td>
<td>3.100</td>
<td>1.648 - 2.738</td>
<td>0.002</td>
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<td></td>
<td>with ELN 0.750</td>
<td>0.06268</td>
<td>0.7000</td>
<td>0.5000</td>
<td>1.000</td>
<td>0.5966 - 0.9434</td>
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<tr>
<td>Masseter activation (µV)</td>
<td>without ELN 34.940</td>
<td>2.350</td>
<td>35.000</td>
<td>25.000</td>
<td>41.000</td>
<td>29.190 - 40.690</td>
<td>0.002</td>
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<tr>
<td></td>
<td>with ELN 11.438</td>
<td>2.512</td>
<td>12.000</td>
<td>2.245</td>
<td>22.820</td>
<td>5.291 - 17.585</td>
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<tr>
<td>Submental activ. (µV)</td>
<td>without ELN 10.209</td>
<td>1.498</td>
<td>8.000</td>
<td>5.930</td>
<td>16.000</td>
<td>6.543 - 13.874</td>
<td>0.0033</td>
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<tr>
<td></td>
<td>with ELN 26.931</td>
<td>4.861</td>
<td>25.500</td>
<td>7.245</td>
<td>46.000</td>
<td>15.037 - 38.825</td>
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<td>Footrest unbalanc. (kg)</td>
<td>without ELN 3.029</td>
<td>0.5037</td>
<td>3.100</td>
<td>1.000</td>
<td>4.600</td>
<td>1.796 - 4.261</td>
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<tr>
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<td>with ELN 0.7714</td>
<td>0.06061</td>
<td>0.8000</td>
<td>0.5000</td>
<td>0.8000</td>
<td>0.6231 - 0.9197</td>
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<tr>
<td>Footrest area differ. (mm²)</td>
<td>without ELN 66.614</td>
<td>11.511</td>
<td>76.500</td>
<td>22.400</td>
<td>99.000</td>
<td>38.477 - 94.781</td>
<td>0.0102</td>
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<tr>
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<td>with ELN 20.529</td>
<td>1.471</td>
<td>20.300</td>
<td>17.000</td>
<td>28.000</td>
<td>16.929 - 24.128</td>
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<tr>
<td>Footrest Velocity oscillat.</td>
<td>without ELN 5.257</td>
<td>0.4715</td>
<td>5.200</td>
<td>3.300</td>
<td>7.000</td>
<td>4.103 - 6.411</td>
<td>0.0102</td>
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<tr>
<td></td>
<td>with ELN 3.200</td>
<td>0.1363</td>
<td>3.100</td>
<td>2.800</td>
<td>3.900</td>
<td>2.867 - 3.533</td>
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</table>

SEM : Standard error of means
CI: Confidence Interval
Significance level: p < 0.05

Table 1 - Patients evaluation without and with ELN. Time muscle contraction in oral phase without and with ELN; mean M masseter activation in sEMG swallow record without and with ELN; mean submental muscle activation in sEMG G swallow record without and with ELN; Computerized postural test: foot kg unbalancing record without and with ELN; Computerized postural test: Area of body oscillation (mm2) without and with ELN; Computerized postural test: Velocity of body oscillation (mm/s) without and with ELN.
Discussion

The study on swallowing started in 1813 with Magendie, who established the concept of three stages in the act of swallowing: oral, pharyngeal and oesophageal [Magendie, 1813]. Masticatory muscle functions and temporomandibular joint movement have been studied for many years, but a lack of scientific data regarding swallowing and treatment of atypical swallowing has been shown. It is well known that the tongue is a structure with a high presence of nerves and muscles, and for this reason its rehabilitation is not easy. The human neuromuscular circuits activated during swallowing are still unknown. Tongue position and its function are regulated by particular structures in the central nervous system. Ertekin and Aydogdu [Ertekin 2003] explain that these structures are premotor neurons called central pattern generators (CPG), which are located within the nucleus tractus solitarius (NTS), the adjacent reticular formation surrounding NTS and in the reticular formation around and just above the nucleus ambiguus (NA) of the ventrolateral medulla oblongata, and have the role to activate swallowing. Thus, the swallowing interneurons or premotor neurons are located in these two main brain stem areas: the dorsal swallowing group (DSG) in and around NTS and ventral swallowing group (VSG) just above the NA. The DSG contains the timing generator of the sequential or rhythmic swallowing pattern. The VSG contains the switching neurons, which distribute the swallowing drive to the various pools of the motorneurons involved in swallowing [Miller, 1982; Miller, 1987; Palmer, Rudin et al., 1992; Zougrana, Amri et al., 1997; Zougrana, Lamkadem et al., 2000; Car, Roman et al., 2002].

Another unclear aspect regards the nervous sensitive system that regulates tongue position. Much research suggests that the hypoglossal nerve (XII), a pure motor nerve that innervates all intrinsic tongue muscles, reaches some sensitive fibre coming from the first two cervical sensitive nerves [Jean, Amri et al. 1983; Amri and Car, 1988; Schipper, Arndt et al., 2005]. These fibres may give a proprioceptive function to tongue muscles. Clinically AS is characterised by alteration of tongue position, and nervous and muscular alteration that finally generates maxillary growth alteration (i.e. anterior or posterior open bite, teeth diastemas, maxilla transverse contraction, long face). Maxillary growth alteration induced by AS is treated with oral appliances reducing tongue interposition between the dental arches [Ito, 1990]. Many studies show the clinical effect of these appliances on the treatment of maxilla growth alteration, but none of them show the effect of oral appliances on tongue neurophysiological correction.

The purpose of this work was to evaluate an oral appliance devised by Bonnet, its neurophysiological effect on the coordination of swallowing (cf. with electromyography), and its efficacy in stabilising head and neck muscle activity (i.e. with electromyography and computerised postural testing).

A lot of research indicates that the differences between normal swallowing and un-physiological swallowing are: the variation in muscle activity duration in oral phase of saliva swallowing and the variation of electric activity range in masseter (MM) and submental muscles (SUB). Vainman suggests that the oral phase duration of saliva swallowing is 0.7 ± 0.2 sec in physiological swallowing and the mean electric activity at the SUB is 30%-50% higher than the activity of MM [Vaiman, Eviatar et al., 2004 a; Vaiman, Eviatar et al., 2004 b; Vaiman, Eviatar et al., 2004 c; Vaiman, Segal et al. 2004]. Monaco suggests that in healthy people the act of swallowing presents sEMG values of MM and SUB activation as in Vainman’s research [Monaco, Cattaneo et al., 2008]. sEMG is a simple method used by many authors to evaluate swallowing [Vaiman, 2007; Vaiman and Eviatar, 2009]. Studies of tongue position and swallowing function with intraoral electrodes carried out by other authors were evaluated [Mitsuyoshi and Michael, 2007; Sangave, Manuccia et al., 2008; Pittman and Bailey, 2009], however, the specific appliance being evaluated (i.e. ELN) impedes correct and stable electrode position, so authors preferred to use sEMG testing.

This paper focuses on the effect of ELN on swallowing, on muscle activation and body balance. With an ELN the tongue reaches the physiological position during swallowing and it is possible to have low dental contact without tongue impediment. The ELN has no dental retention or contact [Bonnet, 1992; Bonnet, 1994; Buraglio, 2002]. The sEMG swallow test shows that the presence of an ELN induces both a reduction in masseter activation as regards the swallowing test without ELN (p = 0.002), and an increase of SUB activation (p = 0.0033). In the same way, with an ELN there is an extremely significant reduction in swallowing time (c.f. oral phase) (P = 0.002). These results are comparable with results of other authors that suggest that in normal swallwers SUB activation is 30-50% higher than MM activation. ELN’s function is only to rehabilitate the tongue’s oral position thanks to a lingual ramp, which is tilted 60 degrees with reference to the occlusal plane. The ELN was not constructed with dental retention or contact, its oral presence induces continual tongue muscle contraction. The lingual ramp allows the tongue to obtain a physiological position. Bonnet suggests to use the appliance during the night to stimulate the tongue’s correct position by the activation of the involuntary reflex arc [Ciavarella, Mastrovincenzo et al., 2008]. Other appliances, with front gratings, have the only function of blocking tongue interposition between dental arches. ELN’s effect on body balance has been evaluated by a computerised postural test that shows how great an influence the tongue has on body posture. Patients with ELN changed their posture with a complete modification of barycentre (Footrest unbalancing P = 0.0110), of oscillatory movement area (Footrest Area difference P = 0.0102) and oscillatory velocity (Footrest Velocity oscillation difference P = 0.0102) (Table 1). The effect of ELN on body balance seems to be related to the elevation of the hyoid bone and to its effect on muscle activity variation.

Conclusion

Tongue rehabilitation must start early in young children for the normalisation of all neuro-muscular reflex arcs utilised in all tongue functions. The position of the tongue is not only important for swallowing but also for body
posture control. It is possible that the role of swallowing "reflex" is to induce, through periodical low periodontal stimulation, a continuous control of head and neck posture muscles stabilising mandible to cranium.

ELN is a new appliance used by authors for children's swallowing alterations. In this study it is shown how this type of treatment helps patients to normalise muscular function and improve body control.

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References


