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MUSCLE RESPONSE WITH FLEXIBLE FIXED FUNCTIONAL APPLIANCE

An EMG study of masseter and anterior temporalis muscles

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Abstract:

Objective: To evaluate mechanism of muscle response with flexible fixed functional appliance.

Material and method: An electromyographic study was performed on 20 young growing females with Class II Division 1 malocclusion. Group 1 (n=10) served as control group and group 2 (n=10) were treated with flexible fixed functional appliance. Bilateral EMG activity from anterior temporalis and masseter muscles was monitored longitudinally to determine changes in postural, swallowing, and maximal voluntary clenching during an observation period of 6 months.

Results: There was a significant decrease in EMG activity during swallowing of saliva ($p < .05$) and maximal clenching ($p < .05$) & ($p < .01$) in group 2, which persisted for up to 1 month, gradually returning toward pre appliance levels near the end of the experimental period.

Conclusion: A definite response of anterior temporalis and masseter muscles was observed and there was adequate neuromuscular adaptation following insertion of flexible fixed functional appliance at the end of six months. As the EMG activity in the muscles investigated in the present study is decreased significantly, our data is consistent with the concept which assigns a major role to the viscoelastic elements of muscle and increased lip strength as the source of stimulus for bone remodelling associated with the action of these appliances.

KEY WORDS

Muscle response, Flexible fixed functional appliance, EMG activity, Masseter, Anterior temporalis.

CLINICAL RELEVANCE

We conducted an EMG study on patients treated with Forsus Fatigue Resistant Device, a flexible fixed functional appliance. Although response of masticatory muscles to Herbst appliance (a rigid fixed functional appliance) is available in literature, we could not find any study in published literature that has been conducted to see the muscle response with flexible fixed functional appliance. Even though this appliance functions much like Herbst, it has greater elasticity and flexibility; allows greater range of movement of mandible; uses spring and smaller tubes and rods, is readily available in pre fabricated assembly, is a simple, effective and reliable corrective appliance that benefits not only growing patients but also adult malocclusions that previously required extractions, headgears and surgery.

Introduction:

Functional appliances used in the correction of Class II malocclusion modify the neuromuscular environment of the dentition and associated bones¹ and the ensuing skeletal alterations have been attributed to morphologic adaptations to an altered muscular tone and to a change in direction of traction exerted by the masticatory muscles². However, the interaction between bone and muscle and the mechanism of neuromuscular adaptation to functional appliance therapy is complex and open to discussion. Andréßen and Häupl³ claimed that myostatic reflex leading to isometric contractions from the activities of the jaw-closing muscles is produced, which stimulates the protractor muscles and inhibits the retractor muscles of the mandible. Selmer- Olsen⁴, Umeharas, failed to observe active muscle contractions and claimed that the viscoelastic properties of the muscles and the stretching of soft tissues are decisive. Between the 2 extremes Witt⁶ supported a combination of isometric muscle contractions and viscoelastic properties being responsible for the forces delivered.



Fig 1: Lateral View of flexible fixed functional appliance: FORSUS.

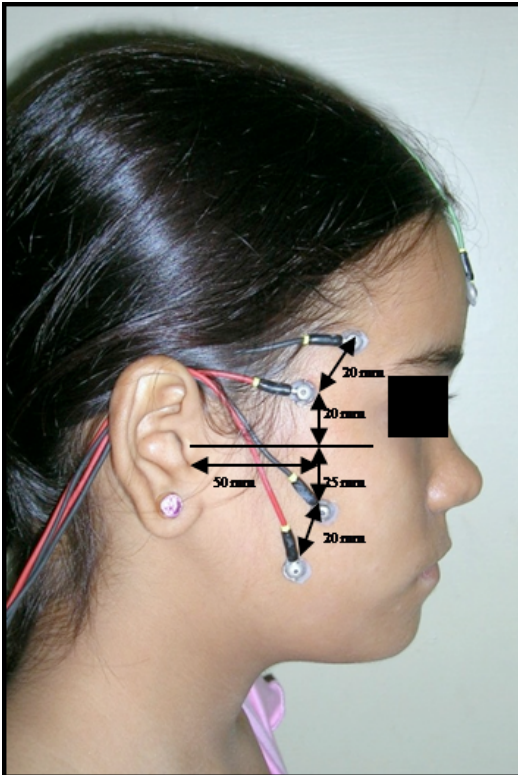


Fig 2: Electrode placement on anterior temporalis and masseter muscles.

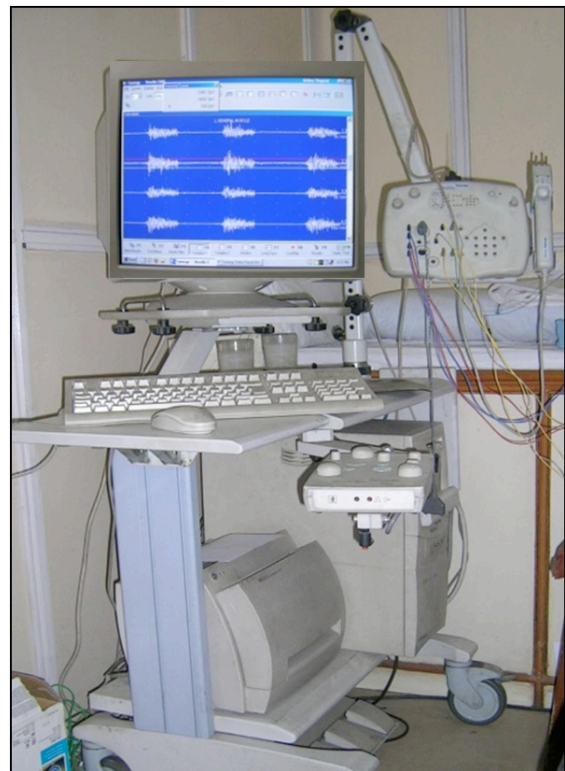


Fig 3: Electromyographic equipment with recording displayed on the monitor.

Concepts of Herren⁷ (increased tonus), Schwartz⁸ (long-lasting isometric biting), and Ahlgren⁹ (passive elastic muscle tension) became important on testing the original hypothesis of Andréßen-Häupl³. The hallmark of all these previous EMG studies was that they were based on a removable functional appliance that uses intermittent condylar displacement. Fixed functional appliances on the other hand are worn full-time, use continuous displacement and therefore can be expected to elicit a greater and more rapid neuromuscular response. Flexible fixed functional appliances have more elasticity/flexibility and they exert a continuous and elastic force that allows greater freedom of movement of the mandible; patients can carry out the lateral movements with ease; can close in centric relation; repeatedly bite with the appliance voluntarily and during swallowing of saliva; greater occlusal contacts are activated on biting; muscular force is distributed over a larger periodontal area; jaw elevator muscle inhibition is diminished by periodontal mechanoreceptors thereby resulting in better mandible stabilization. Thus aim of this study was to evaluate mechanism of muscle response with flexible fixed functional appliance.

MATERIAL AND METHODS

This study was conducted on 20 young growing females with Class II Division 1 malocclusion having ANB angle $> 3^\circ$ (Mean ANB 4.5° and Range $3-6^\circ$), Average growth pattern (FMA $<25^\circ$), minimum crowding ($<2\text{mm}$), a positive VTO (Visual Treatment Objective) and were free of subjective neuromuscular, auditory, or mandibular dysfunction symptoms. Group 1 (control group) (n=10), Cervical Vertebral Maturation (CVM) stage I and Stage II, age 8 - 10 years (mean age 8.5 years) comprised of patients in late mixed dentition stage whose treatment with fixed functional appliance could not be started immediately. Group 2 (Treatment Group) (n=10), Cervical Vertebral Maturation (CVM) stage III and Stage IV, age 10 - 14 years (mean age 12.5 years) underwent non extraction treatment with flexible fixed functional appliance for the correction of retrognathic mandible, for which we used Forsus Fatigue Resistant Device (available as pre fabricated assembly from 3M Unitek). Informed consent was taken from parent/guardian of these patients for being a part of this study.

Patients in group 2 (n=10) underwent fixed orthodontic mechanotherapy with standard edgewise, and before ligating Forsus (Fig 1), lingual crown torque of $10-15^\circ$ was given in the lower anterior segment in 0.019×0.025 stainless steel wire and the upper and lower arch wires were cinched back. Mandible was advanced to Class I molar relation and the muscle activity was recorded longitudinally over a period of six months.

The procedure of recording the EMG was explained in detail to the patient to allay anxiety. The environment in which recordings were made was calm, quiet, and in a semi dark shielded room to eliminate outside electrical interferences. The patients sat in a comfortable upright position, with the head parallel to the ground, feet on the floor, and arms resting on their thighs. Postural position at rest was defined as its position when the subject was sitting motionless in the chair with maxillary and mandibular teeth a few millimetres apart and with no visible oral and facial activity such as tongue thrusting or licking of lips and they were instructed to relax and remain that way. The position of the electrodes was determined by palpation, and maximum voluntary contraction was performed to guarantee that the muscles were accurately located. Before placing the electrodes, the subjects were asked to wash their face with soap and water. The patients' skin was cleansed with alcohol to eliminate any grease or pollution residue and dried thoroughly and conductive paste was applied on to the surface electrodes before placing them. The electrode placement (Fig 2) was standardized according to the method advocated by Yuen et al¹⁰. A 5-channel EMG, Medelec Synergy N-EP system (Oxford Instruments Medical, Inc.) were used (Fig 3) with simultaneous acquisition, common grounding for all channels. Four channels recorded EMG activity from the anterior temporalis and masseter muscles. The remaining one channel which was used as reference electrode to reduce electromagnetic interferences and other acquisition noise was positioned over the forehead of the subject just above the glabella and it was ensured that there was no interference from the anterior temporal muscle (during various functional activities) before placing the other electrodes. The EMG activity was filtered for the range of 10 Hz (low cut filters) to 5 KHz (Hi cut filters); entrance of $10\text{ G}\Omega$ in a differential mode, 12 bits of dynamic resolution, band of amplitude, -10 V to $+10\text{ V}$; and sample frequency by channel of 2 KHz.

Flow Chart of EMG Record

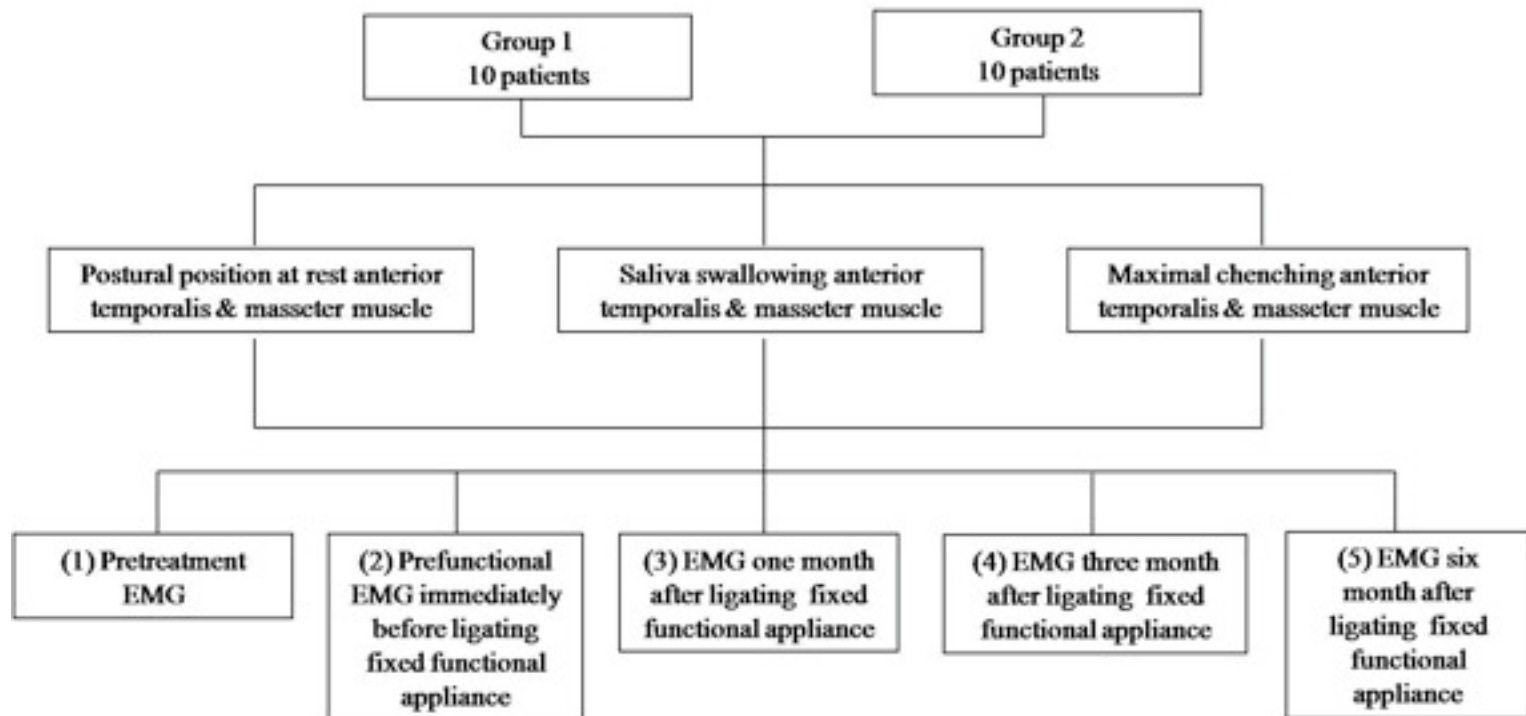


Fig 4: Flow chart of EMG record.

Myoelectric signals were captured by various active bipolar surface disk electrodes with 2 contacts with a distance of 20 mm apart, impedance upwards of 10 GΩ, and a common rejection value of 130 dB to 60 Hz. Length of the recording session of EMG for each activity was 5 seconds. To avoid muscle fatigue a relaxation period of 3 minutes was allowed between each functional activity and the next.

Each patient underwent 5 EMG registration sessions (Fig 4). In order to evaluate the reproducibility of the EMG records, a section of the EMG signal, where the activity in all channels was steady and minimal over a 5-second period was measured twice on 3 different locations for each recording and the average of the first 3 different consecutive measurements of 1 function in 1 recording session was compared with the second measurement. For example, the average of the first 3 consecutive pre-treatment amplitude values of maximum voluntary clenching was compared with the average of the second 3 consecutive pre-treatment amplitude values of maximum voluntary clenching. Intraclass correlation coefficient values were calculated for each function at each session and were statistically significant, with values between 0.80 and 0.92. The same operator made all recordings. The EMG data were analyzed with SPSS for Windows software. Descriptive statistics including arithmetic mean and standard deviation were calculated. Friedman two-way nonparametric analysis of variance was employed to see the change in EMG activity in both the groups over the six-month observation period. Multiple range tests were employed to determine the change in EMG activity between various recording sessions at different time intervals and to confirm the time interval in which significant change occurred.

RESULT

When observing the EMG activity in control group over an observation period of six months (Table I, II & III), there was no significant differences detected in the present study. However in patients treated with Forsus, the mean level of EMG activity decreased at one month which was found to be statically significant during swallowing of saliva ($p < .05$) (Table II) and maximal voluntary clenching ($p < .05$) & ($p < .01$) (Table III). The EMG values remained decreased for up to 1 month, gradually returning toward pre appliance levels near the end of the experimental period (6 months). The rigid fixed functional appliance used in our study was very effective in correcting the malocclusion.

DISCUSSION

Mode of action of functional appliance therapy has been linked to neuromuscular and skeletal adaptations to altered function in orofacial region. Modification of functional position of the mandible results in an immediate alteration of the neuromuscular activity of orofacial muscles¹¹. Several investigations have been carried out to correlate the timing of the appearance and disappearance of altered functional patterns to the rate and extent of skeletal and dental adaptations¹²⁻¹⁴.

For both the groups our control was the subjects at pre treatment stage (1). We believe that using the subjects as controls avoids variables (such as different cutaneous and subcutaneous tissue thickness, age, sex, facial characteristics, and other biologic characteristics) in assessing the muscular alterations with the treatment and we can attribute that the difference between groups was really related to altered occlusion. Other studies also evaluated the EMG activity of the masticatory muscles before and after orthodontic treatment with the subjects as the control group^{15, 16}.

Our results are in accordance with the findings of Thilander and Filipsson¹², Ingerval and Bit-sanis¹⁷ and Tabe et al¹⁸ who reported decrease in the muscle activity of masticatory muscles in children undergoing 6 months of activator treatment. The findings of our study also agree with the studies done on Herbst appliance^{19, 20, 21} where the muscle activity was found to decrease. Our results do not support the findings of Ahlgren⁹, Aggarwal et al¹⁵ who reported increase in postural & swallowing EMG activity following treatment with an activator and twin block respectively. Swallowing of saliva on command is a very commonly used experimental procedure to evaluate muscle function, often referred to as “empty swallowing.” During natural “reflex” swallowing, the effort is less. A limitation of the procedure is that it depends largely on how much effort is exerted during the exercise. Alternatively the increased muscle activity seen in these studies done with removable functional appliances can be explained, as result of greater flow of saliva caused by the introduction of an insoluble material in the mouth. Also with removable functional appliances, there are chances of exceeding the vertical dimension which might also lead to increased muscle activity observed during swallowing of saliva seen in these studies.

Alternatively it could be a result of better mandible stabilization and the increase of occlusal contact area with the removable functional appliance, thereby causing the muscular force to be distributed over a higher periodontal area and diminishing jaw elevator muscle inhibition by periodontal mechanoreceptors.

In an animal study²⁰ initial placement of the Herbst appliance to induce marked mandibular protrusion was associated with a statistically significant decrease in EMG activity which persisted for approximately six weeks. From the changing pattern of EMG recordings obtained in our study (Fig 5), it was obvious that the lowest EMG activity during treatment also occurred within the first month. During the third to the sixth month of treatment period, when most of the skeletal adaptations occur and occlusal contacts are achieved, there was a steady increase of EMG activity. During the final six months of treatment, the EMG activity seemingly continued to increase towards the pre treatment level which indicates that there was no obvious difficulty in adapting to a new position of the mandible achieved after six months of active treatment with the flexible fixed functional appliance. These results are in accordance with the findings of Pancherz and Anehus- Pancherz²¹ who reported that the immediate response to treatment was a strong reduction in masseter and temporalis activity during clenching and a gradual increase in muscle activity occurred from 1 month onward until the end of 6 months. Biting on an activator has also shown a reduced masseter and anterior temporal muscle activity^{17, 22}. In normal occlusion also, when the mandible was protracted, the anterior temporal muscle activity has also been found to be reduced¹⁴. Myofunctional appliances have been shown to decrease orofacial muscle activity during oral function²³. The results of our study support a concept that no increases are induced in the EMG activity while using functional appliances^{9, 12, 17, 20}.

In our view muscle activity decreases following insertion of a Forsus, as it results in occlusal instability due to changed tooth position and inter maxillary relations brought about by active protrusion with the appliance. A correlation exists between impaired EMG activity from the masticatory muscles and cusp-to-cusp occlusion and a stable occlusion is a prerequisite for maximal muscle activity during biting^{19, 21}.

When clenching in the intercuspal position is directed anteriorly, as with FORSUS during first month, muscle activity decreases dramatically with lessening numbers of posterior teeth in contact and drops significantly when only the incisors are in contact.

It has been found that during biting in the maximal occlusion a vast number of mechanoreceptors, located in the periodontal ligaments of the posterior teeth are activated. This number is probably decreased in the incisor edge to-edge position, whereby antagonistic tooth contacts are restricted to a few anteriorly located teeth thus leaving the posterior teeth out of occlusion. This alters the sensory input to receptors in masticatory muscles thereby altering the position of muscle balance, so that it becomes painful for the patient to retract the mandible¹¹ and results in immediate change in the neuromuscular response, thus interfering with the physiologic function of the stomatognathic system, masticatory performance is reduced, the lateral mandibular movement capacity is decreased, muscle tenderness is increased and this continues during the first few months of treatment. The muscles must re-establish their balance if the teeth are to remain in their new position achieved as a result of treatment with fixed functional appliance.

A stimulus is sent to CNS and a very complex interaction takes place to determine the appropriate response. The cortex with influence from thalamus, central pattern generator (i.e. pool of neurons that controls muscle activities), limbic system, reticular formation and hypothalamus determines the action that will be taken in terms of direction and intensity. For central pattern generator to be most efficient, it receives constant sensory input from tongue, lips, teeth, periodontal ligament, masticatory muscles and temporomandibular joint to determine the most appropriate path of closure. Once this is established, it is learned and repeated and this learned pattern is called muscle engram. It is rare for such a response to be observed with functional appliances that are not worn full time. Forsus keeps the mandible in a protrusive posture constantly and does not permit shortening of the elevators as a result of which the muscle fibers develop a higher tension. This uninterrupted stretch on the muscle spindles increases the frequency of reflex contractions in the masticatory muscle¹¹ which involves a change in γ (gamma) efferent output via the reticular formation and the cerebellum rather than purely reflex stimulation of muscle spindles.

After a few months when some occlusal contacts are re-established, temporal and masseter muscle activity starts gradually increasing to pre-treatment levels, as when skeletal adaptations occur the need for compensatory muscle function is reduced.

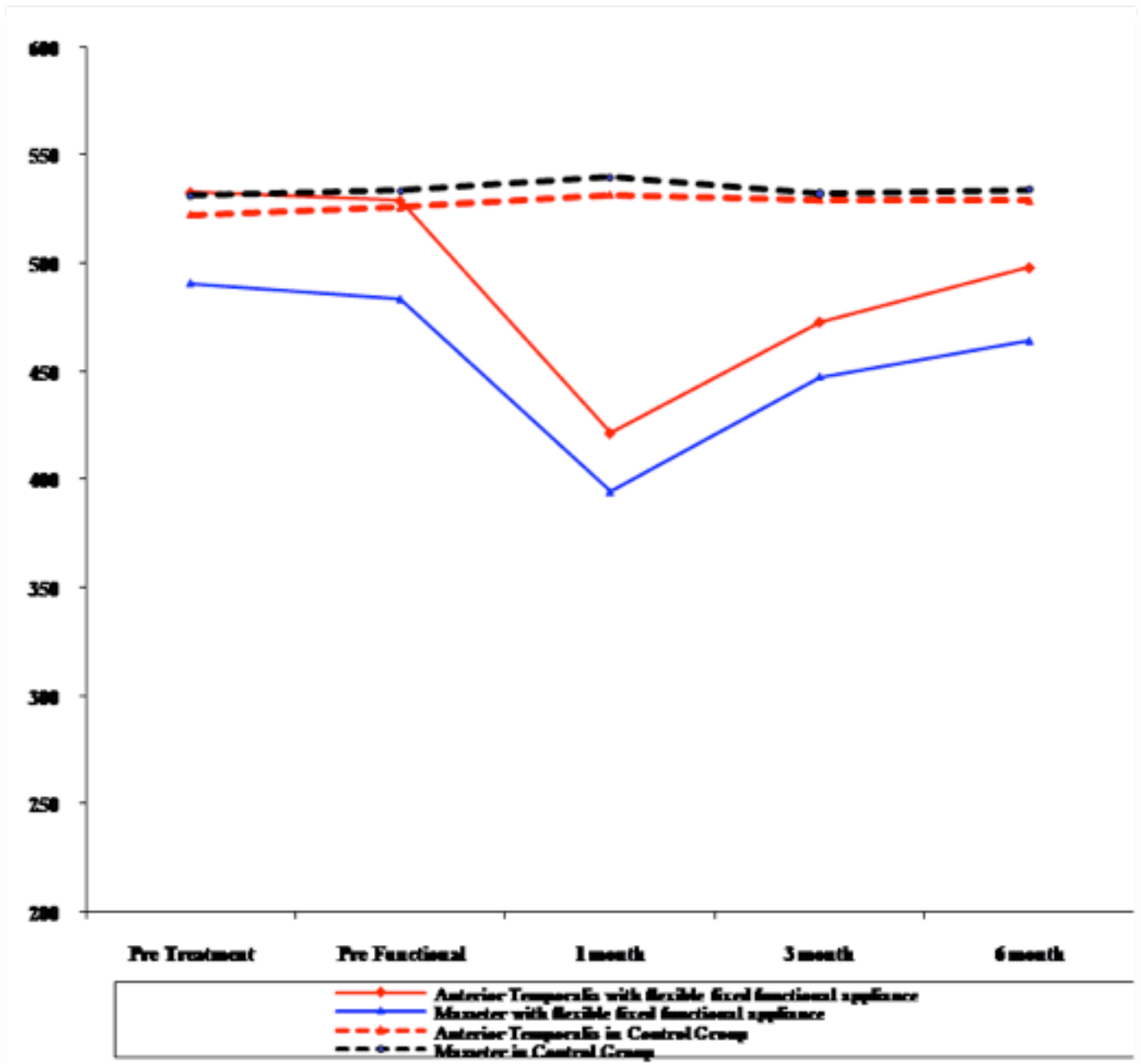


Fig 5: Graph of comparison of changes in EMG activity in anterior temporalis and masseter muscles during maximal voluntary clenching over six month observation period with flexible fixed functional appliance (Forsus) & Untreated controls (n=10 each).

TABLE-I

Mean and S.D. values of the muscle activity in the postural position of the mandible over six month observation period

Appliance	Muscle	EMG Recordings (in μ V)					Difference p
		(1) Pre Treatment	(2) Pre Functional immediately before ligating the flexible fixed functional appliance	(3) 1 month after ligating the flexible fixed functional appliance	(4) 3 months after ligating the flexible fixed functional appliance	(5) 6 months after ligating the flexible fixed functional appliance	
Untreated Controls (n=10)	Anterior Temporalis	42.67 $\pm$ 8.16	42.9 $\pm$ 8.42	43.8 $\pm$ 7.53	42.31 $\pm$ 7.44	42.54 $\pm$ 8.16	NS
	Masseter	41.5 $\pm$ 8.82	42.08 $\pm$ 8.84	42.7 $\pm$ 7.92	41.81 $\pm$ 8.2	41.8 $\pm$ 8.51	NS
Flexible fixed functional appliance (n=10)	Anterior Temporalis	43.59 $\pm$ 8.14	42.79 $\pm$ 8.16	40.93 $\pm$ 8.06	41.84 $\pm$ 8.22	42.03 $\pm$ 8.09	NS
	Masseter	41.17 $\pm$ 8.12	41.62 $\pm$ 8.3	40.83 $\pm$ 8.21	41.8 $\pm$ 8.11	42.02 $\pm$ 8.23	NS

TABLE-II

Mean and S.D. values of the muscle activity during swallowing of saliva over six month observation period

Appliance	Muscle	EMG Recordings (in μ V)					Difference p
		(1) Pre Treatment	(2) Pre Functional immediately before ligating the flexible fixed functional appliance	(3) 1 month after ligating the flexible fixed functional appliance	(4) 3 months after ligating the flexible fixed functional appliance	(5) 6 months after ligating the flexible fixed functional appliance	
Untreated Controls (n=10)	Anterior Temporalis	108.28 $\pm$ 11.01	109.7 $\pm$ 10.81	110.92 $\pm$ 10.75	107.43 $\pm$ 10.64	109.72 $\pm$ 10.91	NS
	Masseter	109.70 $\pm$ 11.69	110.33 $\pm$ 11.53	112.69 $\pm$ 12.75	110.84 $\pm$ 10.8	111.44 $\pm$ 11.25	NS
Flexible fixed functional appliance (n=10)	Anterior Temporalis	119.02 $\pm$ 19.02	117.02 $\pm$ 18.51	91.21 $\pm$ 12.09	101.04 $\pm$ 16.07	105.31 $\pm$ 18.37	1 Vs 3* 2 Vs 3* 3 Vs 5* 3 Vs 4*
	Masseter	105.95 $\pm$ 11.46	103.12 $\pm$ 11.22	85.58 $\pm$ 11.99	94.74 $\pm$ 13.72	97.22 $\pm$ 17.51	1 Vs 3* 2 Vs 3* 3 Vs 5* 3 Vs 4*

TABLE-III

Mean and S.D. values of the muscle activity during maximal voluntary clenching over six month observation period

Appliance	Muscle	EMG Recordings (in μ V)					Difference p
		(1) Pre Treatment	(2) Pre Functional immediately before ligating the flexible fixed functional appliance	(3) 1 month after ligating the flexible fixed functional appliance	(4) 3 months after ligating the flexible fixed functional appliance	(5) 6 months after ligating the flexible fixed functional appliance	
Untreated Controls (n=10)	Anterior Temporalis	522.39 $\pm$ 101.61	525.7 $\pm$ 102.74	531.65 $\pm$ 85.51	529.24 $\pm$ 99.38	528.78 $\pm$ 103.52	NS
	Masseter	531.21 $\pm$ 101.88	533.29 $\pm$ 103.54	539.64 $\pm$ 108.75	532.01 $\pm$ 96.73	533.93 $\pm$ 104.68	NS
Flexible fixed functional appliance (n=10)	Anterior Temporalis	532.57 $\pm$ 108.04	528.75 $\pm$ 106.59	421.39 $\pm$ 88.56	472.82 $\pm$ 95.65	497.95 $\pm$ 106.25	1 Vs 3** 2 Vs 3** 3 Vs 5** 3 Vs 4** 1 Vs 4* 2 Vs 4* 4 Vs 5*
	Masseter	490.36 $\pm$ 100.35	483.17 $\pm$ 100.39	394.11 $\pm$ 89.11	447.34 $\pm$ 92.65	463.81 $\pm$ 104.8	1 Vs 3** 2 Vs 3** 3 Vs 5** 3 Vs 4** 1 Vs 4* 2 Vs 4* 4 Vs 5*

* =p < 0.05; ** = p<0.01; ***=p<0.001 & (-) = Not Significant

The 3-month registration appears crucial for analyzing the neuromuscular changes occurring with treatment, indicating a strong possibility that sagittal repositioning of a retruded mandible in Class II Division 1 cases takes place approximately within 3 months of initiating the flexible fixed functional appliance treatment. By the end of 6 months with progress of treatment, as a result of better mandible stabilization and an increase of occlusal contact area, the occlusal load of clenching was distributed over a larger periodontal area, and a significant increase in clenching activity occurred.

Alternatively this decrease in EMG activity can also be explained by the fact that when the muscle is lengthened and isometrically contracted, the EMG activity falls, although the tension is greater. This is in accordance with the active muscle activity in the isometric length-tension curve²⁴. This can also be interpreted as an effect of reciprocal innervation²⁵ the temporalis muscle being an antagonistic muscle to a protrusive movement of the mandible. Alternatively, it can be accounted for because of the relative inexperience with the wear of the fixed functional appliance during the first few months and apprehension of soft tissue damage and breakage.

From the significant decrease in EMG activity of masseter and anterior temporal muscles seen in our study, we support the view that passive tension associated with viscoelastic properties of soft tissues rather than active contraction of the jaw closing muscles play an important role in mechanism of neuromuscular adaptation with flexible fixed functional appliance, because of a much longer duration of forces from passive tension^{18, 20}. It is proposed that the insertion of Forsus induces motor reprogramming and result in postural adoption which in turn leads to a growth response. The muscle activity, in this study was examined over a period of six months of the treatment with a flexible fixed functional appliance and compared with untreated Class II div 1 malocclusion subjects who served as control group. All subjects in Group 2 were in the active phase of sagittal correction by the end of 6 months wherein there was unbalanced and reduced number of occlusal contacts in the posterior dental arch segments. After six months the appliances were removed and orthodontic treatment was continued. Even though the flexible fixed functional appliance used in our study had presumably imposed alterations in the neuromuscular response in the treated subjects, and a complete neuromuscular adaptation had occurred as seen by the lack of statistically significant differences in EMG values at the start of the treatment and at the end of six months (1 vs. 5), a six month observation period may not be lengthy enough to draw definite conclusions. The possibility of adaptation effects later with treatment is an important factor for which a long term investigation needs to be undertaken.

It seems that quantitative EMG of the masticatory muscles can be used as an informative tool in the evaluation of treatment results and can be added to the conventional dentofacial measurements.

CONCLUSIONS

A definite response of anterior temporalis and masseter muscles was observed and there was adequate neuromuscular adaptation following insertion of flexible fixed functional appliance at the end of six months. There was a significant decrease in the muscle activity at one month after flexible fixed functional appliance insertion during swallowing of saliva and maximal voluntary clenching. Since EMG activity in the muscles investigated in the present study is decreased significantly, our data is consistent with the concept which assigns a major role to the viscoelastic elements of muscle and increased lip strength as the source of stimulus for bone remodelling associated with the action of these appliances. It is proposed that the insertion of fixed functional appliance induces motor reprogramming and results in postural adoption which in turn leads to a growth response.

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