

Comparing the Electromyographic Features of the Masseter and Temporal Muscles in Patients with full Mouth Implant-supported FDPs and Natural Dentition

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ABSTRACT

Background: Due to increasing demands for a full mouth implant reconstructions and the fact that the most failures are associated with biomechanical complications, determining the effect of different occlusal patterns on these complications seems inevitable. The aim of this study is to compare affection of different occlusal designs in full mouth implant reconstructed patients on electromyographic activity of temporal and masseter muscles compared to natural dentition. **Methods:** Thirty-two patients were included in this study, considering that 16 patients had natural dentition and the other 16 were full mouth implant reconstruction patients. In both groups, the participants were divided into two subgroups: 8 patients had canine guidance occlusal pattern and the other eight had a group function occlusal pattern. Muscle contractions were studied during both maximum intercuspation and lateral excursions to the point of intercanine contact using an electromyography device. **Results:** The average percentages of masseter muscle contraction in lateral excursions relative to maximum intercuspation were as follows: 72.20% in full mouth implant reconstruction patients with group function occlusion 69.49% in natural dentition with group function occlusion 58.85% in full mouth implant reconstruction patients with canine guidance occlusion 30.91% in natural dentition with canine guidance occlusion. The average percentages of temporal muscle contraction in lateral excursions relative to maximum intercuspation were as follows: 70.87% in full mouth implant reconstruction patients with group function occlusion 78.57% in natural dentition with group function occlusion 51.99% in full mouth implant reconstruction patients with canine guidance occlusion 31.55% in natural dentition with canine guidance occlusion. **Conclusion:** A canine guidance occlusal pattern in both, natural dentition and full mouth implant-supported FDP, patients resulted in decreased muscle contraction. This decreasing is more significant in natural dentition and it is better to establish a canine guided occlusion in a full mouth reconstruction patient.

Keywords: Electromyography, Canine, Occlusal pattern, Muscles, Implant.

1. INTRODUCTION

The aim of any dental treatment is retrieving contour, function, comfort, esthetics and health of the dental system. What makes implant dentistry a unique approach is its ability to achieve these goals despite deficiencies such as atrophy, the disease and injuries to the dento-skeletal system. Statistical and demographic evaluations indicate an increase in average population and age. Since aging usually accompanies edentulism (1, 2) therefore an increase in demand for implant treatment is expected. Implant-supported fixed dental prostheses (FDPs) can restore masticatory function better than removable complete dentures based on both objective and subjective indices. An im-

portant factor to consider during reconstruction is an occlusal pattern establishment (3). Occlusal reconstruction might be canine guided or group function during excursions (4). The rules of occlusion in natural dentition also apply to full mouth implant reconstruction procedures; yet there isn't a general consensus regarding natural dentition occlusal relationships during excursions. An ideal occlusion is compatible with stomatognathic system (5). Regarding the biomechanics, it's essential to understand the limitations of implant treatment and differences between the implant and natural dentition. The most basic difference is the presence of PDL in natural dentition while an implant is fixed rigidly via

Osseo integration. The PDL acts as a shock absorber distributing the imposing stress to the tooth, in addition, it has a unique neurofeedback system which leads to proprioception (6). This feedback system prevents premature contacts and establishes a stable habitual occlusion though not compatible with the centric relation. However, there is no feedback system in implant-supported prostheses and the occlusion is reconstructed very close in centric relation, if there are any interferences or premature contacts in the mandibular path of closure, it would lead to crestal bone loss (6). To analyze the stomatognathic system activity, it is imperative to determine the features of the masticatory muscle function. A good part of the masticatory muscle function is controlled by bio-feedback from PDL (7). Electromyography is used to study the effect of occlusion on normal muscle activity (8). Several studies have compared the effect of canine guided and group function occlusion on electromyographic activity of anterior temporal, masseter, sternocleidomastoid, infrahyoid and suprahyoid muscles.

In this study, the effect of different occlusal patterns on electromyographic activity of the masseter and temporal muscles have been investigated and compared patients with natural dentition and full mouth implant. This evidence may help the practitioner make a better decision regarding occlusal reconstruction in implant patients.

2. MATERIALS AND METHODS

Two groups of 16 patients (a total of 32 patients), one with natural dentition and the other with full mouth implant-supported FDPs were included in the study. Each group consisted of 8 patients with group function occlusion and 8 patients with canine guided occlusion. After a thorough occlusal exam by a clinician in the Mashhad School of Dentistry, the subjects were selected. Inclusion criteria for case group consisted of, [I], Full mouth implant-supported FDPs [II], At least 6 maxillary implants and 5 mandibular implant-supported prostheses [III], At least 12 teeth in each arch are in occlusal contact with their opposing tooth [IV], No signs of TMD or muscle disorder [V], At least 6 months since prosthesis placement (for patient adaptation considerations) [VI], Not taking drugs that affect muscle activity. Inclusion criteria for control group consisted of, (1) Presence of all teeth except for 3rd molars (b) Class I canine relationships on both sides (c) Normal overjet and overbite (d) No existing extensive restorations or restorations involving incisal edge (e) No history of orthodontic treatment (f) No histories of TMDs and muscular disorders (g) Not taking drugs that affect muscle activity.

The control group consisted of 9 female and 7 male patients and 8 female and 8 male were included in the case group. All implant patients were treated directly by or under the supervision of Mashhad dental school professors and had desirable occlusion and of course satisfied with treatment outcome. After patient selection, each of them received a written consent explaining the study description, the advantages and possible risks. Patients underwent electromyography of left and right masseter and anterior temporal (4 muscles in each patient). The patients were free to leave the study whenever they wanted. The test was performed by an expert professor of neurology department of the Mashhad Medical School in



Figure 1. Electrode placement on masseter muscle



Figure 2. Electrode placement on temporal muscle

Ghaem Hospital, Mashhad. He was totally unaware of types and classifications of occlusion.

The electromyographic device was Neuropack s1 made by Nihon Kohden in Germany. Time division or sweeps speed was set at 10 msec/Cm and the voltage division or device sensitivity was set on 200 μ volt/Cm. The device filter received signals between 20 and 2000 Hz. The patients were instructed about jaw movements before the experiment. They were asked to practice the instructed movements in the mirror under the practitioner supervision. Electromyography was conducted while the patients were comfortably seated upright, without any head support and gazing straight ahead at a mark, 3 meters away on the wall. All the patients were tested in the neurology ward of Qaem Hospital between 9 and 12 am. The skin on the test area was wiped with alcohol to enhance conductivity. The neutral pad of the device, 15 mm in diameter, was placed on the patient's forehead. Two other pads, each 10 mm in diameter, were placed on the muscle body and muscle, tendon, 18 ± 3 mms far from each other. To test the temporal and masseter muscles, the anterior portion and superficial portion were selected respectively. The location of the pads was adapted from the Hans Pancherz pattern which was also used by Millars's study (9) (Figure 1 and Figure 2).

To standardize the test, a primary electromyography was obtained, while the patient clenched on a cotton roll placed in second premolar area on both sides and the subsequent records were compared with this one.

Electromyography during central clenching and excursions: The next step was obtaining records while the patients made the following movements:

- Clenching in maximum intercuspation (task A),
- Clenching while canines are tip to tip (task B).

During each record, the highest amplitude displayed by the device was reported.

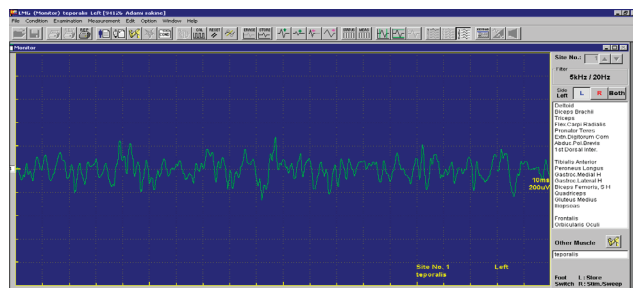


Figure 3. Sample electromyogram of left temporal in control group

These maneuvers were repeated for both sides and muscles. Each contraction lasted for 5 seconds and a 3 minutes rest was considered to prevent muscle fatigue.

Three amplitudes were recorded for each muscle, standard amplitude while clenching on cotton rolls, centric amplitude in maximum intercuspation and excursion amplitude which would make a total 12 amplitudes for each participant. Standard data were obtained by estimating the percentage of centric or excursion data to standard data ratio. The reason for this is that the participants were males or females with varying ages and body mass indices therefore the data had to be standardized for each person. Confirmatory analysis of muscle contraction symmetry and elevator muscle harmonious function was conducted. The analysis consisted of:

- Percentage of overlapping coefficient (POC%) (10),
- Torque coefficient (TC%) (11),
- Anterior-posterior coefficient (APR%) (12),
- Activity index (12),
- Asymmetry index (12).

$$IP\ ratio = \frac{EMG\ recorded\ during\ each\ clenching\ task}{EMG\ recorded\ during\ clenching\ in\ IP}$$

After confirming normal muscle function, IP ratio (comparison of muscle contraction during the excursion) was estimated by the following formula:

$$IP\ ratio = \frac{EMG\ recorded\ during\ each\ clenching\ task}{EMG\ recorded\ during\ denching\ in\ IP}$$

To analyze the data, SPSS software version 22 and Turkey test was utilized.

3. RESULTS

Symmetry and contraction analysis

Four groups, each consisting of 8 participants were surveyed for muscle function harmony. As you can see in Table 1, none of the seven variables between the 4 groups vary significantly. These indices merely indicate that muscle function is harmonious among subgroups. After confirmation of muscular balance and harmony in centric relation, the function during excursions was scrutinized.

IP ratio results (muscle contraction analysis during excursions)

As observed in Table 2, the IP ratio of masseter and temporal muscles on both sides differ significantly among the four groups of study.

The average percentage of masseter muscle contraction during excursions relative to maximum intercuspation were: 72.20% in full mouth implant patients with group function, 69.49% in patients with natural dentition and group function occlusion, 58.85% in full mouth implant patients with canine guided occlusion, 30.91% in patients with natural dentition and canine guided occlusion. The average percentage of temporal muscle contraction during excursions relative to maximum intercuspation were: 70.87% in full mouth implant patients with group function, 87.57% in patients with natural dentition and group function occlusion, 51.99% in full mouth implant patients with canine guided occlusion, 31.55% in patients with natural dentition and canine guided occlusion.

The average IP ratio of masseter muscles indicate that the highest value pertains to case group with group function oc-

Variables	Group	Mean(SD)	95%CI	F	P-value
Activity.in- dex.C	c.gf	-3.48(12.69)	-18.8 to 20	0.607	0.616
	c.cg	-5.26(15.31)	-21.57 to 25.31		
	ca.gf	1.88(9.76)	-9 to 19.54		
	ca.cg	-0.84(4.74)	-8.62 to -4.76		
Asymmetry index of masseter of centric	c.gf	4.79(11.86)	-14.29 to 20	1.602	0.211
	c.cg	0.73(15.24)	-25 to -21.95		
	ca.gf	2.89(12.11)	-14.29 to 23.08		
	ca.cg	-9.78(18.5)	-30.43 to 30		
Asymmetry index of temporal of centric	c.gf	3.84(9.99)	-9.09 to 20	0.341	0.796
	c.cg	-1.50(9.35)	-14.29 to 11.11		
	ca.gf	1.36(13.58)	-17.65 to 30.43		
	ca.cg	1.29(8.69)	-11.11 to 16.67		
Poc index of masseter of centric	c.gf	95.21(11.86)	80 to 114.29	1.602	0.211
	c.cg	99.27(15.24)	78.05 to 125		
	ca.gf	97.11(12.11)	76.92 to 114.29		
	ca.cg	109.78(18.5)	80 to 130.43		
Poc index of temporal of centric	c.gf	96.16(9.99)	80 to 109.09	0.341	0.769
	c.cg	101.5(9.35)	88.89 to 114.29		
	ca.gf	98.64(13.58)	69.57 to 117.65		
	ca.cg	98.71(8.69)	83.33 to 111.11		
Torque co- efficient of centric	c.gf	6.77(4.46)	1.93 to 13.68	0.403	0.752
	c.cg	7.78(6.84)	1.23 to 19.44		
	ca.gf	7.52(5.14)	2.33 to 16.59		
	ca.cg	9.73(5.81)	2.94 to 20		
Antero-pos- terior co- efficient of centric	c.gf	89.68(7.27)	80 to 99.95	2.372	0.092
	c.cg	87.55(9.42)	74.69 to 96.92		
	ca.gf	92.35(5.70)	80.46 to 98.88		
	ca.cg	96(2.22)	91.38 to 99.24		

Table 1. Average, standard deviation, maximum and minimum indices of study variables (n=8) (Ca.gf: case group with group function, Ca.cg: case group with canine guidance, C.gf: case group with group function, C.cg: case group with canine guidance)

Variables	Group	Mean(SD)	95%CI	F	P-value
IP Ratio ma- sseter right	c.gf ^b	68.39(11.85)	50 to 83.33	15.01	<0.001
	c.cg ^a	29.96(13.46)	12.5 to 50		
	ca.gf ^b	72.08(16.21)	50 to 100		
	ca.cg ^b	67.5(15.81)	50 to 100		
IP Ratio ma- sseter left	c.gf ^b	70.58(14.11)	57.14 to 100	12.29	<0.001
	c.cg ^a	31.88(13.41)	12.50 to 50		
	ca.gf ^b	72.32(14.01)	57.14 to 100		
	ca.cg ^a	50.21(19.34)	25 to 80		
IP Ratio temporal right	c.gf ^b	85.1(13.8)	62.5 to 100	20.61	<0.001
	c.cg ^a	34.35(14.57)	6.25 to 50		
	ca.gf ^b	70.73(9.88)	60 to 85.71		
	ca.cg ^a	50.58(16.47)	28.57 to 75		
IP Ratio temporal left	c.gf ^c	72.04(10.17)	57.14 to 87.5	17.49	<0.001
	c.cg ^a	34.74(17.36)	17.36 to 62.5		
	ca.gf ^c	71(6.69)	6.69 to 83.33		
	ca.cg ^b	53.39(10.8)	10.8 to 66.67		

Table 2. The average, standard deviation, maximum and minimum IP ratio values in left and right masseter and temporal muscles and statistic results (n=8). *: for each group the small letter indicates significant statistical difference with other peers

clusion and the lowest value belongs to control group with canine guided occlusion and the difference is statistically significant. The control group with group function occlusion has the highest average IP ratio of temporal muscle and the least value belongs to control group with canine guided oc-

clusion. The average percentage varies significantly among the four groups. The least IP ratio belongs to control group with canine guidance, canine guidance also renders less IP ratios in case groups compared to group function participants. The IP ratio doesn't vary significantly between group function case and control group.

4. DISCUSSION

By maxillary fixed prostheses have a physiological advantage since they resemble the natural dentition, whereas an overdenture even if fully supported by implants is a removable prosthesis at the end of the day. That is why the demand for full mouth FDPs is increasing day by day. However, these treatments may fail due to biomechanical complications, the most common of which is stress due to occlusal trauma in implant supported FDPs (6). Reduction in muscle contraction leads to reduced stress, trauma and prolonged service life of the restorations (13). Similar to Dellavia, Ferrario, Tartaglia's studies, due to the patient scarceness in the case group, one case had a mandibular hybrid prosthesis opposing maxillary implant supported FDP with group function occlusion. He exhibited more muscle contraction compared to his peers which are in agreement with Tartaglia's findings (14). Patients with acrylic prostheses have a lower muscular harmony due to the flexibility of materials which in turn reduces the occlusal awareness. This study had three good reasons for choosing static over dynamic method (by chewing gelatinous material while testing) as Okano (14), Forrester (15), Williamson (16) and Manns (7) did in their studies:

Maximum force is usually applied during clenching in maximum intercuspation or unilateral excursions (13).

Patients tend to react differently following the same instructions. When we guide a patient to bring the canines in cusp to cusp relationship, we minimize the effect of subjective and psychological factors (4).

Mandibular movement varies among patients while chewing, which results in alterations in electromyogram.

In the present study, all the necessary criteria were considered to obtain a reliable electromyogram: [I] Electrodes were located based on specific anatomic landmarks [II] Immobility of electrodes during contractions [III] Equal distance of at least 1.5 Cm between electrodes (17). Factors, affecting muscle contraction and electromyographic activity include: [a] Visual system which plays an important role in perceiving head position, affects the neck muscle activity. Like José Campillo's study (4), our subjects kept an open eye during the test, but the results differed from this study. He concluded that clenching with open eyes results in muscle contraction reduction, therefore visual system has such effect on masticatory system, but it is less significant than mechanoreceptors' effect (4). [b] Fear of pain or dental fracture has psychological effects that should be considered. Ferrario states that subjects don't respond similarly to the same instruction. To minimize this psychological effect, we asked the subjects to bite as hard as they could (3, 4).

A harmonious electromyogram during maximum intercuspation indicates that the neuromuscular system is well adapted to the patient's occlusion (17). Considering muscular, functional balance equations, we observed that masseter and temporal muscles of both case and control groups

were in total functional balance. Ferrario et al. (3) observed the same finding in his study. In addition to natural dentition and full mouth implant patients, he investigated a group of implant supported overdenture patients and found that the overdenture patients exhibit a less harmonious function. In the present study, the average muscular activities of both groups were similar, but Ferrario showed that the muscular activity was higher in the natural dentition group. He concluded that it might be due to lower average age of control group subjects (3). José Campillo et al. (4) stated that we'd better compare muscular activity during excursions (which is accompanied by muscle relaxation and length increase) with activity during maximum intercuspation (which is accompanied by muscle contraction and length decrease). The same analysis has been utilized in this study. In this study, we observed that masseter and temporal muscles activity reduces significantly in the control group with canine guided occlusion compared to group function occlusion. This finding is in agreement with Manns's, Williamson's and Weinberg's studies (7, 16, 18). However, Okano witnessed a different result with masseter muscle. Of course, the study outcome can vary when different study designs, e.g. dynamic versus static methods have been used. Most studies indicate a significant muscular activity reduction during posterior disclusion with an anterior guidance which is why a natural dentition occlusion better be reconstructed by a mutually protected occlusion. This study showed that a canine guided occlusion results in a reduced muscle activity compared to group function occlusion.

According to "peripheral neural mechanisms" theory, since the area of PDL in canine is less than posterior teeth, it has a less mechanosensory threshold and thus easily stimulated. Therefore a quicker and more intense reflex is expected to inhibit muscular activity in a canine guided occlusion (4). This theory applies to the findings in our study. However, in the case group with implants, the reduction in muscle activity, due to lack of PDL, may pertain to mandibular biomechanics which is a type III lever. José Campillo et al. (4) conclude that there is no significant difference in the muscular activity in canine guided or group function occlusion, which differs from our findings (4). Occlusal schemes affect activity in the masseter and temporal muscles and canine guidance renders less activity in both groups. In patients with natural dentition and normal occlusion, the muscular harmony is observed. In former studies, it has been demonstrated that after at least 6 months, patients with full mouth implant reconstruction, the muscular function is almost as balanced as patients with natural dentition (3, 19, 20). That's why one of the inclusion criteria of this study was a minimum of 6 months' time since prostheses placement. It seems that periodontal ligament's proprioceptors provide a negative feedback for muscular contraction and that's the reason to less values of muscle contraction in implant cases with canine guided occlusion compared to their peers with natural dentition.

5. CONCLUSIONS

Within the limitations of this study, we may conclude that:

First of all, temporal muscles exhibit more activity than the masseters. Second, muscular harmony is observed in maximum intercuspation in all groups. Third, canine guided oc-

clusion leads to a contraction reduction in both case and control groups. Fourth, the amount of contraction reduction in the canine guided control group is greater than their peers in case group during excursions. At last, in the case group with canine guidance, the masseter muscle activity doesn't differ significantly from case group with group function occlusion but regarding temporal muscle, a canine guided case group exhibited a significantly lower activity than group function case group.

Treatment Suggestions

A crucial consideration in full mouth reconstruction is a healthy temporomandibular joint. Reconstruction should be performed in the stable musculoskeletal jaw position a.k.a. centric relation. In order to prevent excessive force load on implants, the occlusal contacts should be in the form of point contact i.e. tripod cusp fossa contact points (rather than cusp-marginal ridge) (21). During excursions in implant supported FDPs posterior disclusion is recommended, but this disclusion shouldn't be borne only by canine fixture due to excessive off axis forces, therefore an anterior group function is advisable. The reconstructed anterior guidance should have a lighter slope than natural dentition to reduce the imposed stress on anterior fixtures. The resulting posterior disclusion is relatively minor. The recommended posterior disclusion distances for implant supported FDPs are:

- 1 mm during protrusion,
- 0.8 mm during excursions on non-working side,
- 0.3 mm during excursions on working side (22).

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