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ORIGINAL ARTICLE

Does the Use of Surface Electromyography Could Improve Quality of Life among Patients Rehabilitated by Mandibular Overdentures on Different Attachments?

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ABSTRACT

Objective: To analyze and compare changes of quality of life parameter among dental patients rehabilitated by the implant-supported overdentures with different attachment systems. **Material and Methods:** Forty-eight patients were recruited as a study cohort. The implant placement procedure was based on the results obtained by CBCT scanning and individualized surgical templates manufactured for correct implant placement. Each individual received two k3Pro Implants (Sure Type with 4.0 or 4.5 mm in diameter) at the intraforaminal area due to standard protocol of implantation provided by the manufacturer under local anesthesia. All patients were distributed between two groups based on the fact of using either Locator- or ball-attachments. Rank correlation was measured using Spearman correlation coefficient, while linear correlation was evaluated by Pearson correlation coefficient. **Results:** No statistically meaningful differences were noted regarding patients' distribution among groups considering age ($p>0.05$) and gender ($p>0.05$). Provided patient-level analysis demonstrated that increase of conventional full denture service time was positively correlated with escalation of OHIP-EDENT scores. The most prominent inter-correspondences were noted specifically between longevity of denture service and elevation of scores within "Functional limitation" ($r=0.61$; $p<0.05$), "Physical pain" ($r=0.51$; $p<0.05$) and "Physical disability" ($r=0.57$; $p<0.05$) subdomains. No statistically argumented regressions were noted between increase tendency of OHIP-EDENT scores and gender ($p>0.05$) or age ($p>0.05$) parameters. **Conclusion:** Significant improvements of quality of life measured with OHIP-EDENT were noted for both types of attachments compared to the pre-treatment situation independently of additionally provided surface electromyography-based alignment.

Keywords: Dental Implantation; Dental Prosthesis, Implant-Supported; Quality of Life.

Introduction

Dental implants significantly improve quality of life among patients rehabilitated with implant-supported overdentures comparedcompared to the outcomes registered among conventional full removable dentures users [1]. Moreover, patients rehabilitated by implant-supported overdentures reported a higher level of oral satisfaction, which was indirectly associated with their scaled-up contentedness regarding obtained treatment results [1]. Systematic review highlighted the superiority of non-splinted mandibular overdentures for dental rehabilitation of patients with full edentulism compared to conventional complete dentures due to the obtained efficiency levels, satisfaction grades and quality of life parameters [2].

Results of previous studies demonstrated that registered level of masticatory performance obtained after prosthetic treatment was related not only with objective influential factors (number of residual teeth and occlusal units) but also with several subjectively affiliated values (mastication satisfaction, impact on quality of life and masticatory ability) [3]. Based on that, it may be resumed that not only functionally registered or instrumentally diagnosed criteria may be applicable for grading results of prosthetic rehabilitation with implant-supported overdentures, but quality of life parameter in different ways also represents individually oriented criteria of treatment success among patients with full edentulism.

Nevertheless, in the review published in Cochrane Database of Systematic Reviews, it was stated that there is a deficiency of evidence regarding relative effectiveness of different attachment systems used for implant-supported overdentures in means of such criteria as patient's satisfaction and preferences, maintenance need and cost-performance ratio [4]. Considering tremendous changes in dental status among patients who transferred from full edentulism state to implant-based rehabilitated state, there is an on-going need for complex treatment optimization, which would support accelerated patient adaptation to the new functional possibilities [5,6]. Surface electromyography represents an effective method used for the normalization of masticatory muscle balance with different treatment objectives [7-9], but there is a lack of literature data regarding implementation of such an approach specifically into clinical implant practice.

The null hypothesis was formulated as follows: correction of masticatory muscles balance under surface electromyography supervision during implant overdenture try-in phase would not affect the outcome of using overdentures with Locator and ball attachments in means of quality of life parameters changes among dental patients.

To analyze and compare changes of quality of life parameter among dental patients rehabilitated by the implant-supported overdentures with different attachment systems while controlling masticatory muscles balance using surface electromyography.

Material and Methods

Study Design and Sample Formation

The research was designed a longitudinal study provided on the base of University Dental Clinic (Uzhhorod National University, Faculty of Dentistry, Uzhhorod, Ukraine). The patients' cohort was formed out of a number of dental patients who presented with full mandibular edentulism requiring prosthetic rehabilitation using implant-supported overdenture. Following parameters were used as inclusion criteria during realization of study: 1) age of patients over 18 years (minimally required age for legal agreement to participate in the clinical study); 2) full mandibular edentulism; 3) presence of natural teeth or any kind of fixed denture at the maxilla that support normal functioning of maxillary dentition; 4) absence of any somathopathologies that potentially could compromise outcome of implant treatment; 5) sufficient amount of

bone volume within the mental region for implant placement; 6) ongoing use of conventional full removable denture at mandible; 7) personal agreement of patient evidenced by patients signed consent form to take part in the present study considering all aspects of its design. Exclusion criteria included: 1) full maxilla edentulism; 2) single teeth presented on maxilla, amount of which compromise normal maxillary dentition functioning; 3) presence of full or partial removable denture on the maxilla; 3) presence of any allied pathology or habit that may compromise the result of implant osseointegration; 4) deficiency of bone volume within the projection of future implant placement that requires bone augmentation procedure; 5) disagreement of the patient to take part in the study due to the personal non-compliance with some of the study design aspects.

Considering specific inclusion and exclusion criteria, 48 patients were recruited as a study cohort. The implant placement procedure was based on the results obtained by CBCT scanning and individualized surgical templates manufactured for correct implant placement. Each individual received two k3Pro Implants (Sure Type with 4.0 or 4.5 mm in diameter) at the intraforaminal area due to standard protocol of implantation provided by the manufacturer under local anesthesia. All implants placement procedures were provided by the same experienced surgeon properly certified for implant treatment. Right after implant installation, healing abutments were placed over intraosseous fixture, and full mandibular dentures that were previously used by patients were adapted using resilient liner [10-13].

Three months after the surgical phase of rehabilitation, either Locator- or ball-attachments were installed over previously placed implant screws. All patients were distributed between two groups based on the fact of using either Locator- or ball-attachments. Distribution of patients between Locator- and ball-attachments groups was based on the personal patient's agreement regarding the use of different attachments designs while taking into account specific features of each analyzed clinical situation, financial aspects and technical issues. Due to the above-mentioned factors, Locator-attachment group was formed out of 28 patients and ball-attachment group – out of 20 patients. Height of abutment was chosen due to the present thickness of surrounding soft tissue, and males' part was chosen considering measured angulation of each inserted implant [10,12]. Processing of denture caps into the overdenture was held by the direct method following manufacturer's instruction [10,12] (Figure 1A-E).

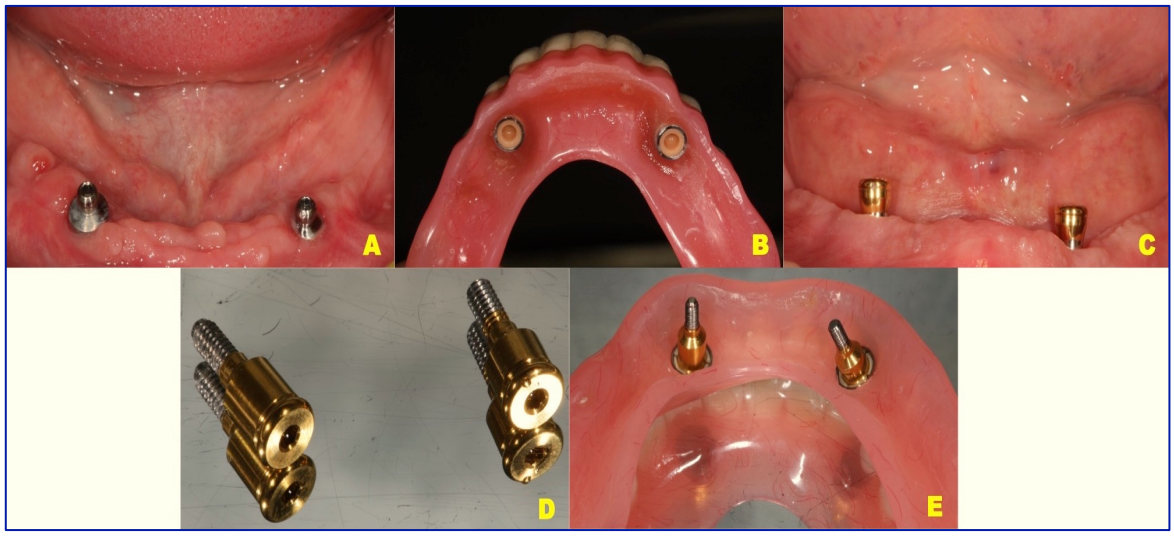

Figure 1. (A) Installed ball-attachments; (B) Implant-based overdenture designed for ball-attachments; (C) Installed Locator-attachments; (D) Locator-attachments; and (E) Implant-based overdenture designed for Locator-attachments.

The prosthetic phase of rehabilitation included the formation of bilateral balanced occlusion. But in each group, half of patients were randomly assigned for the surface electromyography controlling procedure during denture construction try-in with further denture occlusal correction for reaching the most balanced correspondence between left and right temporal and masticatory muscles. Surface electromyography evaluation was provided with the use of a Teethan device (BTS S.p.A., Garbagnate Milanese, Italy) due to the previously described protocol with analysis of such targeted parameters as the symmetry of contraction within homological pair of masticatory muscles (POC-index), asymmetry between left and right sides (ASIM-index), and mandibular torsion index (TORS-index) [14]. Normalization of above-mentioned parameters by occlusal correction supports an establishment of approximal equilibrium between left and right sides temporal and masseter muscles.

Another half of patients in each group was not undergoing above-mentioned procedure and correction of occlusal interrelation among them was done due to the results of bite tracing with articulating paper. This way, four final groups were formed: Locator-attachment SE (Group 1A) (group of patients with overdentures installed over Locator-attachments among which occlusal correction was held under the control of surface electromyography) – 14 patients, Locator-attachment non-SE (Group 1B) group (group of patients with overdenture installed over Locator-attachments among which occlusal correction was held due to the results of bite tracing with articulating paper) – 14 patients, ball-attachment SE (Group 2A) group (group of patients with overdenture installed over ball-attachments among which occlusal correction was held under the control of surface electromyography) – 10 patients, and ball-attachment non-SE (Group 2B) (group of patients with overdenture installed over ball-attachments among which occlusal correction was held due to the results of bite tracing with articulating paper) – 10 patients.

Data Collection

Before receiving any intervention, each patient from the study cohort was evaluated with the use of OHIP-EDENT questionnaire to verify how the translation from conventional removable denture to the implant-retained overdenture could potentially improve oral health-related quality of life (OHRQoL) under the conditions of using attachments of different design and implementing different approaches for occlusal correction.

Repeated evaluation of oral health-related quality of life (OHRQoL) was provided also 1 month and 12 months after definitive overdenture placement. OHIP-EDENT questionnaire composed of 19 questions categorized within seven domains, which include Functional Limitation (3 questions), Physical Pain (4 questions), Psychological Discomfort (2 questions), Physical Disability (3 questions), Psychological Disability (2 questions); Social Disability (3 questions), Handicap (2 questions) [15-17]. All 19 questions were reproduced from an originally developed questionnaire and translated into Ukrainian. Respondents answered each question to specify the frequency of each functional, social or emotional limitation occurring (5 points Likert scale): 0 – never, 1 – seldom, 2 – sometimes, 3 – fairly often, 4 – very often). As a result, range of possible summed OHIP-EDENT scores received among different domains varies between 0 and 76 points, while the higher summed value represents the lower grading for quality of life related to the condition of oral status [15-17].

Additionally, satisfaction with outcome oral status condition was measured by Oral Satisfaction Scale (OSS), which accompanied OHIP-EDENT to stratify patients' self-assessment of well-being regarding oral

changes [18]. In the present study, we used a modified Oral Satisfaction Scale that included the following aspects: provided implant treatment, provided prosthetic manipulation, chewing ability, adaptation to overdenture, phonetic function, esthetic parameters, comfort, hygiene maintenance of the denture, technical maintenance of the denture. In addition, 1-10 points grading scale was used for the evaluation of above-mentioned aspects, with 1 representing total dissatisfaction and 10 standing for full satisfaction with received outcome. OSS evaluation was provided before any intervention during patient's usage of conventional full removable denture and 1 and 12 months after final overdenture placement among all groups.

The chewing ability of patients was measured with the use of chewing ability index (ICA) developed previously by Leake [19,20]. Methodology of index calculation based on patient's answer dichotomy of "Yes" or "No" on five questions regarding the possibility to adequately chew 5 types of food: fresh carrot/celery sticks, fresh lettuce/spinach salad, steaks, chops of firm meat, boiled peas, carrots or green/yellow beans, whole fresh apple without cutting it. If the person can answer "Yes" on all 5 questions, that final score of 5 indicates full chewing competence, while even one "No" answer with a total score equal or lower than 4 indicates deficient chewing ability [19,20].

Data Analysis

The reliability of the registered differences (p) was estimated in accordance with the generally accepted statistical methods, using the Student's t-criterion for parametrical variables and Mann-Whitney's U-test for nonparametric variables. Registered outcomes were categorized as significant only when $p<0.05$ (significance level of 0.95). Rank correlation was measured using Spearman correlation coefficient, while linear correlation was evaluated by Pearson correlation coefficient [21,22]. Obtained correlation levels were interpreted by the Chaddock scale: $0 < r < 0.1$ – non-significant regression, $0.1 < r < 0.3$ – weak regression, $0.3 < r < 0.5$ – moderate regression, $0.5 < r < 0.7$ – noticeable regression, $0.7 < r < 0.9$ – close regression, $0.9 < r < 0.99$ – strong regression, $0.99 < r < 0.1$ – functional regression [23]. Regression analysis was provided regarding OHIP-EDENT, OSS and CAI changes before implant treatment, and 1 and 12 months after overdenture delivery due to their potential interdependences and possible impact of muscle-based occlusion calibration on above-mentioned parameters. Statistical analysis of the obtained data was provided within Microsoft Excel software (Microsoft Office 2019, Microsoft Corp., USA) with the additional use of add-ins, such as Analyse-it (Analyse-it Software, Ltd., Leeds, UK) and XLSTAT (Addinsoft Inc., Long Island, NY, USA).

Ethical Aspects

The study protocol was approved by the Ethics Committee of Faculty of Dentistry at Uzhhorod National University (Uzhhorod, Ukraine) with received number of EC 14022019 (14/02/2019). All patients recruited in the study voluntarily agreed to participate in the clinical survey after a detailed explanation of all study design aspects, evidenced with a signed informed consent form.

Results

Distribution of patients primarily enrolled within specifically formed groups regarding age, gender and service time of previously used mandibular conventional full removable denture represented in Table 1.

Table 1. Distribution of patients among study groups considering parameters of age, gender and service time of mandibular conventional full removable denture.

Variables	Group 1A N (%)	Group 1B N (%)	Group 2A N (%)	Group 2B N (%)
Age				
55-59 Years	4 (28.57)	6 (42.86)	3 (30.0)	5 (50.0)
60-64 Years	5 (35.71)	3 (21.43)	3 (30.0)	2 (20.0)
65-69 Years	5 (35.71)	5 (35.71)	4 (40.0)	3 (30.0)
Gender				
Male	8 (57.14)	7 (50.0)	6 (60.0)	6 (60.0)
Female	6 (42.86)	7 (50.0)	4 (40.0)	4 (40.0)
Service Years of Conventional Full Removable Denture				
1-3 Years	4 (28.57)	5 (35.71)	4 (40.0)	5 (50.0)
3-5 Years	6 (42.86)	5 (35.71)	3 (30.0)	3 (30.0)
≥ 5 Years	4 (28.57)	4 (28.57)	3 (30.0)	2 (20.0)
Overall	14 (100.0)	14 (100.0)	10 (100.0)	10 (100.0)

No statistically meaningful differences were noted regarding patients' distribution among groups considering age ($p>0.05$) (with general tendency of greater amount of 55-59 years old patients participated) and gender ($p>0.05$) criteria (with general tendency of greater number of male patients involved), even though some deviations were noted while comparing Group 1A and 2B. Nevertheless, based on provided statistical analysis, registered quantitative divergencies could not be interpreted as principal ones during inter-groups comparison. For example, most patients were using full removable mandibular dentures for the 1-3 years period, while no statistical difference was noted during comparative analysis of "Service years of conventional removable partial denture" parameter between different groups ($p>0.05$).

Two patients from Group 1A and one person from Group 2A were lost during long-term monitoring for an unknown principal reason (ignored invitation to come for control check-up after 12 months of implant overdenture service); because of this reason, they were excluded from the further analysis.

While using conventional mandibular full removable dentures, patients within all groups were characterized with a compromised level of Oral Health-Related Quality of Life levels with no registered differences between groups ($p>0.05$). Provided patient-level analysis demonstrated that increase of conventional full denture service time was positively correlated with escalation of OHIP-EDENT scores by the meaning of correlation equal to $r=0.52$ ($p<0.05$). The most prominent inter-correspondences were noted specifically between longevity of denture service and elevation of scores within "Functional limitation" ($r=0.61$; $p<0.05$), "Physical pain" ($r=0.51$; $p<0.05$) and "Physical disability" ($r=0.57$; $p<0.05$) subdomains. No statistically argumented regressions were noted between increase tendency of OHIP-EDENT scores and gender ($p>0.05$) or age ($p>0.05$) parameters.

Provided analysis revealed a statistically significant reduction of general OHIP-EDENT scores and also at the level of each subdomain within all groups after 1 month of implant overdenture functioning while comparing it with primary registered OHIP-EDENT levels before intervention: Group 1A – 10.9±5.3 *vs.* 34.0±6.8 ($p<0.05$), Group 1B – 13.9±3.7 *vs.* 35.5±7.2 ($p<0.05$), Group 2A – 12.8±4.5 *vs.* 34.8±6.9 ($p<0.05$), Group 2B – 15.5±4.8 *vs.* 35.5±5.9 ($p<0.05$), with no differences noted between Locator-attachment and ball-attachment users ($p>0.05$) (Table 2).

Table 2. Comparison of OHIP-EDENT subdomains scores before and one month after treatment.

OHIP-EDENT Domains	OHIP-EDENT Subdomains	Group 1A		Group 1B		Group 2A		Group 2 B	
		Before Treatment	1 Month After Treatment	Before Treatment	1 Month After Treatment	Before Treatment	1 Month After Treatment	Before Treatment	1 Month After Treatment
Functional Limitation	Chewing difficulties	2.6±1.1	0.7±0.3	2.9±0.8	1.0±0.4	2.7±1.0	0.9±0.4	2.5±0.8	1.2±0.3
	Food entrapment	1.1±0.3	0.5±0.3	1.4±0.4	0.5±0.2	1.2±0.5	0.5±0.3	1.4±0.3	0.4±0.2
	Ill-fitting denture	3.1±0.7	0.7±0.6	2.9±1.2	1.1±0.4	3.3±0.8	0.9±0.6	3.0±0.9	1.4±0.5
Physical Pain	Pain within oral cavity	1.9±0.4	0.5±0.2	1.7±0.6	0.4±0.2	1.6±0.5	0.4±0.3	1.5±0.4	0.5±0.2
	Eating comfort	2.3±0.5	0.5±0.6	2.5±0.8	0.6±0.3	2.0±0.9	0.6±0.4	2.4±0.7	0.5±0.3
	Presence of sore spots	1.1±0.6	0.3±0.2	0.9±0.4	0.4±0.3	1.2±0.5	0.4±0.2	1.4±0.5	0.5±0.3
	Uncomfortable denture	1.9±0.7	0.8±0.3	2.2±0.8	1.2±0.4	2.0±0.6	0.9±0.4	2.3±0.5	1.4±0.3
Psychological Discomfort	Worry due to the dental problems	2.5±0.8	1.2±0.4	2.4±0.5	1.4±0.3	2.4±0.5	1.3±0.5	2.0±1.0	1.5±0.4
	Self-Conscious due to the dental problems	1.7±0.8	1.3±0.3	2.0±0.6	1.3±0.3	2.1±0.6	1.3±0.3	1.9±0.8	1.2±0.4
Physical Disability	Avoiding some type of food	2.5±0.9	0.9±0.5	2.7±1.0	1.4±0.4	2.7±1.0	1.2±0.5	2.9±0.7	1.7±0.6
	Inability to eat	1.4±0.5	0.7±0.3	1.5±0.4	0.9±0.5	1.7±0.4	0.7±0.3	1.6±0.5	0.9±0.1
	Interruption of eating	1.4±0.7	0.5±0.3	1.6±0.5	0.6±0.4	1.5±0.8	0.5±0.4	1.7±0.9	0.6±0.3
Psychological Disability	Upset due to the dental problems	1.4±0.6	0.4±0.3	1.8±0.7	0.6±0.4	1.5±0.7	0.4±0.3	1.6±0.8	0.6±0.4
	Embarrassed due to the dental problems	1.3±0.5	0.3±0.1	1.2±0.8	0.5±0.2	1.6±0.5	0.4±0.2	1.7±0.4	0.5±0.2
Social Disability	Avoiding going out	1.5±0.6	0.2±0.1	1.9±0.8	0.3±0.2	1.3±0.9	0.4±0.2	1.4±0.4	0.5±0.3
	Less tolerant with friends and family	1.4±0.2	0.3±0.2	1.6±0.4	0.3±0.1	1.4±0.7	0.5±0.3	1.5±0.6	0.5±0.2
	Irritable to other	1.7±0.5	0.4±0.3	1.2±0.5	0.5±0.2	1.5±0.7	0.6±0.4	1.6±0.5	0.5±0.3
Handicap	Unable to enjoy company	1.5±0.4	0.4±0.2	1.6±0.3	0.5±0.2	1.4±0.8	0.5±0.3	1.5±0.7	0.5±0.4
	Dissatisfaction with life in general	1.7±0.9	0.3±0.2	1.5±0.7	0.4±0.2	1.7±0.6	0.4±0.3	1.6±0.9	0.6±0.5
Total Score		34.0±6.8	10.9±5.3	35.5±7.2	13.9±3.7	34.8±6.9	12.8±4.5	35.5±5.9	15.5±4.8

The most prominent, but still not statistically reasoned differences between the group of patients with provided procedure of occlusal correction due to the surface electromyography control and group of patients occlusal correction among which was realized with the use of articulating paper, were noted at the subdomains "Ill-fitting denture" (0.7±0.6 *vs.* 1.1±0.4 at the Locator-attachment group 1A and 1B respectively; 0.9±0.6 *vs.* 1.4±0.5 at the ball-attachment group 2A and 2B, respectively) and "Uncomfortable denture" (0.8±0.3 *vs.* 1.2±0.4 at the Locator-attachment group 1A and 1B, respectively; 0.9±0.4 *vs.* 1.4±0.3 at the ball-attachment group 2A and 2B, respectively).

After one year of service, no statistically differences regarding OHIP-EDENT values were noted neither between the group of patients with provided procedure of occlusal correction due to the surface electromyography control and group of patients occlusal correction among which was realized with the use of articulating paper ($p>0.05$); nor between group of patients with installed overdentures upon Locator-attachments and group of patients with placed overdentures upon ball-attachments ($p>0.05$). Obtained OHIP-EDENT levels were statistically lower compared to those registered during the use of conventional full removable denture before implant treatment ($p<0.05$) and similar to those gained after 1 month of implant overdenture functioning ($p>0.05$) (Table 3).

Table 3. OHIP-EDENT domains values 12 months after treatment.

OHIP-EDENT Domains	Group 1A	Group 1B	p-value	Group 2A	Group 2B	p-value
Functional Limitation	1.3±0.5	1.5±0.4	>0.05	1.9±0.6	2.3±0.5	>0.05
Physical Disability	1.7±0.7	1.6±0.5	>0.05	2.0±0.7	2.4±0.6	>0.05
Physical Pain	1.9±0.2	2.1±0.7	>0.05	2.3±0.4	2.5±0.7	>0.05
Psychological Discomfort	2.5±0.4	2.5±0.5	>0.05	2.6±0.5	2.4±0.6	>0.05
Psychological Disability	0.6±0.3	0.7±0.5	>0.05	0.8±0.4	0.9±0.5	>0.05
Social Disability	0.9±0.3	1.1±0.3	>0.05	1.2±0.3	1.3±0.3	>0.05
Handicap	0.5±0.2	0.5±0.3	>0.05	0.9±0.2	1.1±0.2	>0.05
Total Score	9.1±0.4	9.5±0.5	>0.05	11.7±0.4	12.9±0.6	>0.05

Due to the results obtained with Oral Satisfaction Scale as a measurement of subjective satisfaction with treatment outcome patients with occlusal control provided via surface electromyography procedure demonstrated higher OSS values of "Adaptation to overdenture" ($p<0.05$) and "Comfort" ($p<0.05$) after 1 month of overdenture functioning compare to the patients occlusal correction among which was provided via classical algorithms by the use of articulating paper (Table 4).

Table 4. Oral Satisfaction Scale results from one month after treatment.

Criteria of OSS	Group 1A	Group 1B	p-value	Group 2A	Group 2B	p-value
Provided Implant Treatment	8.3±1.6	8.8±0.9	>0.05	8.5±1.4	8.4±1.1	>0.05
Provided Prosthetic Manipulation	8.5±0.9	8.6±0.8	>0.05	8.8±1.1	8.6±1.3	>0.05
Adaptation to Overdenture	8.7±1.4	6.8±1.7	<0.05	8.2±1.0	6.1±1.5	<0.05
Phonetic Function	8.1±0.8	8.4±1.5	>0.05	8.4±1.4	8.3±1.3	>0.05
Esthetic Parameters	8.3±1.2	8.5±1.0	>0.05	8.5±1.3	8.4±1.3	>0.05
Comfort	8.2±0.5	6.5±0.4	<0.05	8.4±0.7	6.7±0.9	<0.05
Hygiene Maintenance of the Denture	8.3±1.4	8.5±1.2	>0.05	8.5±1.2	8.0±1.4	>0.05
Technical Maintenance of the Denture	8.1±0.9	8.4±0.7	>0.05	8.0±0.5	8.2±0.6	>0.05

No differences were noted regarding any parameter of OSS neither between the group of patients with provided procedure of occlusal correction due to the surface electromyography control and group of patients occlusal correction among which was realized with the use of articulating paper ($p>0.05$); nor between group of patients with installed overdentures upon Locator-attachments and group of patients with placed overdentures upon ball-attachments ($p>0.05$) at the 12 months control check-up (despite the fact that matrix-related events of denture technical-maintenance were registered more frequently among ball-attachments users). Technical maintenance issues in form of matrix and/or patrix-related events were noted with a prevalence of 7.69% among patients with Locator-attachments and 10.52% among patients with ball-attachments after 12 months of implant overdentures service. Even when considering some frequency of technical maintenance issues occurrence among all study groups, level of subjective satisfaction by OSS after 1 year of implant overdentures functioning was more than 8 points average based on all studied parameters (provided implant treatment,

provided prosthetic manipulation, adaptation of overdenture, phonetic function, esthetic parameters, comfort, hygiene maintenance of the denture and technical maintained of the denture).

Due to Chewing Ability Index interpretation usage of conventional mandibular complete removable denture provoked deficient chewing ability among all 100% of patients, while after 1 year of implant overdenture functioning, only 33.33% of patients reported inability to chew some specific type of food. Prevalence of patients with deficient chewing ability demonstrated decreased tendency while comparing results registered 1 month and 12 months after placing overdenture (52.08% *vs.* 33.33%). Variations of CAI values at the patient level demonstrated no statistically interrelation neither with fact of Locator- ($p>0.05$) or ball-attachment ($p>0.05$) use, nor with the fact of providing procedure of occlusal correction under surface electromyography guidance or through articulating paper tracing ($p>0.05$).

Discussion

Implant-based prosthetic rehabilitation of patients with full edentulism represents an effective treatment option for chewing ability restoration and resolution of functional and physiological disabilities [1,2,4,6,24]. Moreover, rehabilitation of edentulous patients with implant-supported overdentures also decreases the risk of malnutrition among patients aged 60 years and older compared to the outcomes registered during the use of conventional removable prosthetic constructions [25]. Nevertheless, there are still relevant issues that argue the need for further treatment protocol optimization regarding patients' adaptation to the overdenture design, occlusal scheme modification, technical maintenance aspects, and personal satisfaction with obtained outcome [10,11,13].

Considering the outreached results of present study, formulated null hypothesis could be approved since correction of masticatory muscles balance under surface electromyography supervision during implant overdenture try-in phase had not affected the long-term service outcome of overdentures based either at Locator- or ball-attachments in means of quality of life parameters among dental patients. In 12 months perspective usage of surface electromyography for masticatory muscle balance during prosthetic try-in phase, or support of overdentures by either Locator- or ball-attachments, demonstrated no statistically argumented impact on the variations of quality of life values. The only statistical difference registered among groups was noted at 1-month control period while comparing derivates of Oral Satisfaction Scale, due to which it could be presumed that equilibration of masticatory muscles by occlusal correction under the guidance of surface electromyography supports quicker patient's adaptation to overdenture and associated with higher comfort in a short-term perspective.

Compared to the conventional removable dentures, all kinds of attachments used with mandibular overdentures demonstrated significant improvement within OHRQoL and patient satisfaction levels, nevertheless when compares between each other different types of attachments are characterized with different clinical, biomechanical and biological advantages and issues [26]. Positive effect on quality of life during the service of overdentures with a different type of attachments was registered among patients irrespectively to the type of implemented retention system, age and gender-based on outcome obtained with OHIP-49 questionnaire [27]. Due to the results obtained in a systematic review provided by Chaware and Thakkar [28] ball- and Locator-attachments were characterized with relatively analogically high survival rates, patient's satisfaction levels and tissue responses during the monitoring for 3 years of functioning. Similar findings were also registered within our study: it was found that the use of implant-based overdentures have improved both quality of life and oral satisfaction parameters among patients compared to the results registered among them

during the use of conventional full removable dentures. Moreover, regarding OHIP-EDENT values and OSS scores, no difference was found between Locator- and ball-attachments users.

In Matthys et al. [29] study, it was found that even though both Locator- and ball-attachments were associated with improvements within Oral Health Related Quality of Life (OHRQoL), but clinical cases with Loc-types attachments demonstrated a higher frequency of retention correction need, thus affecting QOL through the impact of additional expenses due to the maintenance issues. On the other hand, Brandt et al. [30] found that ball-attachments were associated with a higher need of maintenance during monitoring period, while in most cases, maintenance measures for both ball- and locator-attachments included matrix-related corrections. Within present study, technical maintenance issues in the form of matrix and/or patrix-related events were characterized with a higher level of prevalence among ball-attachments users, but no statistical difference was noted while comparing the need of maintenance measures among both Locator- and ball-attachments users ($p>0.05$). Such outcomes are aligning with results of in vitro study, which demonstrated that ball- and Locator-attachments present no statistically significant differences regarding wear level and technical functioning after 5000 insertion-separation cycles, while retentive properties of such were statistically lower compared to the primary situation in both cases [31]. After the realization of 5000 in-out cycles, Locator-attachment were characterized with relatively higher residual retentive characteristics compared to ball-attachments [31].

Amount of previous studies demonstrated that the type of used attachment system does not significantly influence masticatory muscles activity pattern. In most researches, registered differences within EMG-parameters were not statically approved, even though some studies had shown preferences for some specific type of attachment. Due to the previous study, patients with overdentures on Locator-attachments were characterized with higher amplitude of masseter and temporalis muscles than the users of complete conventional dentures, but general tendency of masseter and temporalis muscles activity increase was noted in both groups of patients with advance of time [32]. In the study of Abdelhamid et al., it was noted that the use of Locator-attachments demonstrated higher masticatory function outcomes in means of muscle activity [33]. Results of previously provided randomized controlled trial demonstrated that during short-term monitoring the highest level of muscles activity was noted after attachment of mandibular dentures onto Locator-abutments, while in long-term perspective, statistical difference between groups with Locator- and ball-attachments in means of muscle activity was not noted [34]. In another study, two implant supported overdentures with the use of ball-attachment system demonstrated higher values of EMG masticatory muscles amplitude, chewing area and duration of chewing cycle compared to the bar and Locator attachments, while all three of them supported more advanced muscle functioning compared to the conventional removable dentures [35]. Data obtained in a randomized controlled study found a correlation between improvement of masticatory efficiency and positive changes within OHIP scores, which was argumented by the fact that OHIP represents subjective grading of quality of life improvement, which in turn also depends on proper mastification function [36]. Our study revealed supportive outcomes: both Locator- and ball-attachments users demonstrated statistically significant improvement of quality of life compared to primary condition of using conventional removable dentures, while no difference regarding chewing ability was noted after one year of monitoring between Locator and ball-attachment groups. Correction of masticatory muscle balance after insertion of overdenture supported quicker patients' adaptation to the formulated occlusal scheme. Nevertheless, the quicker adaptation effect has not significantly influenced the quality of life parameter in the long-term perspective, even though it impacted the Oral Satisfactory Score values after one month of monitoring. We

have not tested surface electromyography parameters among all patients after one year of overdenture functioning because of two reasons: 1) comparison of surface electromyography parameters and their possible use for further masticatory muscles balancing through occlusal correction beneficial only at individual patient level, while it is not helpful for interpretation in group due to the prominent interpersonal variability of chewing muscles interrelation; 2) present study design was aimed at assessment of surface electromyography supervision impact during implant overdenture try-in phase on the outcome of using overdentures with Locator- and ball-attachments in means of quality of life parameter among dental patients in general, while future study will be aimed at in-detail analysis of patient-oriented parameters changes for development of customized treatment protocol.

Some differences of outcomes registered in our and previous studies could be argumented by the several factors: targeted use of surface electromyography was provided only at strict time point of overdenture try-in, but not in on-going manner during regular check-ups; relatively small study sample; usage of OHIP-EDENT form instead of other versions of oral health-related quality of life questionnaires; evaluation of null hypothesis at level of study group, but not at individual patient level. Such specifics of study design considering all above-mentioned aspects could be interpreted as its partial limitations. In the present study, we have used translated international short version of Oral Health Impact Profile for edentulous patients since there were no studies on developing Ukrainian version of OHIP-EDENT or OHIP-14. Meanwhile, an international version of OHIP-EDENT have demonstrated adequately evidenced results during verification and validation. Also, considering the results of an international multicenter study, cultural features associated with the study population influence the different domains of quality of life questionaries' in cases of rehabilitation with implant-supported overdentures [37].

The perspective of further study could be aimed at investigation of quality of life changes among edentulous patients through the ongoing monitoring with periodical check-ups while using surface electromyography as a routine diagnostic tool during every visit. Such an approach will support quantitative normalization and metric interpretation of quality of life parameters among patients with various dental functional alterations through the customization of treatment algorithm. Furthermore, in our future study, we will also use the value of minimal important difference parameter [1], which helps evaluate such minimal changes within the score range, basically providing factual benefit and arguments the better effect of one patients' management method another.

Conclusion

The use of surface electromyography as an instrument for masticatory muscles control and their symmetrical balancing by occlusal correction support quicker adaptation of patients to the provided implant-supported overdentures with the attachments of different designs but not principally affects it. Optimization of the adaptational period to the placed overdentures by the masticatory muscles balancing was related to the improvements within oral satisfaction scale parameters during short-term monitoring of one month. Nevertheless, long-term outcomes had not demonstrated any statistically significant differences regarding maintenance and quality of life parameters among patients rehabilitated by overdentures on ball- and Locator-attachments irrespectively of surface electromyography method usage with the muscle balancing objective at the time of the dentures try-in. On the other hand, significant improvements of quality of life measured with OHIP-EDENT were noted for both types of attachments compared to the pre-treatment situation independently of additionally provided surface electromyography-based alignment. Therefore, it may be

hypothesized that periodical control of masticatory muscle balance during follow-up visits with the use of surface electromyography method potentially could have a positive impact on appropriate quality of life level assurance, but such effect should be studied in a detailed manner during future researches, while also considering peculiarities of differently designed occlusal schemes.

Authors' Contributions

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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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