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Electromyographic Activity Changes of Jaw-Closing Muscles in Patients with Different Occlusion Schemes after Fixed Prosthetic Restoration

SUMMARY

Background/Aim: *To investigate the electromyographic (EMG) activity changes of jaw-closing muscles in patients with different occlusion schemes and posterior edentulous span, after the placement of teeth-supported fixed partial denture (FPD).* ***Material and Methods:*** *The study sample consisted of 20 patients (10 men and 10 women, the mean age being 50 years) with a posterior edentulous area that includes two missing premolars or one premolar and one molar. The participants were divided into two groups with different occlusion schemes: canine-guided occlusion (CGO) and group function occlusion (GFO). The metal-ceramic FPD were fabricated according to the clinic-standardized protocol. EMG activities of masseter and anterior temporalis patients' muscles were recorded with bipolar surface electrodes during maximal voluntary clenching. EMG evaluation was repeated twice: (T1) before the fabrication of FPD (T2) after eight weeks of FPD cementation and intraoral functioning of restoration. The data were subjected to Analysis of Variance–ANOVA within the methodological framework of the General Linear Models with Repeated Measures. The Bonferroni test was used to compare multiple mean measures. Statistical analysis was conducted with SPSS ver. 11.5. The level of significance was predefined at a=0.05.* ***Results:*** *Group 1 with CGO presented significantly higher levels of masseter (mean maximum EMG average before 79.36μV and 139.68μV after) and temporalis (mean maximum EMG average before 79.07μV and 149.37μV after) EMG activity after FPD placement. Group 2 with GFO also showed significantly higher levels of masseter (mean maximum EMG average before 61.57μV and 165.30μV after) and temporalis (mean maximum EMG average before 56.94μV and 133.08μV after) EMG activity after the prosthetic restoration.* ***Conclusions:*** *It may be concluded that fixed prosthetic restoration, in both patients with canine-guided and group function occlusion, results in increased EMG jaw-muscle activity.*

Key words: Electromyography, Masseter, Temporalis Anterior, Occlusion Schemes, Fixed Prosthetic Restoration.

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Introduction

It has been reported that masticatory function is dependent on the state of the dentition, particularly on the number of posterior occlusal contacts, the type of dental prosthesis replacing missing teeth and the jaw-closing muscles' recruitment and function[1,2]. The number of occluding teeth and the periodontal receptors provide positive feedback to the jaw-closing muscles during mastication and, therefore, loss of posterior teeth may lead to a reduction in masticatory efficiency and in the overall level of muscle activity[3,4,5].

Surface electromyography (EMG) has become an important research tool for analysis the function and dysfunction of jaw-closing muscles during rest, biting and mastication, because it captures information about the electrical potentials of these muscles[6]. In addition, surface EMG has been used for investigating sleep or waking-state oral parafunctional activity (i.e. bruxism)[7], muscle function and dysfunction in patients with Temporomandibular disorders (TMD)[8,9,10] and the maintenance of posture[11]. Moreover, surface EMG has proven to be a valuable method for studying the influence of occlusal conditions on jaw-muscle activity[2,12], the influence of occlusion scheme on a patient's masticatory system physiology and the effectiveness of various prosthetic treatment interventions[13,14,15]. It has been postulated that an increase in working-side posterior tooth contact is associated with an increase in total jaw-closing muscle activity and the magnitude of EMG activity[16].

Previous studies have evaluated the effect of different occlusion schemes such as canine-guided occlusion (CGO) and group function occlusion (GFO) on muscle activities by masticatory muscle EMG measurements, however the results were inconclusive[14,17,18]. CGO was defined as "a mutually protected articulation, in which the horizontal and vertical overlap of the canine teeth disclude the posterior teeth in the excursive movements of the mandible"[19]. On the other hand, GFO was described as "the existence of multiple contact relations between the maxillary and mandibular teeth in lateral movement on the working side"[19]. There is no sufficient scientific evidence to suggest that a CGO is better or worse than a GFO, either from a functional or from an EMG point of view[17,20]. It seems that jaw-closing muscles were influenced by the occlusion scheme in a different way, with the anterior temporalis muscle being the most affected[20].

Thus, the aim of the present study was to investigate the EMG activity changes of jaw-closing muscles in patients with different occlusion schemes and posterior edentulous span, after the placement of teeth-supported fixed partial denture (FPD).

Material and Methods

Study sample

Twenty volunteers (20 men and 20 women, the mean age being 50±3.5years) having reported 2 missing posterior teeth in one sextant (two premolars or one premolar and one molar) as their main complaint to the Clinic of Fixed Prosthesis and Implant Prosthodontics, School of Dentistry, Aristotle University of Thessaloniki, were selected to participate in this study. The inclusion criteria were: a history of good health and age between 25 and 60 years; unilateral absence of two posterior missing teeth with an edentulous span being defined by terminal teeth; absence of painful dental problems and periodontal disease; Class I Angle's classification of occlusion relationship; and CGO or GFO occlusion scheme. In contrast, the exclusion criteria were: no signs and symptoms of TND or recent occlusal splint therapy; no parafunctional habits and no skeletal malocclusions. The participants were divided into two groups: Group 1, consisting of ten patients, presented a canine guidance occlusal pattern (CGO) and Group 2, made up of the other ten patients, presented a group function occlusal (GFO) pattern. All participants provided written informed consent for the study, which was approved by the Ethical Committee of Aristotle University of Thessaloniki's School of Dentistry and observed the guidelines in accordance with the Declaration of Helsinki.

Experimental protocol

All patients underwent thorough clinical examination, and the medical and dental history of their dental and periodontal status was taken. The metal-ceramic 4 or 5-unit FPDs were fabricated in accordance with the restorative procedures of the clinic-standardized protocol applied by the Aristotle University of Thessaloniki, School of Dentistry, Fixed Prosthesis and Implant Prosthodontics clinic [21,22,23]. The fixed prosthetic restorations were provisionally cemented for a week for an intraoral inspection before permanent cementation. The number and position of patients' anterior and posterior occlusal contact sites were recorded in the maximum intercuspation position, before and after the placement of FPD, by using both 40μm-thick articulating paper (Bausch articulating papers, Inc. Nashua, NH 03060, USA) and 8μ metal-foil Shimstocks (Hanel, Roeko, D-89122 Langenau, Germany).

Electromyographic (EMG) recordings were obtained from the left and right masseter and anterior temporalis muscle bilaterally using surface bipolar, self-adhesive and pre-gelled electrodes (FIAT Spa, Torino, Italy) with an inter-electrode distance of 20mm. Bipolar electrode configuration was used in every case, with a ground electrode being placed below the earlobe. For the purpose of recording EMG activity of the superficial masseter muscle, the electrodes were placed parallel to the exocanthion-gonion line over the lower anterior part of the main belly of the muscle determined by palpation[24,25,26]. For the anterior temporalis, the electrodes were positioned vertically about 1cm above the zygomatic arch and 1.5cm behind the orbital oris[24,25,27]. A detailed description of the method is given in a previous study[26]. EMG evaluation was repeated twice: (T1) before the fabrication of FPD and (T2) eight weeks after permanent cementation and intraoral functioning of FPD .

The EMG recording instrument (Myotronics-Noromed, Inc., Seattle, WA, USA) consisted of an isolated preamplifier with an input impedance>100MΩ, a differential main amplifier and computerized integrated system K6-I (K6-1/EMG hardware and software for eight channel surface EMG) connected to a compatible PC computer for data storage and analysis.

The participants were seated upright in a dental chair with the Frankford plane parallel to the floor in a specially modified clinic. Each subject was asked to clench as hard as possible on 9mm cotton rolls placed between the maxillary and mandibular posterior teeth at least 3 times for about 3s. EMG measurements during subject's maximum voluntary clenching were performed by a single operator who was blind to the patient's group.

In each EMG recording the variables examined were the peak and the average EMG activity of the muscles in each of the three clenches at maximum voluntary contraction. The data (EMG peak and average from the four tested muscles) processed for statistical analysis were the mean of the three values obtained from the three clenches for the masseter and temporalis muscles corresponding to the side with FPD placement (Peak-M-P, Average-M-P, Peak-T-P, Average-T-P), and the mean value of the three clenches for the masseter and temporalis muscles corresponding to the opposing side with natural dentition (Peak-M-N, Average-M-N, Peak-T-N, Average-T-N). The side having received the fixed dental prosthesis appears as P, while the opposing side with natural dentition appears as N. These constituted the comparable data on the EMG recordings resulting from the three EMG recordings of each patient, in two different sessions (T1, T2).

Statistical method

The experimental design is considered to be mixed factorial with one factor between subjects and one factor within subjects, as far as the parameters of EMG activity (peak and average) of the jaw-closing muscles are concerned (masseter and temporalis muscles for the side with fixed dental prosthesis (P) and for the opposing side with natural teeth (N)).

The two-level occlusion scheme (canine-guided occlusion (CGO) and group function occlusion (GFO)) constituted the "between" factor, while the two-level time factor ((T1) before the fabrication of FPD and (T2) after eight weeks of FPD cementation and intraoral functioning of restoration) constituted the "within" factor. The experimental data were subjected to Analysis of Variance (ANOVA) within the methodological framework of the General Linear Model with Repeated Measures. The Bonferroni test was applied for multiple comparisons of mean values and contrasts.

Testing the homogeneity of both groups of patients in terms of age and EMG activity of the masseter and anterior temporalis muscles at the first time point (T1), before the application of the FPD, was conducted using t-test.

Statistical analyses were conducted using SPSS software v.11.5. The level of significance was predefined at a=0.05.

Results

The results of the EMG recordings of the masseter and anterior temporalis muscle, and specifically the mean value of peak and average for the side where the FPD was placed (P), as well as for the opposing side (N), for both groups (CGO and GFO) and for two time points of recordings (T1 and T2), are presented below. The level of significance was predefined at a=0.05.

Mean maximum EMG Peak and Average (and Standard error-SE) of the masseter muscle (on the P-side with missing teeth, before and after FPD placement) for both groups (CGO and GFO) are shown in Table 1. A statistically significant difference in mean EMG activity (peak and average) was found for the masseter muscle in two groups (CGO and GFO) between T1-T2.

Table 1. Presents the mean maximum EMG Peak & Average (μV) and Standard error (SE) of the masseter muscle for the P-side with missing teeth before (T1) and after FPD placement (T2) for both groups (CGO and GFO)

	EMG peak			EMG average		
Occlusion	T1	T2	P^+	T1	T2	P^+
CGO	154.57 ±25.32	239.82 ±32.74	0.002	79.36 ±13.20	139.68 ±21.44	<0.001
GFO	123.00 ±25.32	307.05 ±32.74	<0.001	61.57 ±13.20	165.30 ±21.44	<0.001
P^*	0.330	0.164		0.353	0.409	

* *P*-value for between groups' comparisons
\+ *P*-value for within groups' comparisons

Mean maximum EMG Peak and Average (and Standard error-SE) of the masseter muscle (on the N-side without missing teeth, before and after FPD placement) for both groups (CGO and GFO) are shown in Table 2. A significantly higher mean EMG activity (peak and average) of the N-side of the masseter muscle was found after the fixed prosthetic restoration in both groups (CGO and GFO).

Table 2. Presents the mean maximum EMG Peak & Average (μV) and Standard error (SE) of the masseter muscle for the N-side without missing teeth before (T1) and after FPD placement (T2) for both groups (CGO and GFO)

	EMG peak			EMG average		
Occlusion	T1	T2	P^+	T1	T2	P^+
CGO	169.20 ±29.05	239.90 ±32.75	0.011	93.82 ±18.31	167.22 ±22.56	<0.001
GFO	136.00 ±29.05	307.10 ±32.75	<0.001	73.35 ±18.31	138.82 ±22.56	0.001
P^*	0.430	0.164		0.440	0.385	

* *P*-value for between groups' comparisons
\+ *P*-value for within groups' comparisons

Mean maximum EMG Peak and Average (and Standard error-SE) of the anterior temporalis muscle (on the P-side with missing teeth, between T1-T2) for both groups (CGO and GFO) are presented in Table 3. A statistically significant difference was reported in the EMG activity (peak & average) of the P-side of the temporalis muscle in the CGO and GFO groups, between T1-T2.

Table 3. Presents the mean maximum EMG Peak & Average (μV) and Standard error (SE) of the anterior temporalis muscle for the P-side with missing teeth before (T1) and after FPD placement (T2) for both groups (CGO and GFO)

	EMG peak			EMG average		
Occlusion	T1	T2	P^+	T1	T2	P^+
CGO	146.48 ±25.94	270.38 ±30.74	0.001	79.07 ±13.65	149.37 ±19.40	<0.001
GFO	115.76 ±25.94	234.14 ±30.74	<0.001	56.94 ±13.65	133.08 ±19.40	<0.001
P^*	0.413	0.416		0.267	0.560	

* *P*-value for between groups' comparisons
\+ *P*-value for within groups' comparisons

Mean maximum EMG Peak and Average (and Standard error-SE) of the anterior temporalis muscle (on the N-side without missing teeth, before and after FPD placement) for both groups (CGO and GFO) are presented in Table 4. A significantly higher mean EMG activity (peak and average) of the N-side of the anterior temporalis muscle was found after the fixed prosthetic restoration in both groups (CGO & GFO).

Table 4. Presents the mean maximum EMG Peak & Average (μV) and Standard error (SE) of the anterior temporalis muscle for the N-side without missing teeth before (T1) and after FPD placement (T2) for both groups (CGO and GFO)

	EMG peak			EMG average		
Occlusion	T1	T2	P^+	T1	T2	P^+
CGO	131.30 ±20.45	250.43 ±31.24	0.004	72.06 ±12.22	142.65 ±19.61	<0.001
GFO	116.80 ±20.45	195.84 ±31.24	0.010	68.77 ±12.22	111.14 ±19.61	0.010
P^*	0.622	0.233		0.851	0.271	

* *P*-value for between groups' comparisons
\+ *P*-value for within groups' comparisons

Discussion

In the current investigation, masseter and anterior temporalis EMG activity changes in patients with different occlusion schemes were analyzed and compared, after fixed prosthetic restoration of their posterior unilateral edentulous span. The findings of the present study have shown that there was a significant increase in the EMG activity of the masseter and anterior temporalis muscles eight weeks after the completion of teeth-supported FPD in both groups (Group 1 with CGO and Group 2 with GFO) (Tables 1, 2, 3, 4).

Surface EMG is a simple, non-invasive, sensitive method for the analysis of jaw-closing muscle function before and after various dental treatment interventions; for this reason prosthodontics, orthodontics and oral physiology have been the main fields of EMG application[6,15,28,29]. The masseter and anterior temporalis muscles have been the most examined masticatory muscles because of their ease of accessibility to surface-electrode recordings[30,31]. EMG measurement reliability was found to be dependent on various factors such as electrode type and location, impedance of the skin, subcutaneous fat and depth of the muscle under study[6,8,32]. However, the use of standardized and repeatable protocols eliminates such factors and makes EMG signals measurement reliable as well as clinically useful[33,34]. In regard to EMG muscle recording, a static analysis, such as maximum voluntary clench on cotton rolls, was proffered in the present study as it represents the simplest and best described oral task. It has been suggested that with this mouth opening space, an ideal sarcomere length of 3μm is provided for the maximal force of muscle contraction[35,36], although other studies report the figure to be 2.27 – 2.55μm[37]. Additionally, it has been reported that a patient's masseter and temporalis muscles contract similarly when clenching either with cotton rolls or in the maximum intercuspation position[38,39].

The association of surface EMG activity and occlusion alterations has been reported in several studies, however heterogeneous data emerge from the literature[12,40,41]. A modification in the occlusion parameters and pattern may indicate changes in surface EMG characteristics[12]. The recruitment of the jaw-closing muscles changes markedly depending on the number and position of occlusal contacts[40]. The findings of the present study are in agreement with previous investigations on the jaw-closing muscles, which have shown that subjects with higher occlusal stability present larger EMG activity during maximum clenching[15,42,43]. This might be because a higher number of posterior contacts provides a stable occlusal support in the intercuspal position, which allows jaw-closing muscles to achieve higher levels of muscular activity during clenching and chewing[42]. This study demonstrated that the muscular activity of masseter and temporalis muscles in both groups (Group 1 with CGO and Group 2 with GFO) was improved by increasing the EMG activity of both sides after teeth-supported FPD placement (Tables 1,2,3,4). The results of this investigation are in line with previous findings showing that the number of replaced missing natural teeth and their position in the dental arch, the design and type of conventional dental prosthesis or implant-supported prostheses could positively influence jaw-closing muscle activity during clenching and, by extension, masticatory function[15,44,45,46,47]. It seems that the change in neuromuscular pattern and EMG activity is modified by continuous sensory feedback from the state of the dentition, the balanced occlusal contacts between the opposite sides and other sensory inputs from the periodontal ligaments and bilateral temporomandibular joints.

Harmonious canine-guided occlusion and group function occlusion have been described in the literature as being clinically acceptable elements of a functional occlusion[20]. The results of this study revealed that fixed prosthetic restoration and more posterior occlusal contacts, in both groups (Group 1 with CGO and Group 2 with GFO), resulted in increased EMG jaw-muscle activity (Tables 1,3). These findings are in agreement with other studies, in which greater jaw muscle activity was observed through an increase in the number of occlusal contacts to the posterior region, especially in simulated group function occlusion[16,40,48]. Additionally, observations during the gum chewing procedure revealed that there was no significant difference in EMG activity between the two different occlusion schemes[14]. On the other hand, it has been found that EMG activity in the anterior temporalis significantly increased during maximal clenching in the simulated GFO compared to the simulated CGO[18]. The contradictory findings in the literature concerning the EMG changes of jaw-closing muscles in patients with different occlusion schemes might be explained by the difference in the clenching force level exerted during each occlusal condition, the different asymptomatic and dysfunctional jaw muscles examined and the various EMG parameters used during static muscle contractions (clenching) or dynamic contractions (chewing).

The limitation of the present study was the relatively small number of patients as a result of the specific inclusion criteria. Furthermore, the EMG recording was limited to the masseter and anterior temporalis muscles, and other jaw-closing muscles were not examined. It must be also taken into consideration that there is still a lack of general agreement on standards for surface EMG signal detection from jaw-closing muscles during static and dynamic oral tasks. An important element that needs to be taken into account in the future is the change in EMG activity resulting from the restoration of dental occlusion in patients with different occlusion schemes during dynamic tasks (chewing).

Conclusions

Within the limitations of this clinical study, it may be concluded that fixed prosthetic restoration and more posterior occlusal contacts, in both patients with canine-guided and group function occlusion, results in increased EMG jaw-muscle activity. It seems that the change in EMG activity resulting from the restoration of dental occlusion is possibly related to a new neuromuscular pattern that was induced in both groups within the well-regulated, balanced occlusal contacts between the opposite sides.

The findings suggest that both occlusal schemes can be used for the fixed prosthetic restoration of patients with a posterior edentulous area in one sextant.

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