Access this article online

Quick Response Code:

Website:
www.jorthodsci.org

DOI:
10.4103/jos.jos_208_23

Comparison of muscle response in patients treated with rigid and flexible fixed functional appliances

Ruchi Saini, Puneet Batra[1], Nidhi Saini[2], Komal Punia[3], Tanjula Shair and Monis Raza[4]

Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College, Subharti University, Meerut, Uttar Pradesh, [1]Department of Orthodontics and Dentofacial Orthopedics, Manav Rachna Dental College, Faridabad, Haryana, [2]Department of Orthodontics and Dentofacial Orthopedics, Maulana Azad Institute of Dental Sciences, Delhi, [3]Department of Orthodontics and Dentofacial Orthopedics, Indraprastha Dental College and Hospital, Sahibabad, [4]Department of Orthodontics and Dentofacial Orthopaedics, Institute of Dental Studies and Technologies, Modinagar, Ghaziabad, Uttar Pradesh, India

Address for correspondence:
Dr. Monis Raza, Department of Orthodontics and Dentofacial Orthopaedics, Institute of Dental Studies and Technologies, Modinagar, Ghaziabad, Uttar Pradesh, India.
E-mail: monis8raza@gmail.com

Submitted: 09-Dec-2023
Revised: 02-Feb-2024
Accepted: 22-Apr-2024
Published: 17-Sep-2024

Abstract

AIM: The present study was undertaken to evaluate and compare muscle activity after the treatment with rigid and flexible fixed functional appliance.

MATERIAL AND METHOD: The study was conducted on 14 skeletal Class II malocclusion patients in the age group of 13–17 years, divided into two groups comprising 7 patients in each group. Group I was treated with a rigid fixed functional appliance (MPA IV), and Group II was treated with a flexible fixed functional appliance (Churro Jumper). Masseter and anterior temporalis muscle activities were recorded using needle electromyography (EMG) at postural rest, saliva swallowing, and clenching during five intervals (T_0 to T_4) during fixed functional appliance treatment. Unpaired *t*-test, Mann–Whitney U, and Wilcoxon sign rank test were applied for statistical analysis, and a P value of <.05 was considered statistically significant.

RESULTS: Group I (MPA IV) showed a significant increase in EMG activity during postural rest position ($P = 0.003$, $P = 0.001$), swallowing ($P = 0.013$, $P = 0.005$), and clenching ($P = 0.001$, $P = 0.002$) in masseter and anterior temporalis muscle, respectively. Group II (Churro jumper) also showed a significant increase in EMG activity during postural rest position ($P = 0.000$, $P = 0.000$), swallowing ($P = 0.001$, $P = 0.000$), and clenching ($P = 0.001$, $P = 0.000$) in masseter and anterior temporalis muscle, respectively.

CONCLUSION: Both rigid (MPA IV) and flexible (Churro Jumper) fixed functional appliances caused a significant increase in EMG activity of masseter and anterior temporalis muscle during postural rest position, swallowing, and clenching in 6 months of the observation period, but the flexible appliance (Churro Jumper) showed more significant increase.

Keywords:

Electromyography, malocclusion, myofunctional appliance

Introduction

A functional appliance, which is considered to stimulate mandibular growth in growing patients with retrognathia, is widely used in orthodontic practice.[1] These appliances are used in the improvement of Class II skeletal and dental conditions. The ensuing skeletal alterations have been attributed to morphologic adaptations to altered muscular tone and to a change in the traction direction exerted by the masticatory muscles.[1] Andresen V and Haupl K[2] claimed that a myotatic reflex is produced, leading to isometric contractions from the activity of the jaw-closing muscles, which in turn stimulates the protractor muscles and inhibits the mandibular retractor muscles. Selmer-Olsen R[3] and Umehara Y[4] failed to observe active muscle contractions, claiming that the muscles' viscoelasticity and the stretching of soft tissues are decisive. Between these two extremes, Witt E[5] supported a combination of isometric muscle contractions and viscoelastic properties being responsible for

How to cite this article: Saini R, Batra P, Saini N, Punia K, Shair T, Raza M. Comparison of muscle response in patients treated with rigid and flexible fixed functional appliances. J Orthodont Sci 2024;13:29.

the forces delivered. Previous electromyography (EMG) studies[1,6-8] were based on removable functional appliances that produce intermittent condylar displacement. However, fixed functional appliances are worn full time, leading to continuous displacement; they can, thus, be expected to elicit a greater and faster neuromuscular response. There is published evidence of the response of masticatory muscles to the Herbst appliance[9-11] and to Forsus.[12] Most of the previous studies used surface EMG,[1,8-10,11,13] but needle EMG has many advantages over surface EMG.[6]

The mandibular protraction appliance (MPA IV) is a noncompliant rigid fixed functional appliance having easy chair side construction with ordinary and inexpensive wires and no special bands, crowns, or wire attachments and are easily inserted, adjusted, and removed and versatile.[14]

The Churro Jumper is an interarch flexible force module that creates a pushing force, forcing the attachment points of the appliance away from one another. This appliance produces both sagittal and intrusive forces and also allows much more freedom of mandibular movement than does the MPA.[15]

The present EMG study was undertaken to investigate and compare the changes in the activity of masseter and anterior temporalis muscle in Class II div1 patients treated with rigid (MPA IV) and flexible (Churro Jumper) fixed functional appliances and to analyze, quantitatively, the various changes with treatment.

Material and Methods

Sample size calculation was performed based on an alpha level of significance of 5% and a beta of 20% to achieve a power of 80% of the test to detect a minimum difference of 1.45 mm with a standard deviation of 1.57 in overjet change.[7] The calculation showed that 7 patients were needed for each group. The study was conducted on 14 skeletal Class II div1 malocclusion cases selected from the patients visiting the Department of Orthodontics and Dentofacial Orthopedics for correction of malocclusion. They were in the age group of 12–16 years, with MPA IV group having a mean age of 14.57 ± 2.10 years and Churro Jumper group having a mean age of 14.71 ± 2.30 years. The parents or guardians of these patients were informed, and consent was taken prior to inclusion in this study. All pretreatment records were taken including photographs, radiographs, and study models.

Two groups were formulated of seven patients randomly selected. In group I, sagittal correction was done with a rigid fixed functional appliance (MPA IV), and in group II, it was done with a flexible fixed functional appliance (Churro Jumper). Both were customized for each patient. All subjects were the patients with skeletal class II malocclusion (ANB = 3^0–7^0) due to mandibular retrognathism, requiring skeletal mandibular sagittal correction with at least CVMI-S5, molar relation with a minimum of half the cusp width of Class II molar relationship, increased overjet (more than 5 mm), the SN/Go-Gn angle ranging from 25^0 to $32^{0.}$, an incisor mandibular plane angle (IMPA) of not more than $95^{0.}$, and a positive clinical visual treatment objective (VTO). None of the subjects have pretreatment signs and symptoms of temporomandibular joint dysfunction, facial asymmetry, history of asthma or any chronic systemic illness, incompletely formed roots, or any sign of root resorption.

All selected patients were treated with a 0.022″ MBT preadjusted edgewise appliance using consistent contemporary biomechanic principles. The sequence of the wire placed was 0.016″ NiTi, followed by 0.019″ × 0.025″ NiTi and finally 0.019″ × 0.025″ stainless-steel archwire. A reverse torque of 10^0 in the lower anterior region was given to minimize proclination of the lower incisors and was cinched behind the molar tube. The wire was left in place for 4 weeks for torque expression. Then MPA IV and Churro Jumper were inserted in patients for 6 months for class II correction. Variation was there for the time of placement of appliance, but the total time period of using the appliance was the same (6 months) [Figure 1].

The EMG recording was done using an RMS EMG EP MARK II machine manufactured using RMS recorders and a medicare system, Chandigarh, India. Sensitivity was set at 100 mV/cm [Figure 2]. The EMG activity was recorded using a needle at T0, after leveling and aligning up to 0.019″ × 0.025″ stainless-steel wire and before placement of the fixed functional appliance (for considering it as a baseline), T1, immediately after the insertion of the appliance (to watch the immediate effect), T2, 1 month after insertion of the appliance (as change may occur after leveling in the muscle activity due to disturbance of the occlusion), T3, 3 months after insertion of appliance (as neuromuscular changes may take place sooner than the morphological changes), and T4, 6 months after insertion of the appliance (because

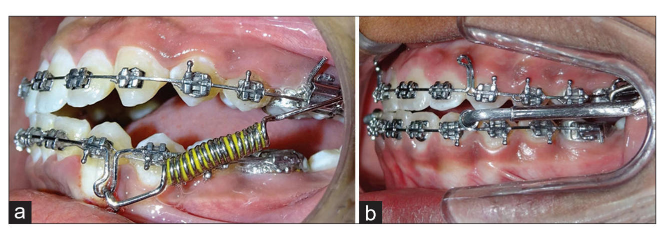

Figure 1: Fixed functional appliances in situ. a. Churro Jumper. b. MPA

a positional response of the mandible often becomes apparent with functional appliances at this stage when the functional appliance was removed).[12]

Each patient underwent three EMG registrations (postural rest position of mandible, swallowing of saliva, and maximum voluntary clenching in the intercuspal position) at each of five-time intervals as stated above in both groups.

Before each recording session, the procedure was explained in detail to the patient and her parents to allay anxiety. The subjects were asked to wash their face with soap and water. The skin over the muscles was cleaned with spirit and dried thoroughly. The subject was comfortably seated in a shielded room to eliminate outside electrical interferences. The needle used was a concentric EMG Needle Electrode [Figures 2 and 3] of size 26G × 40 mm. The used needle had been discarded after single use. A new needle had been used for every patient and at every recording. Needle placement was standardized according to the method advocated by Yuen *et al*.[16] EMG signals for each patient were recorded on the right side of face from masseter and anterior temporal muscles by needle penetration as shown in Figures 4 and 5.

EMG activity was recorded on heat-sensitive paper, and the EMGs obtained were analyzed. Two parallel lines were drawn through the majority of the peaks representing the average peak-to-peak amplitude. The distance between them was measured with a digital caliper on three different locations. The mean of these measurements was computed and then multiplied by the calibration factor to obtain the absolute value in microvolts. The same operator made all recordings.

The data were collected and tabulated in Excel file and were subjected to statistical analysis. The software used for the statistical analysis was SPSS (Statistical Package for Social Sciences) version 16.0 and Epi-info version 3.0. The statistical tests used were unpaired or independent samples. T-test is used for comparison of mean values of two groups when data follow the normal distribution, Mann–Whitney U test was used for comparison of mean values between two groups, and Wilcoxon sign rank test was used for comparison of two mean values obtained from the same group when data do not follow the normal distribution. The correlation between the two variables was calculated using the Pearson's correlation coefficient (r). All the patients finished completely their orthodontic treatment protocol. The patients were asked to inform immediately in case of breakage of appliances, and breakages were repaired only on the next day. Patients were highly motivated for using the appliances and were asked to strictly follow the appointments. A written approval had been taken from the ethical committee of the institute before conducting the study. The power of study was calculated using the n master 2.0 software. The power of study was found to be 82% with a confidence interval (CI) of 95% was.

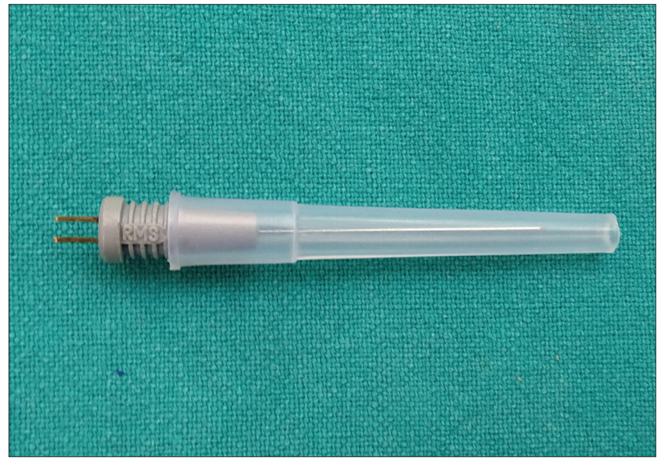

Figure 2: Concentric EMG needle electrode of size 26 G × 40 mm used

Figure 3: Assembly for EMG

Figure 4: EMG signals were recorded on the right side of face of patient by needle penetration (from masseter muscle)

Results

EMG activity during the postural position of mandible

The EMG activity of masseter muscle decreased in the first month and then it showed a progressive increase during the 6 months of observation period, which was a statistically significant increase from the pretreatment value ($P = 0.003$, $P = 0.000$), respectively, in group I and group II. The EMG activity of anterior temporalis muscles also decreased in the first month and then it showed a progressive increase, which was significant in group I and group II, respectively, from the pretreatment value ($P = 0.000$, $P = 0.000$). On comparing the two groups, the changes were significant ($P = 0.001$ and $P = 0.004$) in masseter and anterior temporalis muscle, respectively [Tables 1 and 2].

EMG activity during saliva swallowing

The EMG activity of masseter muscle decreased in the first month and then it showed a progressive increase during the 6 months of the observation period, which was statistically significant from the pretreatment value ($P = 0.013$, $P = 0.001$), respectively, in group I and group II. The EMG activity of anterior temporalis muscles

Figure 5: EMG signals were recorded on the right side of face of patient by needle penetration (from temporalis muscle)

Table 1: Mean and SD (μV) values of the masseter muscle activity with MPA IV and Churro Jumper

	EMG Recordings						
	Fixed functional appliance	T0	T1	T2	T3	T4	*P* (Intragroup comparison)
Masseter muscle activity in postural rest postion	MPA group						0.003**
	Churro	11.10±7.63	5.29±1.25	7.14±3.63	10.61±8.85	16.25±8.67	0.000***
	Jumper appliance	49.14±16.48	27.45±5.37	31.90±7.00	34.95±7.30	45.67±14.50	
	P	0.000***	0.000***	0.000***	0.000***	0.001***	
Masseter muscle activity at saliva swallowing	MPA group						0.013*
	Churro	193.90±178.24	85.36±61.85	115.19±96.31	265.14±211.12	337.67±259.53	0.001***
	Jumper appliance	246.33±129.67	138.99±67.73	197.76±128.16	282.81±116.29	501.76±289.99	
	P	0.541#	0.148#	0.198#	0.850#	0.286#	
Masseter muscle activity at clenching	MPA group						0.001***
	Churro	513.32±369.35	336.06±169.45	349.77±274.31	413.47±233.01	609.43±217.61	0.001***
	Jumper appliance	784.57±296.27	416.43±324.98	494.14±361.02	570.86±293.74	870.81±197.91	
	P	0.155#	0.573#	0.416#	0.289#	0.037*	

*Significant difference. #Nonsignificant difference

Table 2: Mean and SD (μV) values of the anterior temporalis muscle activity with MPA IV and Churro Jumper

	EMG Recordings						
	Fixed functional appliance	T0	T1	T2	T3	T4	*P* (Intragroup comparison)
Anterior temporalis muscle activity in postural rest postion	MPA group						0.000***
	Churro	20.17±6.94	14.47±8.34	15.81±8.13	20.96±9.09	28.96±9.47	0.000***
	Jumper appliance	34.96±10.68	25.90±5.63	30.67±5.77	36.81±7.78	48.14±10.75	
	P	0.010*	0.011*	0.002**	0.004**	0.004**	
Anterior temporalis muscle activity at saliva swallowing	MPA group						0.005**
	Churro	204.19±170.63	77.46±77.51	97.70±76.23	154.10±81.07	277.00±156.18	0.000***
	Jumper appliance	279.00±133.96	117.81±75.19	246.38±132.60	285.95±119.54	392.67±186.67	
	P	0.379#	0.342#	0.024*	0.033*	0.233#	
Anterior temporalis muscle activity at clenching	MPA group						0.002**
	Churro	511.19±289.72	275.04±195.79	309.09±263.96	379.67±235.93	613.66±239.29	0.000***
	Jumper appliance	697.90±280.91	284.09±91.63	429.90±193.13	639.47±211.71	897.52±221.58	
	P	0.244#	0.914#	0.348#	0.051#	0.040*	

*Significant difference. #Nonsignificant difference in also decreased in the first month and then it showed a progressive increase, which was significant from the pretreatment value (P = 0.005, P = 0.000), respectively, in group I and group II. On comparing the two groups, the changes were insignificant (P = 0.286 and P = 0.233) in masseter and anterior temporalis muscle, respectively.

EMG activity during clenching

The EMG activity of masseter muscle decreased in the first month and then it showed a progressive increase during the 6 months of the observation period, which was statistically significant from the pretreatment value (P = 0.001, P = 0.001), respectively, in group I and group II. The EMG activity of anterior temporalis muscles also decreased in the first month and then it showed a progressive increase, which was significant from the pretreatment value in group I and group II, respectively (P = 0.002, P = 0.000). On comparing the two groups, the changes were significant (P = 0.037 and P = 0.040) in masseter and anterior temporalis muscle, respectively.

Discussion

Functional appliances used in the correction of Class II malocclusions are shown to modify the neuromuscular environment of the dentition and associated bones.[16-18] Modifying the functional position of the mandible results in an immediate change in the neuromuscular activity of orofacial muscles, and that can be studied with EMG.[13,19] EMG can be done by two methods: needle EMG and surface EMG. Numerous studies[1,8-11,13] using surface EMG for assessment of the effect of appliances and occlusal schemes on masticatory muscle function are reported in the literature. This study includes use of needle EMG because of many advantages over surface EMG, which includes good access to deeper muscle fibers, a high range of recording frequency, and no influence of subcutaneous fat thickness on recording. It is also possible to accurately reposition needle electrodes between experimental periods. Moreover, surface EMG has been reported to produce mean recording errors for temporal and masseter muscles of 20.0% and 27.2%, respectively.[6] Various types of electrodes[20,21] have been used for recording EMG. Concentric needle electrodes were selected for this study because of many advantages like only one electrode to be inserted, more accurate assessment, easy to place in the hairy region (anterior temporalis), and no interference in recording from the skin impedance. The method used for placing electrodes was similar to the one advocated by Yuen SVH *et al*.[16]

Our study showed that EMG values decrease after ligating both rigid and flexible functional appliances during the first month and it had increased gradually up to the pretreatment level or more than that at the end of the sixth month when functional appliances were removed.

Williamson EH and Lunquist DO[22] compared the responses of temporal and masseter muscles to mutually protected and group function occlusal schemes during various mandibular movements via two different splint designs. They concluded that posterior disocclusion rather than canine guidance reduces electromyographic activity of these muscles. Using surface electromyographic evaluation, Wood WW and Tobias A[23] reviewed reports of the actions of the major muscles of mastication for clenching tasks and found increased activity of the masseter and temporal muscles in conjunction with posterior contact and decreased anterior temporal activity with anterior contact alone. Other authors[24] reported similar findings using surface EMG. Manns A *et al*.[25] further demonstrated considerable reduction of temporal activity secondary to the use of an anterior splint with surface electrodes during maximal voluntary clenching. Borromeo GL *et al*.[26] used surface EMG to demonstrate similar decreases in masseter activity in canine-protected and group function occlusal schemes in asymptomatic individuals.

The increased postural activity of the masseter is explained as a balancing contraction as a result of the protrusion of the mandible imposed by both the appliances. These findings are in confirmation with the anatomic functions of the masseter, which plays a dominant role in elevation when the mandible is protracted. These results were in accordance of Andresen's original hypothesis that in Class II treatment with an activator, the protractor muscles are stimulated.[7]

We observed variation of the muscle activity was seen during swallowing in both the groups. Miralles R *et al.*,[27] on the other hand, found higher swallowing activity with the activator, especially in the masseter, and proposed that it could be a result of better mandible stabilization and the increase of occlusal contact area, thereby causing the muscular force to be distributed over a higher periodontal area and diminishing jaw elevator muscle inhibited by periodontal mechanoreceptors. Miralles R *et al*.[27] and Stavridi R and Ahlgren J.[27] found a considerable increase in swallowing EMG activity with an activator in the mouth; they explained it as being the result of a greater flow of saliva caused by the introduction of an insoluble material in the mouth. It was not so in the fixed functional treatment which was used in our study.

The occlusal instability caused by changed tooth position and intermaxillary relations brought just after placement of appliances (T_1) is reflected in a reduced EMG activity of masseter muscle during maximal clenching from T0 to T1 in both the groups. Muscle activity during clenching decreases with lessening numbers of posterior teeth in contact and drops dramatically when only the incisors are in contact. When clenching in the intercuspal position is directed anteriorly (as with clenching in both the groups), the superficial masseter muscles attain maximal activity. 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. During the functional appliances therapy, the ability to chew is impaired, lateral mandibular movement capacity is decreased, and muscles become tender; these symptoms persist during the first few weeks of treatment, which was more in rigid fixed functional appliances than the flexible functional appliances.[13] The decrease in EMG activity in the first few weeks might also be explained by the fact that when the muscle lengthens and is isometrically contracted, EMG activity drops despite the greater tension. A drop-in EMG activity might also have been due to the patient's inexperience in wearing a fixed functional appliance, sore teeth during treatment, worries about soft-tissue damage, and breakage during the first few months.[28]

The muscles must regain their balance if the mandible is to remain in its new position. After a few months, once some occlusal contacts have been re-established, temporal and masseter muscle activity starts to gradually rise to pretreatment levels, just as the need for compensatory muscle function is reduced when skeletal adaptations occur.[12]

Flexible fixed functional appliances are more elastic than the rigid fixed functional appliances as they allow lateral movements of the mandible with ease, and patients can close in centric relation and repeatedly bite with the appliance voluntarily and when swallowing saliva, resulting in a more stable mandible. This could be the reason that the flexible functional appliances show more EMG activity than the rigid functional appliances.[12] That was also seen in our study. Anehus-Pancherz M,[10] also reported that the immediate response to treatment with fixed functional appliances was a strong reduction in masseter and temporalis activity during clenching and that a gradual increase in muscle activity occurred from the first month onward until 6 months.[22]

There was change in the postural activity of anterior temporalis immediately on insertion of both the appliances, which is in agreement with Ahlgren J.[8] During the 6-month period, the values at each recording were higher with both the appliances, presumably the result of the reciprocal innervation of the retractor muscles in protruded mandibular movements. These findings are in agreement with Moyers RE,[19] Carlsoo S,[28] Latif A,[29] and Ralston HJ and Libet B[30]

Muscle activity during maximal voluntary clenching immediately on insertion of the appliance was less in both the groups. This can be accounted by the fact that when the muscle is lengthened and isometrically contracted, the EMG activity falls, although the tension is greater.[31-34] This is in accordance with the active muscle activity in the isometric length-tension curve.[10] This can also be interpreted as an effect of reciprocal innervations as the temporalis muscle is an antagonistic muscle to a protrusive movement of the mandible. This agrees with the results of Ahlgren J,[8] who reported a decrease in electrical activity during biting contractions in the anterior temporalis muscles in 82% of the cases and a decrease in contraction of masseter muscle in 59% of the cases immediately after insertion of the activator. It can be because of the relative inexperience with the wear of the removable functional appliances and apprehension of soft tissue damage and breakage.[7]

There was a significant increase in EMG activity of masseter and anterior temporal muscles in our study, so we deduce that active contraction of muscles plays a more important role in treatment with both the appliances, MPA IV and Churro Jumper, than passive tension associated with viscoelastic properties of soft tissues unlike the activator. This increase in postural EMG activity may reflect an adaptation to a new mandibular position during the active phase of treatment with MPA IV and Churro Jumper.[7]

Limitations: During the course of our study, saliva swallowing was frequently the most difficult recording to achieve. A limitation of the procedure is that it depends largely on how much effort is exerted during the exercise. The effort is less during natural "reflex" swallowing. In this study, all subjects were in the active phase of sagittal correction by the end of 6 months that might not be lengthy enough to draw definite conclusions. The possibility of adaptation effects later with both the appliances, MPA IV and Churro Jumper, is an important factor.[7] Another limitation is the small sample size.

Conclusion

Both rigid (MPA IV) and flexible (Churro Jumper) fixed functional appliances caused a significant increase in EMG activity of masseter and anterior temporalis muscle from the pretreatment value during postural rest position, swallowing, and clenching in 6 months of the observation period, but the flexible appliance (Churro Jumper) showed a more significant increase in muscle activity.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Hiyama S, Kuribayashi G, Ono T, Ishiwata Y, Kurodam T. Nocturnal masseter and suprahyoid muscle activity induced by wearing a bionator. Angle Orthod 2002;72:48–54.
2. Andresen V, Haupl K. Funktions kieferorthopädie; Die Grundlagen des Norwegischen System. Leipzig: JA Barth; 1936.
3. Selmer-Olsen R. En Kritisk betraktning over "Det norske system." Nor Tannlaegefor Tid 1937;47:85-91,134-42, and 176-93.
4. Umehara Y. An experimental study on the functional jaw orthopedics. J Stomatol Soc 1941;15:482.
5. Witt E. Investigations into orthodontic forces of different appliances. Trans Eur Orthod Soc 1966;391-406.
6. Greco PM, Vanarsdall RL Jr, Levrini M, Read R. An evaluation of anterior temporalis and masseter muscle activity in Appliance therapy. Angle Orthod 1999;69:141-6.
7. Aggarwal P, Kharbanda OP, Mathur R, Duggal R, Parkash H. Muscle response to the Twin-block appliance: An electromyographic study of the masseter and anterior temporal muscles. Am J Orthod Dentofac Orthop 1999;116:405-14.
8. Ahlgren J. Early and late electromyographic response to treatment with activators. Am J Orthod 1978;74:88-93.
9. Pancherz H. Activity of temporal and masseter muscles in Class II division 1 Malocclusions: An EMG investigation. Am J Orthod 1980;77:679–88.
10. Pancherz H, Anehus-Pancherz M. Muscle activity in Class II Division 1 malocclusions treated by bite jumping with the Herbst appliance: An electromyographic study. Am J Orthod 1980;78:321-9.
11. Sessle BJ, Woodside DG, Bourque P, Gurza S, Powell G, Voudouris J, Metaxas A, *et al*. Effects of functional appliances on jaw-muscle activity. Am J Orthod Dentofac Orthop 1990;98:222–30.
12. Sood S, Kharbanda OP, Duggal R, Sood M, Gulati S. Neuromuscular adaptations with flexible fixed functional appliance-a 2-year follow-up study. J Orofac Orthop 2011;72:434-45.
13. McNamara JA Jr. Neuromuscular and skeletal adaptations to altered function in the orofacial region. Am J Orthod 1973;64:578-606.
14. Surface Electromyography (sEMG) Activity of Masticatory Muscle (Masseter and Temporalis) with Three Different Types of Orthodontic Bracket. Biomed Res Int 2021;2021:6642254.
15. Filho CMC. Mandibular protraction appliance IV. J Clin Orthod 2001;35:18-24.
16. Yuen SWH, Hwang JCC, Poon PWF. Changes in power spectrums of electromyograms of masseter and anterior temporal muscles during functional appliance therapy in children. Am J Orthod Dentofac Orthop 1990;97:301-7.
17. Castanon R, Valdes MS, White LW. Clinical use of the Churro jumper. J Clin Orthod 1998;32:731-45.
18. Graber TM, Rakosi T, Petrovic AG. Dentofacial Orthopedics with Functional Appliances. St Louis: CV Mosby; 1985.
19. Basri R, Alam MA, Imanishi T, Ping SY, MohdAdirus Z, Idrus M, *et al*. Functional ability of masticatory muscles in treated mandibular fracture cases using surface electromyography (sEMG). J Hard Tissue Biol 2016;25:431-36.
20. Moyers RE. Temporomandibular muscle contraction patterns in Angle Class II division 1 malocclusions: An electromyographic analysis. Am J Orthod 1949;35:837–57.
21. Moller E. The chewing apparatus. An EMG study of the action of the muscles of mastication and its correlation to facial morphology. Acta Physiol Scand 1966;69:280.
22. Moss JP. Function: Fact or fiction? Am J Orthod 1975;67:625-46.
23. Nishi SE, Basri R, Alam MK, Komatsu S, Komori A, Sugita Y, *et al*. Evaluation of masticatory muscles function in different malocclusion cases using surface electromyography. J Hard Tissue Biol 2017; 26:23 8.
24. Uses of electromyography in dentistry: An overview with meta-analysis. Eur J Dent 2016;10:419-25.
25. Manns A, Rocabado M, Cadenasso P. The immediate effect of the variation of anteroposterior laterotrusiveconctact on the elevator EMG activity. Cranio 1993;11:184-91.
26. Borromeo GL, Suvinen TI, Reade PC. A comparison of the effects of group function and canine guidance interocclusal device on masseter muscle electromyographic activity in normal subjects. J Prosthet Dent 1995;74:174-80.
27. Miralles R, Hevia R, Contreras L, Carvajal R, Bull R, Manns A. Patterns of electromyographic activity in subjects with different skeletal facial types. Angle Orthod 1991;61:277-84.
28. Stavridi R, Ahlgren J. Muscle response to the oral-screen activator. An EMG study of the masseter, buccinator and mentalis muscles. Eur J Orthod 1992;14:339-49.
29. Carlsoo S. An electromyographic study of the activity of certain suprahyoid muscles (mainly the anterior belly of digastric muscle) and of the reciprocal innervation of the elevator and depressor musculature of the mandible. Acta Anat 1956;26:81-93.
30. Latif A. An electromyographic study of the temporal muscle in normal persons during selected positions and movements of the mandible. Am J Orthod 1957;43:577-91.
31. Ralston HJ, Libet B. The question of tonus in skeletal muscle. Am J Phys Med1953;32:85-92.
32. Saini R, MirYasser A, Singhal G, Sharma N, Lukose A, Kurup A. A retrospective assessment of alterations in gingival crevicular fluid (GCF) after applying fixed orthodontic appliances: An original research study. JCDR 2021;3:647-53.
33. Saini R, Thakur N, Jindal Goyal R. Analysis of smile aesthetic changes with fixed orthodontic treatment. Cureus 2022;14:e32612.
34. Association between muscle activity and overjet in class II malocclusion with surface electromyography. J Orthodont Sci 2018;7:3.