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MUSCULAR AND MASTICATORY FUNCTIONAL CHANGES IN FULLY EDENTULOUS PATIENTS REHABILITATED WITH FIXED IMPLANT SUPPORTED PROSTHESES

323.01 Stomatology

Summary of Doctor of Medical Science Thesis

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Thesis was developed at Department of prosthetic dentistry „Ilarion Postolachi", State University of Medicine and Pharmacy „Nicolae Testemițanu"

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1. INTRODUCTION

The actuality of the subject. Complete edentulism is a disease that implies the loss of all teeth on one or both arches [1]. According to epidemiologic studies, edentulism is a widely spread pathology that affects millions of people [2]. According to recent WHO (World Health Organization) data, 6-8% of world population is fully edentulous. Western countries have over 40 million teethless people and Eastern countries more than 250 million. The incidence of this disease is directly related to age, geographical region, and social and economic status. However, there is no difference between genders [3]. Completely removable denture was previously the treatment of choice which has a lot of disadvantages despite its wide use. Nowadays, the 2 implants supported overdentures are the first option for treatment for complete edentulism [4].

Implant-prosthetic rehabilitation is being used more often in fully edentulous patients [5, 6]. The development of biomaterials and techniques allows implant placement using standard and alternative techniques [7, 8]. Immediate loading of newly placed implants allowed to restore immediately the lost function of dental system with a high surgical and prosthetic success [9–11]. Besides the success rates, other objective measurements are required to determine the integration of implant-supported prostheses. This may include electromyography, evaluation of masticatory efficiency and performance etc. Surface electromyography is used to assess the muscle response to implant rehabilitation and its superiority over other treatments. However, the literature data on this subject are contradictory depending mainly on the chosen treatment method [12–14].

Another parameter that indicates the degree of prostheses integration into masticatory system is the masticatory efficiency. The most widely used method for the evaluation of masticatory efficiency is the gravimetric method. It consists of a specific number or time of chewing different food types like carrot, almonds, cheese, optical, etc. [15–17]. It allows to assess the functional capacity of different prostheses and compare with the dentate patients.

Aim

Comparative and dynamic evaluation of electromyographic activity of muscles and masticatory efficiency in fully edentulous patients rehabilitated with fixed implant supported prostheses for treatment optimization.

Study objectives:

1. Evaluation of muscle electroactivity in maximum voluntary contraction in dentate patients with edentulous patients during fixed implant prostheses delivery as well as after 6 months.

2. Comparative analysis of muscle electroactivity between maximum voluntary contraction and mastication in dentate and edentulous patients during prostheses fixation as well as after 6 months.
3. Determination of electromyographic overlapping coefficients in study and control groups during clenching and chewing.
4. Comparative analysis of deviation coefficients of electromyographic activity in study and control groups.
5. Determination of masticatory efficiency in dentate and edentulous patients during fixed prostheses delivery as well as after 6 months.

Study hypothesis:

1. Muscle electroactivity of patients with full fixed implant-supported prostheses is higher than in dentate patients during maximum voluntary contraction and chewing.
2. Muscle electroactivity will change during time due to neuroadaptation to newly placed prostheses.
3. Masticatory efficiency in rehabilitated patients with full implant supported prostheses will be similar to dentate ones.

Scientific research methodology. The research was based on modern techniques of implant placement with immediate loading and assessment of functional changes that occur after prostheses fixation from muscle perspective evaluated with a 4-channel electromyography and assessment of masticatory efficiency with gravimetric method.

Scientific novelty and originality. For the first time in the Republic of Moldova a prospective study for surface electromyography evaluation in patients with provisional full fixed implant supported prostheses was performed. The measurements were performed both during prosthesis fixations as well as after 6 months which represents a dynamic study not often described in the literature. The study included a healthy, dentate group of subjects which allows to evaluate the degree of muscle contraction capacity after prostheses delivery. It was also possible to evaluate the masticatory efficiency using the gravimetric method along with surface electromyography which allowed to determine the chewing time, frequency, number of chewing strokes and food grinding quality.

Practical importance. The study allowed to evaluate the quality of full arch implant rehabilitation with fixed prostheses by comparing it with healthy subjects. The obtained results will enrich the existing literature with data about the electromyographic activity of masticatory muscles and masticatory efficiency. The study also demonstrated the efficiency of fixed implant rehabilitation in restoring the contractive capacity of masticatory muscles. This research opens new perspective for further research on this topic that would allow to increase the quality of dental treatment by changing the prostheses type, materials and other parameters that will lead to a grater masticatory efficiency in these patients.

Implementation of the results. The obtained results were implemented in the educational process of students and residents from the Department of prosthetic dentistry „Ilarion Postolachi", Department of Oral and Maxillo-facial surgery „Arsenie Guțan" from the State University of

Medicine and Pharmacy „N. Testemițanu". The treatment and diagnostic methods are also applied in the State Dental Clinic „Toma Ciorbă" and private dental clinic „Masterdent".

Approval of the results. The results were published in 8 articles from which 1 in a journal with impact factor (*Medicina*), 1 indexed in Web of Science (*Romanian Journal of Oral Rehabilitation*), 6 in national C-class journals (*Moldovan Journal of Health Science, Medicina Stomatologică*). Six theses were published during different national and international congresses (*Medespera, The Congress Dedicated to 75 years of USMF Foundation*). Six oral presentations have been presented on the thesis's topic during national and international congresses (*Medespera, The Congress of Romanian Association for Education, Connect Dentistry Summit, Interdentis, Implantodays*). A total of three innovation certificates were obtained: "*The use individual titanium healing abutments in fixed implant rehabilitation*" innovative certificate nr. 5909; "*Determination of muscle electroactivity in patients with fixed implant supported prostheses*" certificate nr. 5910; "*Determination of dynamics of masticatory efficiency*" certificate nr. 5901.

2. MATERIAL AND METHODS

The research was realized according to Helsinki Declaration and was approved by the Ethics committee minute nr. 43 from 16.03.2018. The study included patients that needed full implant prosthetic rehabilitation on one or both arches from State dental clinic nr.1 "Toma Ciorbă" and private dental clinic "Masterdent" from 2018 to 2021.

2.1. Study protocol, general characteristics of the research

The required number of patients for each group was calculated according to the following parameters:
t tests - Means: Wilcoxon signed-rank test (matched pairs)
Options: A.R.E. method
Analysis: A priori: Compute required sample size
Input: Tail(s) = One
Parent distribution = Normal
Effect size dz = 0.5
α err prob = 0.05
Power (1-β err prob) = 0.8
Output: Noncentrality parameter δ = 2.5854415
Critical t = 1.7062592
Df = 25.7380304
Total sample size = 28
Actual power = 0.8083058
According to the abovementioned values we have a minimum of 28 patients for each group.

In the study were included 70 patients (49 women and 21 men) aged between 38 and 67 years (mean 56.49 ±1.08 years). Patients were divided in two groups.

The control group had 33 patients from which 21 women and 12 men (mean age 54± 1.26 years). They did not undergo any dental procedures lately and had minimum dental manipulations performed in the past. In cases when there were missing more than one molar on any quadrant, patients were not accepted in the study.

Inclusion criteria in control group:

1. Patients with minimal dental treatment, with artificial crowns or missing teeth that do not exceed 1 tooth on each quadrant.
2. Patients with no muscular and TMJ pathologies.
3. Patients with class 1 malocclusion on first molar.

Exclusion criteria:

1. Patients with decompensated general pathologies that cannot have surgical treatment.
2. Patients that do not accept participation in the study.
3. Patients psychologically unstable.
4. Patients with local or genera muscular pathologies.
5. Patients under medical treatment that may interfere with surgical or diagnostic procedures.
6. Patients with a pacemaker.

The second group consists of 37 patients (28 women and 9 men) with mean age of 59±1.44 years. Patients were completely edentulous on one or both arches or had a severe periodontal disease without the possibility to preserve the remaining teeth.

Inclusion criteria:

1. Edentulous patients that require rehabilitation on one or both arches.
2. Patients without absolute contraindication to implant insertion.
3. Patients without general and local muscular and TMJ pathologies.
4. Patients who accept participation into study.

Exclusion criteria:

1. Patients with decompensated general pathologies.
2. Patients who refuse to sign the informed consent.
3. Patients who are not cooperating.
4. Subjects with local and general muscular pathologies.
5. Patients with a pacemaker.
6. Rehabilitated subject with less than 10 teeth on dental arch.

Clinical and paraclinical investigations like bone volume assessment via panoramic x-ray or computed cone beam tomography have been performed to evaluate the possibility of implant placement. Six patients were excluded from the study group initially. Three patients had zero signal during electromyography. In two of theses cases, the abundance of hair on the temporal area was supposed to be cause of zero signal. Three patients out of 6 initially excluded refused to perform the mastication test. One patient was later excluded from the study group as a result of prostheses fracture with loss of fragments.

In the end, the determination of muscular electroactivity of masseter and temporalis muscle with evaluation of masticatory efficiency was performed in 30 patients that met the inclusion criteria. Patients were twice examined, during the prosthesis delivery and after 6 months. From the overall number of subjects, 11 were edentulous on both jaws, and 19 just on one jaw. A total of 204 dental implants were placed (104 implants Sky-O, Bredent Gmbh, Germany; 65 implants Dentium Superline, South Coreea and 35 implants Alpha-Bio, Israel). In 25 cases the implants were placed according to „*Fast and Fixed"* concept and in 5 patients conventionally. All patients were familiarized with the aim of the study and signed the informed consent.

2.2. Surgical step

After a thorough evaluation of esthetic parameters like position of incisal edge, smile line, buccal corridor, etc., the determination of implant position and angulation was performed on OPG and CBCT. The minimum implant length was 12 mm for angulated and 10 mm for straight ones in 25 patients that were rehabilitated according to "*Fast and Fixed"* concept. Vertical osteotomy was performed in 11 patients to level the crestal bone. In other 5 patients it was preformed due to esthetical reasons, to mask the transition between the artificial and natural gum. The volume of cut bone was calculated on CBCT.

2.3. Prosthetic steps

Prosthetic steps were realized after analyzing 5 key elements for prosthetic prostheses manufacturing:

1. Position of incisal edge of upper incisors.
2. Prosthetic space.
3. Support for upper lip.
4. Smile line.
5. Vertical dimension of occlusion (in cases when anatomical landmarks were preserved).

Impression was taken in all cases with an open tray. All the prostheses were fixed within 7 days after surgical procedure and were manufactured from the acrylic resign reinforced with a Chromium-Cobalt bar. The number of artificial teeth varied from 10 to 12 on each arc. Prostheses were screwed with a 20N/cm torque wrench.

2.4. Determination of surface electromyography

For the determination of masticatory muscle electroactivity, a 4-Channel electromyograph was utilized (ForEMG, Quatrotti, Italy) with concentric electrodes. The position of each electrode was determined via palpation of the respective muscle. For the calibration of the device, two cotton rolls were used. They were placed between the arches at the level of premolars and patients were instructed to clench for about 3 seconds on these cotton rolls. The registration was saved as *"Cottons"* and procedure was repeated afterwards on the newly placed prostheses. Before each registration, the data were recorded in posture for 3 seconds then maximal clenching 3 seconds. Both raw and average data could be visualized in the Formeter 2.0 software. The average values were displayed through 10 parameters on the main screen. First 4 were the muscular electrical biopotential in μV for 2 masseters and 2 temporal muscles (TAL – left temporal, TAR – right temporal, MML – left masseter, MMR – right masseter). The other 6 parameters were so called overlapping coefficients that indicates the interaction of first 4 (PocTA – percentage overlapping of temporal muscles, PocMM – percentage overlapping of masseters, BAR – masseters over temporal muscles, Impact – optimal vertical height of muscles contraction, Tors – torsion of mandible during closing, Asym – presence of asymmetry during closing).

For a better understanding of occlusal contacts and their relation to muscular activity the software displays the above-mentioned coefficients in different colors and symbols.

2.5. Determination of masticatory efficiency

Masticatory efficiency determination with gravimetric method is a reliable measurement for determining the grinding capacity of stomatognathic system. It can be done with a specific number of chewing strokes or in a specific time frame [18]. Taking into account the aim of the study that supposes the determination of masticatory efficiency in the same group at the moment of

prostheses fixation and after 6 months and compare the data with healthy subjects, it was decided to use the one-sieve method. The sieve hole size was 1.68 mm, chosen according to Andries van der Bilt's study [19]. For mastication test were used 5g of almonds. The weighting of food was done with a electronic weight used for golden pieces. Patients were instructed to chew 5g of almonds till the deglutition sensation appear also counting the chewing strokes. Afterwards, the chewed mass was spitted into the sieve and oral cavity thoroughly rinsed with water. At that moment the chronometer was stopped, and the obtained chewed mass was washed and put aside to dry out. During mastication, the EMG recording was also performed, registering the data under *"Chewing"* name in the software (Figure 1). Chewed almonds were dried out at the room temperature because this was the condition in which they were kept. In that case the use of a thermostat could dehydrate the almonds more than they were initially. The mass of almonds that did not pass through the sieve was registered and calculated in percentage from the overall chewed mass.

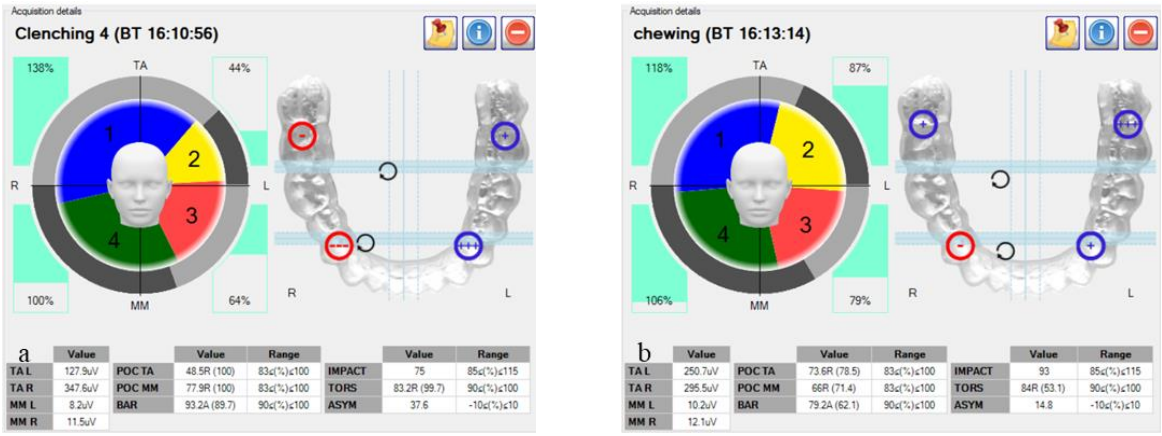


Figure 1. **Electromyographic activity of masticatory muscles during maximum voluntary contraction (a) and chewing (b).**

2.6. Statistical analysis

Collected data were introduced into R-Studio software where statistical evaluation was performed. The following parameter were evaluated: mean with standard deviation, median with interquartile deviation, maximum and minimum and the distribution was assessed using Shapiro-Wilk test. Comparative evaluation was performed using the Wilcoxon test and its variations for dependent and independent variables where the significance level was 0.05. The data were graphically represented using jitter-plot, boxplot or jitter-plot combined with violin-plot. The significance interval was 95 %. The absolute and relative frequencies with a significance interval of 95% were calculated for quality variables. Moreover, the Fisher test was applied depending on relation between the groups, the McNemar test for dependent groups where the significance level was 0.05.

3. COMPARATIVE EVALUATION OF MASTICATORY AND MUSCLE MODIFICATIONS

Many articles demonstrate the relation between the muscle activity and increased stability of implant supported overdentures [12]. However, fixed implant supported prostheses have a lot of variables that may make two studies incomparable. Thus, there are many controversial data in the literature in this topic [20,21]. Moreover, there is no unanimously accepted method of

masticatory efficiency determination. However, despite different methods they still can provide information about the quality of mastication in real-time.

3.1. General characteristics of the groups

The study group was divided in two subgroups: LS – study group immediately after prostheses fixation, and the LSF – the same patients 6 months after. Comparative statistical data are shown in Table 1. The first group had the following data of muscle electrical activity: TAL – 46.9μV (SD 89.8); TAR – 53.5μV (SD 74.4); MML – 33.8μV (SD 57.7) and MMR 41.9μV (SD 66.1). For women, the values were: TAL – 46μV; TAR – 52μV; MML – 39μV and MMR 49μV, and the same parameters were calculated for men: TAL – 48μV; TAR – 57μV; MML – 18μV and MMR 22μV.

From the above-mentioned data, we see that there were no significant differences between muscle electrical activity in men and women. It is worth mentioning that the same bioelectric potential does not mean that patients have the same biting force, due to different muscle length and thickness. The same patients were re-evaluated after 6 months to assess if there were any changes in time after adaptation to newly placed prostheses. The obtained values were TAL – 73.6μV (SD 97.6); TAR – 59.4μV (SD 72.9); MML – 41.7μV (SD 85.4) and MMR 30.5μV (SD 37.1). For women the values were: TAL – 65μV; TAR – 51μV; MML – 39μV and MMR 37μV men had the following values: TAL – 97μV; TAR – 82μV; MML – 48μV and MMR 14μV.

Static evaluation of these data does not allow to say if they are normal or increased. It is necessary to refer these data to healthy, dentate subjects of the same age.

3.2. Comparative evaluation of sEMG between the study group initially after prostheses fixation and control one in MVC

Statistical analysis with Wilcoxon test and its variation has demonstrated the there was no statistical difference in the electrical activity of masticatory muscles in MVC between LS and LC. The obtained data for each muscle were: (TAL0 – p=0.66, TAR0 – p=0.41, MML0 – p=0.95, MMR0 – p=0.95). In all the cases the p value was higher than 0.05 which demonstrates that evaluated masticatory muscles in contraction had similar values in both groups. Restoring the integrity of dental arch allows to immediately obtain similar contracting capacity in patients with fixed implant prostheses like in dentate ones. This is contrary to some article in the literature were the electrical activity of masticatory muscles in dentate subjects proved to be higher than in the study group [21,22].

3.3. Comparative evaluation of sEMG between study group after 6 months and control one in MVC

Statistical analysis has shown the following correlations between groups: TAL – p=042, TAR1 – p=0.88, MML1 – p=0.68, MMR1 – p=0.27. We see that p value is higher than 0.05 in all the cases. This means that there are no statistically significant differences between these groups. At a closer look at the data from table 1 we see a high value dispersion in both groups. The same high dispersion is notices in the literature as well as in the first comparison of LS and LC [12]. This can be caused by the small number of subjects enrolled in the study or the anatomical features of each patient.

Table 1. **Descriptive statistics of muscle electrical activity in control group (LC), study group immediately after prosthesis fixation (LS) and after 6 months (LSF)**

		LC (N=33)	LS (N=30)	LSF (N = 30)	Wilcoxon test (LC vs LS)	Wilcoxon test (LC vs LSF)	Wilcoxon paired test (LS vs LSF)
TAL, µV	Mean (SD)	42.0 (48.5)	46.9 (89.8)	73.6 (97.6)	W = 527, p = 0.6646	W = 554, p = 0.4207	V = 267, p = 0.1482
	Median (IQR)	18.8 (36.3)	21.0 (20.3)	23.6 (79.1)			
	[Min, Max]	[3.80, 190]	[3.80, 434]	[3.80, 326]			
	Shapiro-Wilk normality test	W = 0.72061, p = 1.361e-06	W = 0.72061, p = 1.361e-06	W = 0.6981, p = 1.464e-06			
TAR, µV	Mean (SD)	51.4 (56.8)	53.5 (74.4)	59.4 (72.9)	W = 556, p = 0.4051	W = 483.5, p = 0.8797	V = 202, p = 0.7639
	Median (IQR)	32.9 (35.2)	22.8 (34.6)	31.2 (55.2)			
	[Min, Max]	[7.90, 248]	[1.30, 278]	[1.30, 328]			
	Shapiro-Wilk normality test	W = 0.67751, p = 3.031e-07	W = 0.67751, p = 3.031e-07	W = 0.69981, p = 1.551e-06			
MML, µV	Mean (SD)	48.7 (107)	33.8 (57.7)	41.7 (85.4)	W = 490, p = 0.9506	W = 464.5, p = 0.6797	V = 221, p = 0.9483
	Median (IQR)	12.3 (24.8)	12.8 (21.2)	10.1 (27.6)			
	[Min, Max]	[1.50, 439]	[0.200, 255]	[0.300, 379]			
	Shapiro-Wilk normality test	W = 0.45479, p = 5.957e-10	W = 0.45479, p = 5.957e-10	W = 0.50205, p = 5.634e-09			
MMR, µV	Mean (SD)	42.1 (64.4)	41.9 (66.1)	30.5 (37.1)	W = 500.5, p = 0.945	W = 415, p = 0.2734	V = 145, p = 0.1904
	Median (IQR)	16.3 (16.7)	17.1 (20.3)	14.1 (10.1)			
	[Min, Max]	[11.4, 243]	[11.4, 346]	[11.3, 152]			
	Shapiro-Wilk normality test	W = 0.51507, p = 2.646e-09	W = 0.51507, p = 2.646e-09	W = 0.5765, p = 3.816e-08			

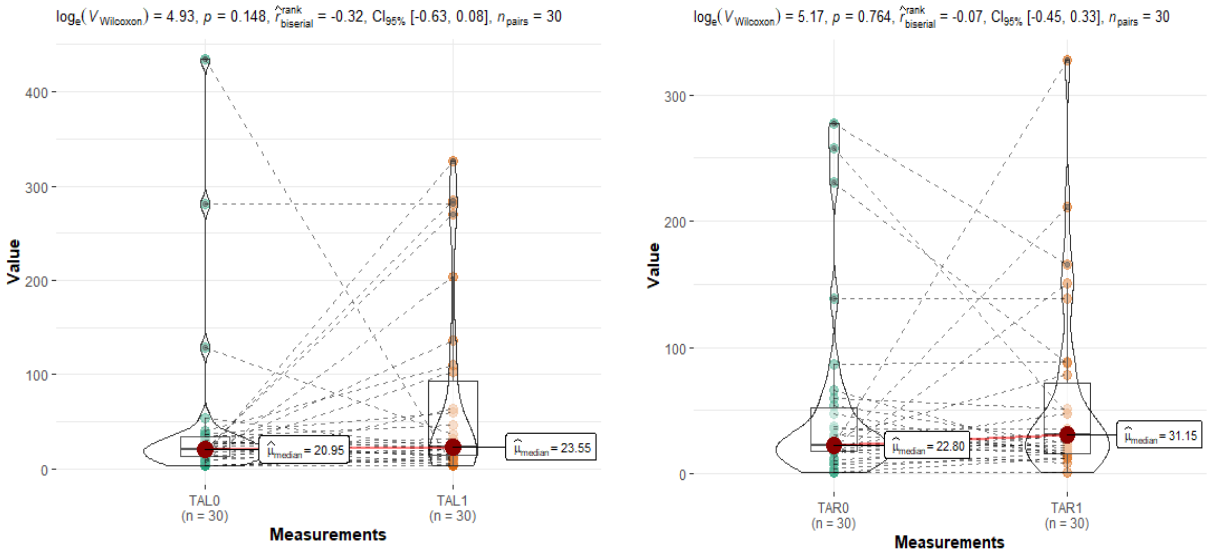
Note: TAL – left temporal muscle, TAR – right temporal muscle, MML – left masseter, MMR – right masseter, ***µV – microvolt,*** *mean (SD) – mean (standard deviation), Median (IQR) – median (interquartile deviation), Min – minimum value, Max – maximum value, df – freedom degree.*

3.4. Comparative evaluation of sEMG between the study group initially after prosthesis fixation and after 6 months in MVC

A time more than 6 months was selected due to two reasons: first is the time for implant osseointegration that in maxilla usually is 6 months. The second reason is the multiple studies that demonstrate the changes that occur from 3 to 12 month according to different authors [20]. Thus, the minimum time had to be 3 months and, this allows the stomatognathic system to get used to newly placed prostheses. Comparative analysis has given the following values:
(TAL $\log_e(V_{Wilcoxon})$ = 4.93, p = 0.148, r = -0.32, $CI_{95\%}$[-0.63, 0.08], n_{pairs} =30; **TAR** $\log_e(V_{Wilcoxon})$ = 5.17, p = 0.764, r = -0.07, $CI_{95\%}$[-0.45, 0.33], n_{pairs} =30; **MML** $\log_e(V_{Wilcoxon})$ = 5.37, p = 0.948, r = -0.02, $CI_{95\%}$[-0.40, 0.37], n_{pairs} =30 and **MMR** $\log_e(V_{Wilcoxon})$ = 5.56, p = 0.190, r = 0.29, $CI_{95\%}$[-0.12, 0.61], n_{pairs} =30. According to these data, muscular electrical activity did not change over time being equal with the initial one and the one of control group. We can notice that in some cases the value increase and in other decrease (Figure 2). Thus, the initial values change despite the fact that occlusal contact remained the same. The device reacts to the contraction of evaluated masticatory muscles which in the end are a structure dependent not only on occlusal contacts. Moreover, for provisional prostheses, artificial teeth for complete dentures are uses, these have 30-degree cusps which allow a free jaw movement that can cause occlusal instability. We recommend using devices that capture the occlusal contact directly from the dental arches (like TScan, from Tekscan) and are meant to complete the sEMG acquired data.

3.5. Electromyographic indicators during mastication

There are many articles that show differences in the EMG activity of masticatory muscles during clenching and MVC [20,22,23]. Moreover, that depends on the prosthesis type, some authors are indicating an increase in dentate patients of EMG activity during mastication others a decrease [12]. This can be dependent also on food type, analysis method, time that has passed after prosthesis delivery, etc. [24]. Some authors mention that different values of sEMG during mastication and clenching can be due to muscle incoordination in implant-supported prostheses [25].



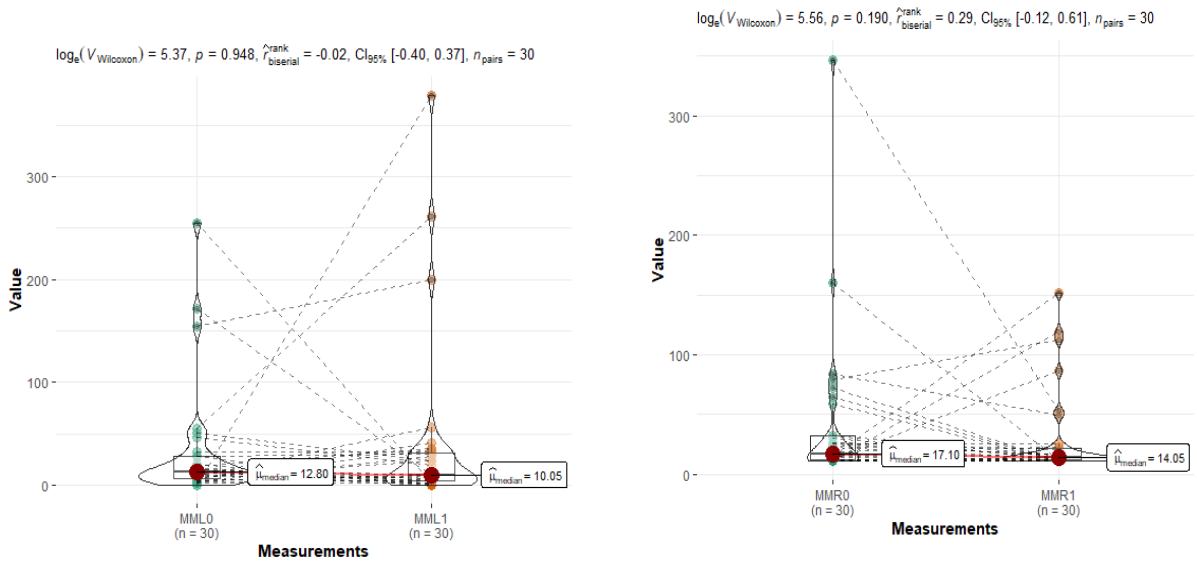


Figure 2. **Comparative evaluation of muscular electroactivity between LS and LSF in MVC**

Note: TAL– left temporal muscle initially (0) and 6 months after (1), TAR – right temporal muscle initially (0) and 6 months after (1), MML – left masseter muscle initially (0) and 6 months after (1), MMR – right masseter muscle initially (0) and 6 months after (1).

3.6. Comparative evaluation of sEMG in control group during MVC and mastication

The following values of statistical analysis of sEMG have been obtained during the comparison between clenching and mastication of 5g of almonds: TAL $\log_e(V_{Wilcoxon})$ = 5.58, p = 0.993, r = 3.79e-0.3, $CI_{95\%}$[-0.37, 0.38], n $_{pairs}$ =33; TAR $\log_e(V_{Wilcoxon})$ = 5.73, p = 0.427, r = 0.16, $CI_{95\%}$[-0.22, 0.50], n $_{pairs}$ =33; MML $\log_e(V_{Wilcoxon})$ = 5.83, p = 0.147, r = 0.30, $CI_{95\%}$[-0.09, 0.60], n $_{pairs}$ =33 and MMR $\log_e(V_{Wilcoxon})$ = 5.46, p = 0.594, r = -0.11, $CI_{95\%}$[-0.46, 0.27], n $_{pairs}$ =33. These data have shown that there are no statistically significant differences (p>0.05) inside the control group between clenching and MVC. This means that patients developed the same amount of muscular electrical potential during both types of activities and the almond chewing requires a high contraction capacity. This is contrary to the initial expectations where we have considered that patients do not need the same amount of contracture during mastication cycles and MVC would develop the highest muscular electrical activity. Mastication has been studied thoroughly and described in the literature. In 1995 Blanksma N.G. et al. have studied the behavior of masticatory muscles and divided them into different regions [26]. Author has shown an increase in muscle contraction during eating of hard food. Moreover, he described the coordination of different muscle regions and showed that they are activated separately depending on the situation. This was not possible in our study because we have used the concentric surface electrodes which cover a wide area and capture the signals from more motor fibers. This was not the aim of our study; we are targeting the effectiveness of implant-prosthetic treatment. However, a dynamic study similar to the Blanksma's ones would indicate if patients with implant-supported prostheses are able to achieve the same muscle coordination patterns as dentate ones.

3.7. Comparative evaluation of sEMG during mastication and MVC in LS

The control group represents the reference and comparing the results with the rehabilitated patients we can say if there is a normal behavior in the study group. After statistical analysis we have obtained the following results: **TAL0** - $\log_e(V_{Wilcoxon})$ = 5.25, p = 0.971, r = 0.01, $CI_{95\%}$[-0.38,

0.40], n_{pairs} =30; **TAR0 -** $\log_e(V_{Wilcoxon})$ = 4.97, p = 0.114, r = -0.34, $CI_{95\%}$[-0.64, 0.06], n_{pairs} =30; **MML0 -** $\log_e(V_{Wilcoxon})$ = 4.91, p = 0.124, r = -0.33, $CI_{95\%}$[-0.64, 0.06], n_{pairs} =30; **MMR0 -** $\log_e(V_{Wilcoxon})$ = 4.91, p = 0.127, r = -0.33, $CI_{95\%}$[-0.64, 0.06], n_{pairs} =30. From these data we see that there are no statistically significant differences between surface EMG during mastication and MVC inside de study group. We see that rehabilitated patients have the same EMG activity during mastication and clenching as dentate ones. It is worth mentioning that we have compared each muscle with itself in both activities so that eliminates the possibility of some misinterpretations that some patients may behave differently having a preferred side of mastication or a dominant side. There are several methods recommended for evaluation of mastication. One of them uses the alternating sides for mastication so that the patient is chewing of one side, then another one and then a global index is formed for both sides [27]. However, Ferario et al., mentions that for full implant supported rehabilitation is better to use the normal mastication tests and not the one with alternating sides. Thus, we have used a normal mastication test in our study.

3.8. Comparative evaluation of sEMG in LSF during mastication and MVC

Comparative statistical analysis of surface electromyography in the LSF between mastication and clenching has given the following results: **TAL1 -** $\log_e(V_{Wilcoxon})$ = 5.23, p = 0.503, r = 0.14, $CI_{95\%}$[-0.50, 0.26], n_{pairs} =30; **TAR1 -** $\log_e(V_{Wilcoxon})$ = 5.45, p = 1.000, r = 2.15_e-0.3, $CI_{95\%}$[-0.39, 0.39], n_{pairs} =30; **MML1 -** $\log_e(V_{Wilcoxon})$ = 5.47, p = 0.934, r = 0.02, $CI_{95\%}$[-0.37, 0.40], n_{pairs} =30; **MMR1 -** $\log_e(V_{Wilcoxon})$ = 4.55, p = 0.008, r = -0.56, $CI_{95\%}$[-0.78, -0.22], n_{pairs} =30. We can see that in almost all comparative pairs p is higher that 0.05 which indicate insignificant statistical differences. The only parameter that had statistically significance is the right masseter where p=0.00831. This is close to results obtained in previous two descriptive analyses even though this group had a period of more than 6 months for adaptation. Despite the presence of significant difference in right masseter, we do not consider it clinically important because this is the only muscle that had changes and might be due to value dispersion and small number of subjects.

3.9. Comparative evaluation of sEMG between LS and LSF during mastication

This is the only comparation of muscle bioelectric potential between groups during mastication. We consider inappropriate to compare the sEMG between groups like study and control groups. This is because mastication might be influenced by different unstable and individual factors like preferable side of mastication or presence of removable dentures in the past, etc. However, comparation between LS and LSF is considered legit because it assesses the mastication of same patient with himself after 6 months, eliminating any individual barriers and features. Statistical analysis has given the following results: **TALch -** $\log_e(V_{Wilcoxon})$ = 4.92, p = 0.136, r = -0.33, $CI_{95\%}$[-0.63, 0.07], n_{pairs} =30; **TARch -** $\log_e(V_{Wilcoxon})$ = 5.58, p = 0.517, r = 0.14, $CI_{95\%}$[-0.26, 0.50], n_{pairs} =30; **MMLch -** $\log_e(V_{Wilcoxon})$ = 5.51, p = 0.531, r = 0.14, $CI_{95\%}$[-0.27, 0.50], n_{pairs} =30; **MMRch-** $\log_e(V_{Wilcoxon})$ =5.35, p = 0.864, r = 0.04, $CI_{95\%}$[-0.35, 0.42], n_{pairs} =30. We see no statistically significant differences between sEMG in mastication of LS and LSF. This means that patients developed the same muscle electrical activity to chew 5g of almonds as 6 months before when the dentures were fixed. This means that there was no a period of adaptation for mastication to newly inserted prostheses.

3.10. Overlapping and deviation coefficients, general description

The previous 4 parameters evaluated in the previous compartments are the bioelectric activity of 4 masticatory muscles (TAL, TAR, MML, MMR) determined during MVC and

mastication which can be named as main indices. Nowadays, incorporated softwires in the EMG devices can give additional parameters that indicates the comparative activity of these 4 main indices. There are 6 additional indices called overlapping coefficients which can be visualized in a scheme or in concrete values. Thus, modification of occlusion will lead to different muscle contraction different overlapping coefficients. This is useful during full mouth rehabilitation procedures because it allows to adjust the occlusion with a digitally guided scheme and create an even contraction of masticatory muscles [28]. This in the end will lead to a better force distribution on the prosthesis and TMJ. However, we found only one article in the literature that evaluates de overlapping indices in dynamics [20]. These indices offer a real time information about the interaction between muscles, but we find it inappropriate for comparison between patients. This is because each overlapping coefficient is important in the overall context, together with other coefficients to assess inappropriate muscle contraction and change it by occlusal adjustments. Thus, we considered more practical to determine how much the coefficient deviates from normal range and percentage. Then we calculated the mean deviation coefficient that in the end indicates how much these patients deviates from a "truly equilibrated" patient. This allows to compare the patients between the groups and how well are rehabilitated patients equilibrated in relation to dentate subjects or manufacturer's normal ranges. One more criterion that can be evaluated is the deviation of overlapping coefficients to a direction. For statistical purposes 0 was given to anterior and left, 1 was given to posterior and right. One overlapping coefficient can have only one direction either anterior/posterior or right or left.

3.11. Evaluation of overlapping coefficients from LS in MVC and mastication

Statistical analysis of overlapping coefficients between MVC and mastication in LS has given the following results: **PocTa0** – $\log_e(V_{Wilcoxon}) = 5.95$, p = 3.18e-04, r = 0.77, $CI_{95\%}$[0.54, 0.89], n_{pairs} =30; **PocMM0** – $\log_e(V_{Wilcoxon}) = 5.87$, p = 0.003, r = 0.63, $CI_{95\%}$[0.33, 0.82], n_{pairs} =30, **BAR0** – $\log_e(V_{Wilcoxon}) = 5.81$, p = 0.013, r = 0.53, $CI_{95\%}$[0.18, 0.76] n_{pairs} =30; **TORS0** – $\log_e(V_{Wilcoxon}) = 5.83$, p = 0.007, r = 0.57, $CI_{95\%}$[0.24, 0.79] n_{pairs} =30; **IMPACT –** $\log_e(V_{Wilcoxon})$ = 5.16, p = 0.364, r = -0.2, $CI_{95\%}$[-0.54, 0.21] n_{pairs} =30; **ASYM0** – $\log_e(V_{Wilcoxon})$ = 4,68, p = 0.031, r = -0.47, $CI_{95\%}$[-0.73, -0.09] n_{pairs} =30;

According to the above data we see a statistically significant difference where $p<0.05$ in 5 out of 6 coefficients (PocTA, PocMM, BAR, TORS, ASYM). This means that overlapping coefficients moved during mastication compared to MVC. This might be explained by the fact that mastication is a dynamic process were occlusal contacts in maximal intercuspation occur only during swallowing. This leads to uneven contact of the food with teeth hence uneven muscle contraction. However, there were no changes in the direction of displacement according to statistical analysis. The coefficients moved more to the same direction as in MVC. Thus, muscle that dominated during contraction in MVC continued to dominate in mastication as well. IMPACT remained the only one unchanged, this might be explained by the fact that it indicates the optimal contraction length, which basically was not modified.

3.12. Evaluation of overlapping coefficients in MVC and mastication in the LSF

The comparison of overlapping coefficients of sEMG during the MVC and mastication inside the LSF has given the following results: **PocTa1** – $\log_e(V_{Wilcoxon}) = 5.92$, p = 0.004, r = 0.60, $CI_{95\%}$[0.28, 0.80], n_{pairs} =30; **PocMM0** – $\log_e(V_{Wilcoxon}) = 5.97$, p = 0.001, r = 0.68, $CI_{95\%}$[0.40, 0.85], n_{pairs} =30, **BAR0** – $\log_e(V_{Wilcoxon}) = 6.00$, p = 4.03e-0.4, r = 0.74, $CI_{95\%}$[0.50, 0.88] n_{pairs} =30; **TORS0** – $\log_e(V_{Wilcoxon}) = 6.06$, p = 4.86e-05, r = 0.85, $CI_{95\%}$[0.69, 0.93] n_{pairs} =30; **IMPACT**

– $\log_e(V_{Wilcoxon})$ = 4.74, p = 0.015, r = -0.51, $CI_{95\%}$[-0.75, -0.14] n_{pairs} =30; **ASYM0** – $\log_e(V_{Wilcoxon})$ = 5.14, p = 0.202, r = -0.27, $CI_{95\%}$[-0.60, 0.13] n_{pairs} =30.
In the above given statistical analysis we see that p<0.05 in 5 out of 6 parameters this means that we have statistically significant differences in all overlapping coefficients except **ASYM**. In the LS that were the initial situation immediately after prostheses fixation we saw a that **IMPACT** had no changes however in the LSF, **IMPACT** coefficient had a p value equal with 0.015 which represents a statistically insignificant difference compared to other coefficients. It is noticeable that in both groups **ASYM** and **IMPACT** had either no changes or statistically insignificant ones. It is necessary to evaluate the same parameters for LC to see if the relation between coefficients remain the same in healthy dentate subjects.

3.13. Evaluation of overlapping coefficients in MVC and mastication in LC

It is necessary to perform the same evaluation for control group so to analyze not only the changes inside the study group over time but also to determine if these changes are valid for healthy dentate subjects. Same analysis has been performed for LC with following results: **PocTa/PocTach** – $\log_e(V_{Wilcoxon})$ = 6.23, p = 5.82e-0.5, r = 0.80, $CI_{95\%}$[0.62, 0.91], n_{pairs} =33; **PocMM/PocMMch** – $\log_e(V_{Wilcoxon})$ = 6.31, p = 1.54e-0.6, r = 0.96, $CI_{95\%}$[0.92, 0.98], n_{pairs} =33, **BAR/Barch** – $\log_e(V_{Wilcoxon})$ = 6.04, p = 0.014, r = 0.49, $CI_{95\%}$[0.14, 0.73] n_{pairs} =33; **TORS/TORSch**– $\log_e(V_{Wilcoxon})$ = 6.19, p = 2.02e-0.4, r = 0.74, $CI_{95\%}$[0.51, 0.87] n_{pairs} =33; **IMPACT/IMPACTch –** $\log_e(V_{Wilcoxon})$ = 5.69, p = 0.782, r = 0.06, $CI_{95\%}$[-0.33, 0.43] n_{pairs} =33; **ASYM/ASYMch** – $\log_e(V_{Wilcoxon})$ = 5.34, p = 0.195, r = -0.26, $CI_{95\%}$[-0.58, 0.13] n_{pairs} =33.

In this case we see that **ASYM** and **IMPACT** had no statistical differences (p = 0.195 and p = 0.782) during mastication and MVC in dentate subjects. This comparable with the LS and LSF that had similar results. This shows that dynamic occlusal contacts do not correspond to static ones like in MVC however there are no changes in the right and left side during mastication (ASYM index) as well as in optical vertical length of muscles during both activities (IMPACT index). Thus, patients rehabilitated with fixed full implant supported prostheses have a similar muscular activity during mastication compared to healthy dentate subjects.

3.14. Evaluation of overlapping coefficients in LS and LSF during MVC

We have anteriorly mentioned that comparison between groups might be inappropriate to evaluate because represents an interaction between the EMG activity of masticatory muscles and are more individual parameters of immediate muscle interaction. However, we consider appropriate to assess the same patients over time form LS and LSF because we compare the same patient after 6 months without any changes made onto prostheses themselves. The statistical analysis has given the following results: **PocTa** – $\log_e(V_{Wilcoxon})$ = 4.54, p = 0.067, r = -0.42, $CI_{95\%}$[-0.77, 0.12], n_{pairs} =30; **PocMM** – $\log_e(V_{Wilcoxon})$ = 4.49, p = 0.14, r = -0.36, $CI_{95\%}$[-0.70, 0.13], n_{pairs} =30, **BAR** – $\log_e(V_{Wilcoxon})$ = 5.31, p = 0.764, r = 0.07, $CI_{95\%}$[-0.35, 0.46] n_{pairs} =30; **TORS** – $\log_e(V_{Wilcoxon})$ = 5.02, p = 0.381, r = -0.20, $CI_{95\%}$[-0.57, 0.24] n_{pairs} =30; **IMPACT –** $\log_e(V_{Wilcoxon})$ = 4.67, p = 0.527, r = 0.527, $CI_{95\%}$[-0.63, 0.39] n_{pairs} =30; **ASYM** – $\log_e(V_{Wilcoxon})$ = 4.31, p = 0.055, r = -0.47, $CI_{95\%}$[-0.80, 0.10] n_{pairs} =30;
From these data we see that in all comparison there were no statistically significant differences where p > 0.05. This indicated that after 6 months were no prevalence of masticatory muscles. This is in accordance with the initial evaluation at the beginning of the chapter where the contraction of masticatory muscles in MVC remained similar after 6 months. However, a more precise data might be obtained after percentual evaluation of deviation for each coefficient.

3.15. Mean percentual deviation

In order to assess if patient's muscle contraction activity has become more or less equilibrated, it is necessary to calculate the percentual deviation of each coefficient and then to find the mean. This allows to compare the rehabilitated patients with the dentate ones. We consider more appropriate to compare the mean deviation coefficient instead of each one separately because this indicates the proper occlusal adjustment and how much is patient deviating from a normal range or a healthy subject. After statistical analysis the following values for mean deviation coefficient have been obtained: LC – 20.5%, median 11.1 (min 0, max 104); LS – 21.4%, median 12.2 (min 0, max 103); LSF – 36.1% median 26.9 (min 0, max 160). This indicates the lack of statistical difference between the LS and LC. There is an increase of mean percentual deviation coefficient of 14.7% comparing to LC however it is statistically insignificant where $p = 0.086$.

It is worth noting that even the healthy subjects have a 20.5% deviation from the normal values provided by the manufacturer which can be due different factors like registration errors, patients' age, dentate patients still had minimum dental procedures, etc.

3.16. Comparative analysis of masticatory efficiency

Masticatory efficiency represents an important part of this study because it offers data along sEMG about the integration of dental prostheses and the quality of mastication. There are multiple studies that uses for this purpose different food products like carrot, almonds, optical, meat, chewing gum, etc. All this food types have different consistency and will give different results [18,29]. Almonds are one of the most widely used food type. The quantity of 5g was selected from the perspective that a smaller quantity of almonds would present errors in case a part of them remained under prostheses, representing a huge percentage of initial one.

3.17. Masticatory efficiency in the initial study group (LS) and control one (LC)

Evaluation between the study and control group is a quality indicator of masticatory efficiency that points out not only prostheses integration into stomatognathic system but also muscle coordination.

According to the statistical analysis the following results have been obtained: **mastic** – $p = 1e\text{-}08$, **cycles**– $p = 6e\text{-}04$, **time** – $p = 9.3e\text{-}07$, **frequency** – $p = 0.11$.

From the above-mentioned data, we see that in 3 out of 4 parameters p is less than 0.05. This means that patients from the study group after prostheses delivery perform an increased number of cycles in an increased amount of time with a worse grinding of almonds than control groups. A high dispersion of values is notices in all patients including the control one which might be explained by the patients' age (54±1.26 years) that still have some dental modifications by this age like: attrition, erosion, abrasion, dental filling, crowns, etc.

3.18. Masticatory efficiency in the study group initially (LS) and after 6 months (LSF)

The statistical analysis has given the following results **mastic** – $p = 0.096$, **cycles** – $p = 0.758$, **time** – $p = 0.210$, **frequency** – $p = 0.58$. Contrary to our initial beliefs that stomatognathic system will adapt over time and masticatory quality will increase did not happen. The p value was higher than 0,05 in all evaluated parameters, even though the mastic was the closest to 0,05 being equal with 0.096. The slight improvement in the mastication quality would not be clinically noticed in these cases. Moreover, we have noticed that the median of cycles remained unchanged 47 against 47.6. Small difference is noticed in mastication time as well 48.77s against 46.3s. That is why the frequency remained also unchanged representing the number of cycles divided by time.

3.19. Comparative evaluation of masticatory efficiency in study group after 6 months (LSF) and control one (LC)

Statistical analysis has given the following results: **mastic –** p = 3e-0.6, **cycles** – p = 0.0024, **time** – p = 4.1e-0.6, **frequency** – p = 0.15. The obtained data are similar with comparison between the LC and LS. There are strong statistical differences in 3 out of 4 parameters where $p < 0.05$. Frequency is the only parameter that remained unchanged in all 3 comparative groups. If during comparative analysis of LS and LSF the number of cycles and time remained unchanged which explained the same frequency, then in other two comparative groups 3 parameters were different with the same frequency. This is easily explained by the fact that in LS and LSF increased both the number of cycles and the mastication time, keeping the same mastication frequency as in dentate subjects by with a worse grinding of almonds. Thus, implant fixed prostheses cannot provide the same masticatory efficiency as in dentate subjects even after adaptation period.

. 4. DISCUSSIONS

4.1. Evaluation of electromyography in MVC

Static evaluation of electromyography has been performed for many years using different prostheses in order to determine the degree of muscle contraction after rehabilitation. The articles that evaluated the mobile prostheses and implant supported overdentures have shown the superiority of the last. This manifested not only by a better capacity to restore the contraction of the muscles but also a greater masticatory efficiency [15,30,31]. The improvement might be due to better prostheses stability that increases along with the number of implants or with different anchorage systems [31]. Continuing the above idea, the fixed prostheses should have the best results due to lack of mobility. However, the results in the literature are controversial. Some articles stated that healthy patients have higher EMG activity other emphasizes the opposite [12,20,22].

In our study, we determined the EMG activity during MVC in patients with fixed implant prostheses in order to understand the degree of masticatory contraction after treatment. The implants do not have periodontium that can lead to an increased threshold of contraction due to lack of feedback from mechanoreceptors [25]. Despite the fact that there are studies in the literature that have previously described this data, the multitude of parameters that change from study to study make their comparison not always possible. In order to minimize the number of variables the selected groups had to be as homogenous and similar as possible. Because there might be errors in registration due to different functional and anatomical characteristics it was decided to compare patients from same population and of the same age.

There were no statistically significant differences during the comparison of EMG activity in patients from LC and LS. Contrary to initial belief the subjects with implant-supported prostheses had similar values of sEMG activity during MVC in all groups. We cannot say that the values of electrical activity in masters and temporals have restored because we do not know the initial parameters of EMG when patients had their own teeth. Similar data have been obtained by Moara de Rosi [22], who evaluated 63 patients divided in 3 groups of 21 subjects. The first consisted of patients with bimaxillary *„All on 4"* and *„All on 6"* prostheses. In the second group were dentate patients and the third one consisted of removable bimaxillary full denture wearers. The first two had similar contraction values in EMG during MVC and the third one had lower values. Different

results were obtained by Bersani who inserted the implants according to Branemark protocol. The values obtained in the control group were lower than in the study one [23]. Similar data were found in other articles as well [32]. Moreover, Bersani did not obtain different values for removable and fixed implant denture which is in contrary with literature data. This might be explained by the small number of patients included in the study (19 subjects). In a 2016 review of Inna von der Gracht was mentioned that most of the articles that evaluated EMG activity of fixed implant supported restorations and healthy subjects did not show any statistical differences. The values of muscular bioelectric activity had a high dispersion from 66 to 520 μV in dentate patients and from 58 to 320 in rehabilitated ones (ES=1.01 [95% CI: – 1.37, – 0.65]) [12]. We also obtained a high dispersion of values in patients from both groups: 1.50 – 439 μV in LC, 1.3 – 434 μV in LS and 03 – 379 μV LSF). We consider that this dispersion could be homogenized by increasing the number of subjects.

One of the goals was to assess the dynamic changes of EMG activity of patients with fixed full implant rehabilitation. The literature data shows that patients tend to adapt to newly inserted prostheses. Giannkopoulous et al. have shown an increase in EMG activity over time. This was noted note immediately after fixation but after 3 months of function [15]. Other authors mentioned a period of adaption from 6 to 12 months [20]. Despite the fact that we have waited for more than 6 months there were no changes in EMG activity between LS and LSF. This was in contrary to our hypothesis that EMG values of 4 masticatory muscles will increase over time. Perhaps the change of material or number of teeth could influence the results in future studies.

4.2. Evaluation of electromyographic activity during mastication

The fixed prostheses used during rehabilitation of full edentulous patients aim to restore the esthetics, phonetics, and psychological status of a patient along with its masticatory capabilities. A recent study by Tanaka mentioned that these patients with full implant restorations are lacking the control over mastication and especially the right moment of muscle contraction [33]. It is logically to assume that muscle activity during MVC is higher than in mastication due to a constant and prolonged muscle contraction. In order to prove this bias, the same calibration was used for mastication as for MVC with a long registration time due to masticatory act. We obtained both raw and mean values for whole registration period. However, the latest is easier to use for comparison. According to the obtained data, patients had no statistically significant differences during MCV and mastication ($p < 0.05$) for all EMG activity of analyzed muscles. This might be due to the food type used that in this research was almonds, that is a hard food which might require more force to be chewed than other types of food.

The obtained results corresponds to similar data from other studies where a sequential contraction of muscle fibers during mastication is measured [26]. However, it was not possible in our study to separate the muscle in different distinct parts due to the specific diagnostic tool (EMG) that acquires the data from a wide area of skin above a muscle. Moreover, the device has 4 channels that does not allow a more detailed intramuscular evaluation.

Another aim in the study was to assess if healthy dentate subjects have the same parameters and results as the study group. After statistical analysis there were no significant differences ($p>0.05$) between the mastication and clenching in LC. Despite the dispersion of values in some specific subjects the median was almost the same in both examinations. In this case we can say that a full edentulous patient rehabilitated with fixed implant supported prostheses behave the same from the perspective of muscle contraction. Despite a longer time of mastication in LS and lack of periodontal ligaments, the muscle activity is similar. In LSF there was a statistically significant

difference between MVC and mastication in one muscle, right masseter where p = 0.008. This alone in our opinion do not present any scientific or clinical significance. Similar deviation of single muscle was obtained by Bersani where right temporal muscle presented the only difference. The author also obtained higher values of bioelectrical activity in control group than study one during clenching [23]. Moara de Rossi also obtained statistically significant differences only in right temporal muscle during MCV in the study group [22].

In our study we do not consider the deviation of single muscle relevant to the results or clinical aspects. Masticatory function is a complex one and involves simultaneously all masticatory muscles. Perhaps the increase of number of subjects or the uses of needle EMG would eliminate the deviation. It is worth mentioning that there were other data in the literature that showed a contradictory result than in our study, where patients fixed implant prostheses had higher EMG activity during mastication than in MVC comparing to dentate subjects [28,34]. We have obtained similar results for all three groups included in our study both during mastication and clenching. Thus, it can be concluded that fixed full implant prostheses restore immediately after fixation the contracture capacity of 4 masticatory muscles, and it remains stable through a period of more than 6 months.

4.3. Evaluation of overlapping coefficients

Overlapping coefficients allow to understand the direction of occlusal forces and make the necessary correction to equilibrate the forces applied to the dentures. According to the literature data, sEMG can be used to check and correct the occlusal contacts depending on the interactions between muscles [35,36]. In our research, there were no observed statistically significant differences between the overlapping coefficients form different groups. An important comparison in our opinion was done between LS and LSF because they are the same patients with unchanged dentures. Thus, we can track the momentum and direction of changes in overlapping coefficients. We could not report our data with the literature because there was no similar research published.

Each coefficient has a deviation to one direction that shows the dominant part during contraction. Giving this direction a binary code like 0 and 1 allowed to compare the groups during MVC and mastication. The results have shown that the deviation to the dominant side remained unchanged from clenching to mastication. This means that domination of the side during clenching remained dominant during mastication as well. It is worth mentioning that only the direction remained unchanged regarding the value of coefficients that deviated statistically significant from clenching to mastication. The IMPACT coefficient had no significant differences during mastication and MVC in control group, p = 0.364. That is logic assuming that IMPACT is a value of optimal vertical contraction that did not changed during both procedures. This coefficient changed only in LSF where p = 0.015. The Asym coefficient had statistical differences in LS where p = 0.031. In all groups, Asym and Impact were the most stable ones having statistically insignificant differences only in two comparisons. This evaluation has shown that mastication is a dynamic process where muscle contraction is different than in MVC. The dominant site remained stable unlike the coefficient itself. This is logic assuming that patient have an uneven contact of teeth with food during mastication that according to Blanksma is leading contraction of separate fiber bundles inside the muscle [26].

Another parameter that was analyzed in the research was the mean deviation coefficient. This is calculated from the deviation of each overlapping coefficient from the normal range provided by the manufacturer. In our opinion, comparison of groups through the mean deviation coefficient would be more informative that comparison of overlapping coefficients between

groups. This allows to say how much a patient is deviating from the „norm" provided by the device or from healthy subjects. Its evaluation during mastication also has no sense because we have anteriorly shown that there is no equilibrium during mastication that will eventually lead to high value of mean deviation coefficient. The control group after statistical analysis had a deviation coefficient of 20.5% from normal range. Subjects from LS and LSF had 21.4% and 36.1% respectively. There is no statistically significant difference between groups. However, the LC where healthy subjects were included, had a 21.4% deviation. This might be explained by the fact that patients were above 50 with modifications in dental system. Another issue might be the ethnic, sex and age groups that serve as a reference for the device calibration and comparison.

4.4. Masticatory efficiency

Gravimetric method was applied for determination of masticatory efficiency using 5g of almonds. In most of the studies, a predetermined number of chewing strokes is used on right and then left side with determination of global index afterwards. Ferrario et al. mentioned that chewing test with involvement of both sides simultaneously is more preferable for patients with full implant rehabilitation in order to mimic a natural dentition an assess the masticatory efficiency in normal conditions [27]. After comparative statistical analysis between LC and LS, major differences were noticed in 3 out if 4 parameters. These were the degree of food grinding, mastication time and number of chewing strokes. The only parameter that remained unchanged was the frequency. Analyzing the Table 2 we can see that the number of chewing strokes and time grew in LS proportionally, having the same ratio of 1:1 as in LC. Another important issue is the dependence of the test on the deglutition. Patients were asked to chew until deglutition sensation appears. In LS despite the increased number of strokes and time required for deglutition, the quality of food grinding was worser. According to Berretin-Felix et al., the number of chewing strokes is increasing over time due to weak orbicularis orris muscle [37]. However, this must be true for both groups because there is no big difference between the age of patients from both groups. But we see that dentate subjects have a lower time and less chewing strokes to chew the same number of almonds. Another explanation may be the decreased number of teeth in provisional denture that are in some cases 10 teeth per arch. However, 20 patients from the study group had 10 teeth per arch, the rest had 12 teeth, but there were no statistically significant differences in the masticatory efficiency. Dellavia et al. mentioned that 10-12 teeth per arch is enough for an efficient mastication [20]. Taking into account that some authors mentioned a period of 6-12 months required for neuromuscular adaptation then it is logical to assume that masticatory efficiency must increase in LSF [15,20,22,25].

Table 2. **Descriptive statistics for masticatory efficiency in the control group (LC), Study group after prostheses fixation (LS) and 6 months after (LSF)**

		LC (N=33)	**LS (N=30)**	**LSF (N = 30)**	**Wilcoxon test (LC vs LS)**	**Wilcoxon test (LC vs LSF)**	**Wilcoxon paired test (LS vs LSF)**
Mastic (%)							
	Mean (SD)	83.0 (11.9)	60.0 (11.7)	63.0 (12.6)	W = 911.5, p-value = 1.032e-08	W = 898, p-value = 3.032e-08	V = 140, p-value = 0.09592
	Median (IQR)	86.8 (8.70)	59.1 (19.3)	66.0 (17.3)			
	[Min, Max]	[38.0, 95.2]	[40.7, 83.1]	[24.4, 81.3]			

Time (s)							
	Media (SD)	30.8 (10.3)	48.3 (12.2)	47.7 (14.8)	W = 138, p-value = 9.259e-07	W = 160, p-value = 4.15e-06	V = 276, p-value = 0.2098
	Median (IQR)	31.6 (8.82)	48.8 (12.2)	46.3 (17.1)			
	[Min, Max]	[10.0, 61.0]	[24.8, 83.0]	[23.9, 89.1]			
Cycles (n)							
	Mean (SD)	33.8 (12.9)	44.7 (10.4)	46.1 (16.3)	W = 245.5, p-value = 0.0006039	W = 274, p-value = 0.002394	V = 189, p-value = 0.7584
	Median (IQR)	31.0 (20.0)	47.0 (11.8)	47.5 (20.0)			
	[Min, Max]	[16.0, 65.0]	[15.0, 65.0]	[14.0, 84.0]			
Frequency (c/s)							
	Mean (SD)	1.13 (0.359)	0.976 (0.289)	0.984 (0.278)	W = 613, p-value = 0.1062	W = 599.5, p-value = 0.1524	V = 192, p-value = 0.5888
	Median (IQR)	1.07 (0.445)	0.937 (0.331)	0.966 (0.301)			
	[Min, Max]	[0.555, 2.00]	[0.231, 1.60]	[0.432, 1.77]			

Note: Abbreviations: mastic – percentage of almonds that passed through a 1.68mm sieve; time – masticatory time; Mean (SD) – mean with standard deviation, Median (IQR) – median with interquartile deviation, Min – minimal value, Max – maximum value, df – degree of freedom.

Statistical analysis has shown that there are no differences between LS and LSF in all 4 parameters. Thus, there were no adaptation of mastication over this period which is the same result as for sEMG. The obtained data are in contradiction with some find in the literature, however there are still not enough articles addressing masticatory efficiency and sEMG in provisional full fixed implant supported prostheses.

If to combine the data obtained from the sEMG analysis, then we see that patients with full implant supported restorations have a similar bioelectrical activity of masseter and temporalis muscles as dentate subjects and it remains stable after 6 months. Despite the fact that there is the same muscle activity, we do not obtain the same quality of mastication. Patients required a longer mastication time with increased number of chewing strokes with a worser food grinding. It is worth mentioning here the study of Trulsson Mats who mentioned that implants have no fine, dynamic motoneurons which could better control the food between the teeth and fire the muscles in the proper time [25]. Thus, these patients do not feel the food and the proper time to chew it having a lower masticatory efficiency due to lack of periodontal feedback mentioned in the study of Tanaka [33]. It is worth mentioning that despite the fact that provisional full implant supported prostheses cannot provide a masticatory efficiency similar to dentate subjects, it does not mean a poor masticatory performance. The later means a self-evaluation of mastication through questionnaire.

GENERAL CONCLUSIONS

1. The comparative analysis of data has shown the similarity of electromyographic activity of masticatory muscles during maximum voluntary contraction between groups which demonstrated that fixed full implant rehabilitation

restores the muscle contraction capacity similar to dentate ones. Bioelectric activity remained constant in the rehabilitated group after a period of 6 months which means lack of adaptation period for these patients.

2. The comparison of electromyographic activity inside the groups during the maximum voluntary contraction and mastication has shown no statistically significant differences ($p > 0.05$). The subjects developed the same average amount of bioelectric activity for both procedures despite the teeth type (natural or acrylic fixed implant denture).

3. The comparison of overlapping coefficients in maximum voluntary contraction and mastication has shown a statistically significant deviation of these coefficients during mastication. Just few coefficients did not have either difference or statistically insignificant one: IMPACT – $p = 0.364$ in LS, ASYM – $p = 0.202$ in LSF, IMAC – $p = 0.782$, and ASYM – $p = 0.195$ in LC. These indicates the presence of asymmetric tooth contacts during mastication. However, the direction of contraction dominance remained unchanged from MVC to mastication for all groups.

4. The mean deviation coefficients did not correspond to the average provided by the manufacturer in all the groups. The control group deviated by 20.5%, LS by 21.4% and LSF by 36.1%. The p was 0.086 which indicates lack of statistical significance between groups. The presence of deviation in control group with healthy dentate subjects indicates the necessity of a control group in the further studies that must be as similar to study groups as possible for calibration of the results.

5. The use of gravimetric method for determination of masticatory efficiency between the study group during prostheses fixation and 6 months after has shown no statistically significant differences. This indicates the lack of neuromuscular adaptation for masticatory function. Comparison of control and study groups has shown statistically significant differences in 3 out of 4 parameters: mastic – $p = 1e\text{-}08$, cycles – $p = 6e\text{-}0.4$, time – $p = 9.3e\text{-}0.7$, which demonstrates a low masticatory efficiency compared to dentate patients.

6. The use of full fixed implant prostheses in completely edentulous patients allowed to restore the contraction capacity of masseter and temporalis muscles similar to a dentate patient immediately after prostheses fixation. The obtained muscle contraction capacity remained unchanged for more than 6 months. Despite the similar bioelectric activity between groups in both static and dynamic tests, the masticatory efficiency of temporary full fixed implant-supported dentures remained poorer than in dentate patients.

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LIST OF SCIENTIFIC PUBLICATIONS AND EVENTS
Where the research results
of doctoral thesis in medical science were presented
with the topic „Muscular and masticatory functional changes in fully edentulous patients rehabilitated with fixed implant supported prostheses”

323.01 – Stomatology,
carried out in the Department of Prosthetic Dentistry „Ilarion Postolachi”
by Mr. Mostovei Mihail „Nicolae Testemițanu” State University of Medicine and Pharmacy, Republic of Moldova.

SCIENTIFIC WORKS

- **Articles in foreign scientific journals:**
  - ✓ **articles in ISI, SCOPUS journals or other international databases ***

1. **Mostovei M**., Solomon O., Chele N., Sinescu C., Duma V-F., Mostovei A. Electromyographic Evaluation of Muscle Activity in Patients Rehabilitated with Full Arch Fixed Implant-Supported Prostheses. In: *Medicina*. 2023; 59(2):299. IF:2.6.
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- **Articles in national accredited journals:**
  - ✓ **articles in category C journals**

1. Sîrbu D., **Mostovei M**., Strîșca S., Popovici V., Mighic A., Mighic V. Particularităţile planificării și tratamentului protetic în reabilitarea pacienţilor edentaţi cu inserarea angulată a implantelor. In: *Medicina Stomatologică*. 2017; 3(44): 54-60. ISSN 1857-1328.

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6. **Mostovei M**., Solomon O., Mostovei A., Chele N. Electromyographic values of masticatory muscles in middle-aged dentate patients. In: *Moldovan Journal of Health Science*. 2022; 2(28): 46-50. ISSN 2345-1467. DOI: 10.52645/MJHS.2022.2.07

- **Summaries/abstract/thesis in national and international conferences**

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2. **Mostovei M**., Solomon O., Chele N., Mostovei A., Fachira A. Utilizarea electromiografiei de suprafață în ajustarea restaurărilor totale fixe cu suport implantar. In: *Congresul consacrat aniversării a 75-a de la fondarea Universității de Stat de Medicină şi Farmacie „Nicolae Testemiţanu”*. Chişinău; 2020, p. 715.
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5. Țurcan V., **Mostovei M**., Particularities of alternative methods of implants placement using all-on-4 and all-on-6 concept. In: *MedEspera International Medical Congress for Students and Young Doctors 9th edition*. Chisinau; 2022, p. 359. ISBN 978-9975-3544-2-4.
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- **Inventions, patents, registration certificates in salons of inventions**

1. **Mostovei M**., Solomon O., Chele N., Mostovei A. Utilizarea conformatoarelor individuale din titan în reabilitările implanto-protetice fixe. Certificat de inovator nr. 5909 from 24.05.2022.
2. **Mostovei M**., Solomon O., Chele N., Mostovei A. Determinarea electroactivității musculare la pacienții cu reabilitări totale fixe cu suport implantar. *Certificat de inovator nr. 5910 from 24.05.2022.*

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- **Participation with oral communications at scientific forums:**

✓ **international**

1. **Mostovei M**. Principles of prosthetic planning of full-implant supported restorations. *MedEspera International Medical Congress for Students and Young Doctors 7th edition*. Chișinău 3-5 Mai 2018.
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4. **Mostovei M**. Evoluția tratamentului edentației totale. *Implantodays congres*. Chișinău 22-23 noiembrie 2019.
5. **Mostovei M**. Erori și complicații protetice în reabilitarea implanto-protetică fixă pe 4 și 6 implante. *Summit Connect Dentistry MD-RO*. On-line 30 noiembrie-4 decembrie 2020.
6. **Mostovei M.** Etapizarea tratamentului implant-protetic în edentații unidentare. *Interdentis 2nd Pandemic Edition*. On-line 19-23 aprilie 2021.

✓ **national**

1. Spijavca E., **Mostovei M**. Particularitățile remodelării țesuturilor moi periimplantare prin mijloace protetice. *Congresul Zilele Universității de Stat de Medicină şi Farmacie Nicolae Testemițanu*. Chișinău 15-19 octombrie 2018.
2. **Mostovei M**., Solomon O., Chele N., Mostovei A., Fachira A. Utilizarea electromiografiei de suprafață în ajustarea restaurărilor totale fixe cu suport implantar. *Congresul consacrat aniversării a 75 ani de la fondarea Universității de Stat de Medicină şi Farmacie „Nicolae Testemiţanu*. Chișinău 21–23 octombrie 2020.

ANNOTATION
Mostovei Mihail
„Muscular and masticatory functional changes in fully edentulous patients rehabilitated with fixed implant supported prostheses”
Doctoral thesis in medical science, Chișinău, 2023

Thesis structure. The thesis is exposed on 108 pages of main text being structured as follows: list of abbreviations, introduction, 4 chapters, general conclusions, practical recommendations, bibliography with 144 sources and 2 annexes. Thesis contains 3 tables and 60 images.
Key words: complete edentulism, implant-prosthetic rehabilitation, electromyography, masticatory efficiency.
Field of study: 323.01 – Stomatology.
Aim: Comparative and dynamic evaluation of electromyographic activity of muscles and masticatory efficiency in fully edentulous patients rehabilitated with fixed implant supported prostheses for treatment optimization.
Study objectives: Evaluation of muscle electroactivity in maximum voluntary contraction in dentate patients with edentulous patients during fixed implant prostheses delivery as well as after 6 months. Comparative analysis of muscle electroactivity between maximum voluntary contraction and mastication in dentate and edentulous patients during prostheses fixation as well as after 6 months. Determination of electromyographic overlapping coefficients in study and control groups during clenching and chewing. Comparative analysis of deviation coefficients of electromyographic activity in study and control groups. Determination of masticatory efficiency in dentate and edentulous patients during fixed prostheses delivery as well as after 6 months.
Scientific novelty and originality: For the first time in the Republic of Moldova a prospective study for surface electromyography evaluation in patients with provisional full fixed implant supported prostheses was performed. The measurements were performed both during prosthesis fixations as well as after 6 months which represents a dynamic study not often described in the literature. The study included a healthy, dentate group of subjects which allows to evaluate the degree of muscle contraction capacity after prostheses delivery. It was also possible to evaluate the masticatory efficiency using the gravimetric method along with surface electromyography which allowed to determine the chewing time, frequency, number of chewing strokes and food grinding quality.
Practical importance: The obtained results will enrich the existing literature with data about the electromyographic activity of masticatory muscles and masticatory efficiency. The study also demonstrated the efficiency of fixed implant rehabilitation in restoring the contractive capacity of masticatory muscles. This research opens new perspective for further research on this topic that would allow to increase the quality of dental treatment by changing the prostheses type, materials and other parameters that will lead to a grater masticatory efficiency in these patients.
Implementation of the results: The obtained results were implemented in the educational process of students and residents from the Department of prosthetic dentistry „Ilarion Postolachi”, Department of Oral and Maxillo-facial surgery „Arsenie Guțan” from the State University of Medicine and Pharmacy „N. Testemițanu”. The treatment and diagnostic methods are also applied in the State Dental Clinic „Toma Ciorbă” and private dental clinic „Masterdent”.

ADNOTARE

Mostovei Mihail

„Modificările de funcție masticatorie și musculară în reabilitarea edentației totale cu proteze fixe cu suport implantar”

Teza de doctor în științe medicale, Chișinău 2023

Structura tezei. Textul tezei este expus pe 108 pagini de text de bază fiind compartimentată din: lista abrevierilor, introducere, 4 capitole, concluzii generale, recomandări practice, bibliografia cu 144 de surse și 2 anexe. Teza conține 3 tabele și 60 imagini.

Cuvinte cheie: edentație totală, reabilitare implanto-protetică, electromiografie, eficiență masticatorie.

Domeniul de studiu: 323.01 – Stomatologie.

Scopul lucrării: Evaluarea comparativă și în dinamică a valorilor electroactivității musculare și eficienței masticatorii la pacienții edentați total, reabilitați prin proteze fixe cu suport implantar pentru optimizarea tratamentului.

Obiectivele cercetării: Evaluarea electroactivității musculare în contracție voluntară maximă la pacienții dentați în raport cu cei edentați la etapa fixării protezelor fixe precum și în dinamică peste 6 luni. Analiza comparativă în contracție voluntară maximă și în timpul masticației a electroactivității musculare la pacienții dentați și edentați la etapa fixării protezelor fixe precum și în dinamică peste 6 luni. Determinarea coeficienților de suprapunere a electromiografiei în cadrul loturilor de studiu și a celui de control la etapa de contracție voluntară maximă și în timpul masticației. Analiza comparativă a coeficienților de deviație medie a electroactivității musculare la pacienții din loturile de studiu și cel de control. Determinarea eficienței masticatorii la pacienții dentați și edentați la etapa fixării protezelor fixe precum și în dinamică peste 6 luni.

Noutatea și originalitatea științifică: Pentru prima dată în Republica Moldova s-a efectuat un studiu prospectiv de determinare a modificărilor electromiografiei de suprafață la pacienții reabilitați cu proteze fixe provizorii cu suport implantar. Evaluarea s-a efectuat atât la etapa de aplicare a protezelor, cât și peste 6 luni de funcție ceea ce prezintă un studiu în dinamică puțin descris în literatura de specialitate. S-a efectuat analiza comparativă a pacienților reabilitați cu cei dentați pentru determinarea gradului de restabilire a capacității de contracție musculară în urma tratamentului implanto-protetic. Este unul din puținele studii din literatură în care s-a evaluat paralel electromiografia și determinarea eficienței masticatorii cu utilizarea metodei gravimetrice comparând calitatea actului masticator atât din punctul de vedere al eficienței triturării, timpului, frecvenței, cât și a valorilor electroactivității musculare pe parcursul masticației.

Importanța practică: Datele obținute vin să completeze literatura de specialitate cu referire la capacitatea de adaptare a activității musculare masticatorii precum și îmbunătățirea actului masticator după o perioadă de 6 luni. Nu în ultimul rând, acest studiu a demonstrat eficiența protezelor fixe asupra contracției și coordonării musculare la pacienții cu reabilitări protetice fixe cu suport implantar. Lucrarea dată deschide noi perspective de cercetare în viitor menite să îmbunătățească calitatea acestor tratamente prin modificarea nemijlocită a tipului de proteză fixă care, la rândul său, ar ajuta la integrarea cât mai bună a acestora și creșterea satisfacției și calității vieții acestor pacienți.

Implementarea rezultatelor. Rezultatele cercetării au fost implementate în procesul de instruire a studenților și rezidenților din cadrul Catedrei de stomatologie ortopedică „Ilarion Postolachi” precum și în procesul reabilitării clinice a pacienților edentați total din cadrul Clinicii Stomatologice Universitare „Toma Ciorbă”, a clinicii stomatologice private SRL „MasterDent”.

АННОТАЦИЯ

«Изменения жевательной и мышечной функции в реабилитации пациентов с полной адентией с помощью несъемных протезов с опорой на имплантах»

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Структура работы: Текст работы представлен на 108 страницах основного текста, разделенного на: список сокращений, введение, 4 главы, общие выводы, практические рекомендации, библиографию со 144 источниками и 2 приложения. Работа содержит 3 таблицы и 60 изображений.

Ключевые слова: полная адентия, имплантопротезная реабилитация, электромиография, жевательная эффективность.

Область изучения: 323.01 – Стоматология.

Цель работы: Сравнительная оценка показателей электроактивности мышц и жевательной эффективности в динамике у пациентов с полной адентией, реабилитированных несъемными протезами с опорой на имплантах для оптимизации лечения.

Задачи исследования: Оценка электроактивности мышц при максимальном произвольном сокращении у пациентов с зубами по отношению к пациентам с полной адентией на этапе фиксации несъемных протезов, а также в динамике через 6 месяцев. Сравнительный анализ электроактивности мышц при максимальном произвольном сокращении и при жевании у пациентов с зубами и без на этапе фиксации несъемных протезов, а также в динамике через 6 месяцев. Определение коэффициентов перекрытия электромиографии в основной и контрольной группах на этапе максимального произвольного сокращения и во время жевания. Сравнительный анализ средних коэффициентов отклонения электроактивности мышц у больных основной и контрольной групп. Определение жевательной эффективности у пациентов с зубами и без зубов на этапе фиксации несъемных протезов, а также в динамике в течение 6 месяцев.

Научная новизна и оригинальность: Впервые в Республике Молдова проведено проспективное исследование по определению изменений поверхностной электромиографии у пациентов, реабилитированных временными несъемными протезами с опорой на имплантах. Оценка проводилась как на этапе применения протезов, так и через 6 месяцев функции, что представляет собой исследование в динамике, мало описанное в специальной литературе. Проведен сравнительный анализ реабилитированных пациентов с пациентами с зубами для определения степени восстановления способности мышц к сокращению после имплантопротетического лечения. Это одно из немногих исследований в литературе, в котором электромиография и определение жевательной эффективности оценивались параллельно с использованием гравиметрического метода, сравнивая качество жевательного акта с точки зрения эффективности растирания, времени, частоты и значения электроактивности мышц при жевании.

Практическая значимость: полученные данные дополняют данные специальной литературы в отношении адаптационных возможностей деятельности жевательных мышц, а также улучшения жевательного акта через 6 месяцев после лечения. И последнее, но не менее важное: это исследование продемонстрировало эффективность несъемных протезов в отношении сокращения и координации мышц у пациентов с несъемной ортопедической конструкцией с опорой на имплантах. Представленная работа открывает новые исследовательские перспективы в будущем, направленные на улучшение качества этих методов лечения путем непосредственного изменения типа несъемного протеза, что, в свою

очередь, поможет максимально их интегрировать и повысить удовлетворенность и качество жизни этих пациентов. пациенты.

Внедрение результатов: Результаты исследования были внедрены в учебный процесс студентов и резидентов кафедры ортопедической стоматологии им. Илариона Постолаки, а также в клиническую реабилитацию пациентов с полной адентией в Университетской стоматологической клинике им. Тома Чорбэ и частной стоматологической клинике MasterDent.