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MUSCLE EFFICIENCY OF PATIENTS WEARING DIFFERENT TYPES OF MANDIBULAR IMPLANT-SUPPORTED OVERDENTURES AND CONVENTIONAL: COMPLETE DENTURES (AN IN-VIVO STUDY)

Kaify Wali Ahmed[1]*, Rizgar Mohammed Ameen Hasan[1]
[1]Department of Prosthodontics, College of Dentistry, Hawler Medical University, Erbil, Iraq.

Correspondence: Kaify Wali Ahmed, Department of Prosthodontics, College of Dentistry, Hawler Medical University, Erbil, Iraq. kaife.wali@hmu.edu.krd

Abstract

Background and objectives: Conventional complete denture (CCD) has been used for many years, and in spite of the benefits it offers, it possesses many drawbacks. In recent years, implant-supported overdentures (ISOD) have been introduced into the dentistry field with various benefits compared to conventional complete dentures. The aim of the current study was to assess the impact of ISOD and CCD on muscle efficiency with soft and hard foods.

Methods: Forty patients (25 males and 15 females) were recruited. The volunteers had a completely edentulous maxilla and mandible. They were divided into five groups, as follows: 8 patients were divided for conventional complete dentures: 8 patients with two-pieces implant ball and socket overdenture; 8 patients with two-pieces implant locator overdenture; 8 patients with a single-piece implant ball and socket overdenture; and 8 patients with an innovative implant overdenture by locator system. The construction of the lower (CCD and ISOD) and upper complete dentures was carried out. Then, the electromyography was practiced to assess muscle efficiency by testing hard foods (carrot) and soft foods (banana) in four consecutive visits.

Results: The muscle efficiency test revealed significant differences between the four visits. These tests demonstrated a significant difference across the five types, although they are almost identical. However, it is evident that there are enhancements in muscle efficiency in ISODs, especially in the temporalis and masseter muscles.

Conclusions: The study findings indicate that the use of implant-supported over-dentures with the locator attachment system resulted in improved muscle efficiency while consuming hard food such as carrots, particularly during the third and fourth visits. These dentures offered superior stability compared to conventional complete dentures (CCD).

Keywords: surface electromyography (sEMG), muscle efficiency, conventional complete denture CCD, implant-supported overdenture ISOD.

Introduction:

The management of edentulous individuals with a conventional complete removable denture (CCD) is a prevalent clinical practice. However, these patients may encounter issues including as discomfort during mastication, diminished masticatory function, and inadequate stability and retention of the mandibular conventional denture. [1] Edentulous is one of the main issues for elderly patients and causes many problems, including less chewing efficiency, less retention of conventional dentures, speech problems, and nutritional problems.

CCD is the first edentulous alternative rehabilitation program consisting of many prosthetic teeth positioned on a base. However, there are further disadvantages, like complete dissatisfaction and variable chewing abilities. Scientists have endeavored to address this problem by employing a range of traditional and innovative approaches. These include the utilize of implant-supported overdentures, which utilize different attachment techniques such as ball and socket, as well as implant locator systems that utilize single-piece and two-piece dental implants. [2] The utilize of dental implants and the subsequent use of implant-supported lower overdentures have enhanced the quality of life for patients who have lost all of their teeth. [3] Implant-supported overdentures (ISODs) have quickly become a viable treatment option for fully edentulous patients. Research had shown that implant-supported overdentures offer enhanced retention and stability in comparison to traditional dentures. [4] Implant-retained overdentures can potentially decrease the loss of bone in the jaw and enhance various aspects of oral function, including chewing ability, muscle efficiency, nutritional condition, verbal communication, and patient self-assurance. Implant-supported overdentures employ several attachment techniques to secure the prostheses to the implants in the patient's oral cavity. These attachment techniques include bar, ball, socket, magnets, and locators.

The evaluation of masticatory function has been thoroughly conducted utilizing several methodologies designed taking either therapeutic or fundamental physiological aims in consideration. The physiological issues need the use of modern methods like bite force measurement, electromyography, and kinematics utilizing magnetic fields or infrared video recordings. Most of these procedures need expensive equipment and personnel with specific skills, making them difficult to use in clinical trials or practice. Several authors have suggested various techniques, such as electromyography, and there is widespread debate on the trustworthiness of specific procedures. Clinicians who are interested in studying the effects of dental diseases or oral therapy want a reliable and sensitive test for measuring mastication. This test should be suitable for routine usage. Assessing one or two indicators of mastication, such as the frequency of cycles or the duration of chewing, either in real-time during a meal or through the analysis of video recordings of a meal sequence, seems to be a feasible and effective therapeutic approach. [5] Electromyography (EMG) is a method used to study and analyze myoelectric signals utilizing sophisticated recording techniques. Myoelectric signals are generated by alterations in the physiological condition of muscle fiber membranes. Kinesiological electromyography primarily involves analyzing the neurological stimulation of muscles during postural activities, physiological motions, occupational conditions, therapeutic interventions, and training programs. In addition to fundamental biomechanical and physiological discoveries, kinesiological electromyography (EMG) is acknowledged as a valuable instrument for assessing practical research, rehabilitation/physiotherapy, sports training, and the interaction between the human body and industrial goods.[6] Due to the growing popularity of ISOD in recent years and its advantageous retention properties, CCD has remained the preferred option for the majority of dentists. This study examined the enhanced effectiveness of the masseter and temporalis muscles when consuming soft food versus hard food. Additionally, it compared several forms of ISOD (interocclusal splint of varying thicknesses) with CCD (centric relation) at different time intervals.[7] The electromyography measurement of a muscle's electrical output is directly related to the amount of energy expended during contractions.[8] Therefore, the overall electromyographic (EMG) activity of the primary masticatory muscles over a complete chewing sequence can be used to approximate the total energy expended during the process of chewing. Different studies have documented enhanced the masticatory functions in individuals with mandibular overdentures with the implementation of four implants connected with bar attachments.[9]Nevertheless, the chewing abilities of unsplinted implants that support overdentures were not assessed. In a recent study conducted by[10], the researchers investigated the impact of mini-implant-retained overdentures on individuals who were wearing dentures in the upper jaw. The study indicated that these overdentures significantly enhanced the patients' quality of life, satisfaction levels, and capacity to chew. The impact of this treatment method on the function of the muscles included in chewing has not been studied yet. Therefore, the purpose of this study aimed to assess the impact of mini-implant-supported lower over-dentures on the (EMG) masseter muscle activity during the mastication of hard and soft meals.

Following to the clinical examination, surface electromyography (sEMG) was conducted on the masseter and temporalis muscles with an electromyography equipment. (Pro Comp Infiniti Encoder SA7500, Montreal, Quebec, Canada). There were a total of three surface leads: two electrodes were utilized as recording electrodes, while an additional electrode functioned as a reference electrode for each side. The electrodes were utilized to measure muscle activity specifically for the temporalis and masseter muscles. A line had been drawn from the superior auricle to the canthus of the eye. in order to identify the location of the temporalis muscle. The electrode was subsequently placed above this line by tactually identifying the point of muscle contraction. The electrode was placed on the masseter muscle, specifically in front of and above the jaw angle, following the palpation of the mandible's angle.

Masticatory function efficiency refers to the capacity of an individual's masticatory system to break down various meal kinds into small particles that can be easily ingested. This task is a complex process influenced by various factors, such as the mandibular movement, the alignment of the teeth, the forces exerted while biting or chewing, the activity of saliva, and the function of the tongue. Edentulous patients experience a decrease in masticatory efficiency due to the replacement of their dental arches with artificial teeth. Patients who wear complete dentures often struggle to chew hard foods, resulting in limited chewing efficiency. [11] The masticatory function of a patient can be objectively evaluated by measuring muscle activity with surface electromyography (EMG). Electromyography (EMG) serves as an effective measure for assessing muscle dysfunction. Surface electromyography (EMG) is a noninvasive technique that use surface electrodes placed on the skin overlying the muscle to assess muscle activity. It is utilized to ascertain the duration of muscular contractions and to examine the muscle's activity during stomatognathic system activities. [12] The study conducted by [13] examined the impact of implant-supported mandibular overdentures on the electromyographic activity of the masseter muscle during the consumption of hard food (carrot) and soft food (gum).[13] The findings indicated that mini-implant-supported overdentures increased masseter muscle activation and decreased the chewing cycle time for both hard and soft meals, relative to traditional complete dentures.

Abdelhamid *et al.*[14], conducted a study to examine the impact of two distinct occlusal systems on the muscle activation in implant-supported lower overdentures using electromyography. [14] The muscular efficiency of the temporalis and masseter muscles was assessed during denture insertion, as well as one and two months following to using each type of prosthesis (CCD, ISOD, and Locator attachment system). The patients were positioned in an erect posture. The dermis covering the muscular tissue was sterilized using alcohol. The researchers positioned surface electrodes on the masseter muscle's bellies on the patient's favorite chewing side. [15] The active electrodes were inserted parallel to the mid-longitudinal fibers of the muscle, while the reference electrode was positioned on the patient's forehead. The positioning of the surface electrodes for the temporalis muscle during clenching was determined by extending an imaginary horizontal line extending from the lateral corner of the eye to the superior border of the external auditory canal. The electrodes were positioned approximately 3 cm above the midpoint of the horizontal line. The electrodes were linked to the measuring apparatus. (MEB-9400K, Nihon Kohden). Prior to being affixed with adhesive bandage tape applied to the skin in order to adhere it to the skin, the electrode was covered with an electro-conductive gel called Elefix, manufactured by Nihon Kohden.

Each participant was directed to bite down on their teeth without consuming any food, as well as on the sample (measuring 3 × 1 x 1 cm) of solid (carrot) and soft (banana) meals until the items were prepared for ingestion. EMG signal analysis was conducted using software programs provided by the EMG equipment. The EMG signals underwent amplification and filtering within a frequency range of 20 Hz to 10 KHz. They were then subjected to full-wave rectification and electronic smoothing. The evaluation involved calculating the average of four peaks of electromyographic activity of the muscles. The operator performed the test five times for each food type, including a minimum rest interval of 2 minutes between repetitions. Mean values were analyzed using one-way ANOVA to compare the three types of dentures: regular dentures, implant overdentures, and Locator attachment system. Measuring ANOVA done repeatedly was employed to assess the impact of time (at denture placement, one month later, and two months later) and clenching circumstances (without food, with hard food, and with soft food) within each group. All statistical analyses were conducted with a significance level of 5%. A separate study discovered that among a cohort of young individuals who lack teeth, implant-supported overdentures demonstrate a functional benefit over implant-supported overdentures, irrespective of the attachment mechanism employed. Enhancing masticatory efficiency can increase patient satisfaction and expand the range of dietary choices available

Multiple studies have documented enhancements in the electromyography (EMG) activity of the muscles involved in chewing and increased efficiency in chewing when using a total implant-supported prosthesis, as opposed to a traditional complete denture. Furthermore, several research had examined the impact of different types of overdenture anchors on electromyography (EMG) activity and chewing efficiency. In a research undertaken by [15], it was discovered that using four implants placed in the canine and first molar regions, and connecting them with bar attachments, resulted in enhanced electromyography (EMG) activity and masticatory efficiency compared to using two-implant overdentures.

[16] The study compared the impact of two distinct occlusal schemes on muscle efficiency by employing sEMG with soft and hard food. The findings indicated that patients fitted with complete dentures designed using the LO scheme exhibited superior results compared to those with dentures constructed using the BBO scheme.

[17] Ten individuals were selected based on the criterion of having a totally edentulous upper arch and a lower arch classified as Kennedy class I. An upper full denture and two lower removable partial dentures (chromium-cobalt and flexible) were fabricated for each patient. Upon completion of the prosthesis, muscle efficiency was assessed using electromyography (EMG), and chewing action was evaluated by the sieve technique. Each patient underwent testing at four distinct time intervals: two days, one week, two weeks, and one month following denture placement. The study determined that the muscle efficiency increased within a month after the placement of either a flexible or chromium partial denture. Flexible dentures exhibit a little superior enhancement in chewing action compared to chrome cobalt dentures. According to, [17] chrome cobalt dentures have a slight advantage over flexible dentures when it comes to chewing hard food.

The purpose of this research was to do an analysis and compare the muscular efficiency of the temporalis and masseter muscles in patients wearing CCD and ISOD for edentulous patients in different time intervals with different types of overdenture attachment systems.

Patients and Method:

In this study, a comparison was made between the masticatory efficiency for masseter and temporalis muscles following different types of mandibular ISOD and conventional complete denture CCD with two implant attachment systems: locator attachment and ball socket attachment. Forty patients were selected with completely edentulous patients. The selected patients were aged from 45 to 65 years old, and 15 of them were females and 25 were males. The patients were selected based on the special inclusion criteria of a normal skeletal Class I relationship, no severe undercuts, no history of systemic diseases, no previous trauma, and no bone grafting required. [16] The exclusion criteria encompassed individuals with systemic diseases and xerostomia, people experiencing psychiatric issues, parafunctional habits, and bony undercuts in the edentulous region. [17]

Conventional complete dentures were fabricated for eight patients, thirty-two ISODs were fabricated for four implant-supported overdenture groups, and the patients worn each pair of the complete dentures with the maxillary conventional CD and mandibular conventional or implant overdentures. In this study, the mandibular overdenture was supported by a two-piece' implant (ImplantSwiss), single-piece implant (MonoImplant) in Switzerland, and a newly innovative implant (NTS) in Italy.

The experimental study design was divided into five study groups. In the first group, the patients were treated with conventional mandibular dentures. In the second group, the patients utilized implant-supported dentures anchored by two typical two-piece implants with locator attachments. In the third group, the patients were worn ISOD with two conventional two-pieces implants with ball and socket attachments; in the fourth group, the patients were worn ISOD supported by two single-piece compressive implants with ball and socket attachments; and finally, in the fifth group, the patients were worn ISOD with two newly innovative implants with locator attachment systems.

The masticatory efficiency test was conducted for patients at four distinct time intervals: (I) after one week of denture insertion; (2) 1 month after denture insertion; (3) six months post-denture insertion; and (4) one year post-denture insertion. For each visit with the patient, four times the test was recorded for biting on the cotton roll, maximum intercuspation, chewing of bananas, and chewing of carrots.

Muscle efficiency test:

A two-channel sEMG device (Neurostyl Ptc. Ltd. Malaysia), as shown in Figure 1, was used to measure the muscle efficiency of the temporalis and masseter muscles. The EMG device in the Prosthodontic Department of the College of Dentistry/Hawler Medical University (HMU) was used. Each patient was tested at four different time intervals, and each patient had muscular examination under three conditions: absence of food, after consuming hard food (carrot), and after consuming soft food (banana). The four muscles were assessed each time: left and right temporalis, and left and right masseter. Although analyzed each muscle with the time, maximum, average, and compare each area of the muscles and for each denture differently,[17]

Figure (1) sEMG (Neutostyle, Pte. Ltd) device.

A. Patient preparation:

Prior to performing the sEMG assessment for muscular efficiency, male patients were directed to cut their beards to improve contact stability in between the skin and electrodes, as well as to optimize the performance of high-input impedance amplifiers, while this preparation was not needed for the female patients. [18] The individual was sitting in upright with the head unsupported and relaxed, assuring alignment with the Frankfort plane. (Fig. 2) parallel to the floor. The skin of the subject was carefully cleaned with 70% alcohol disinfectant (Sanswiss, Switzerland).

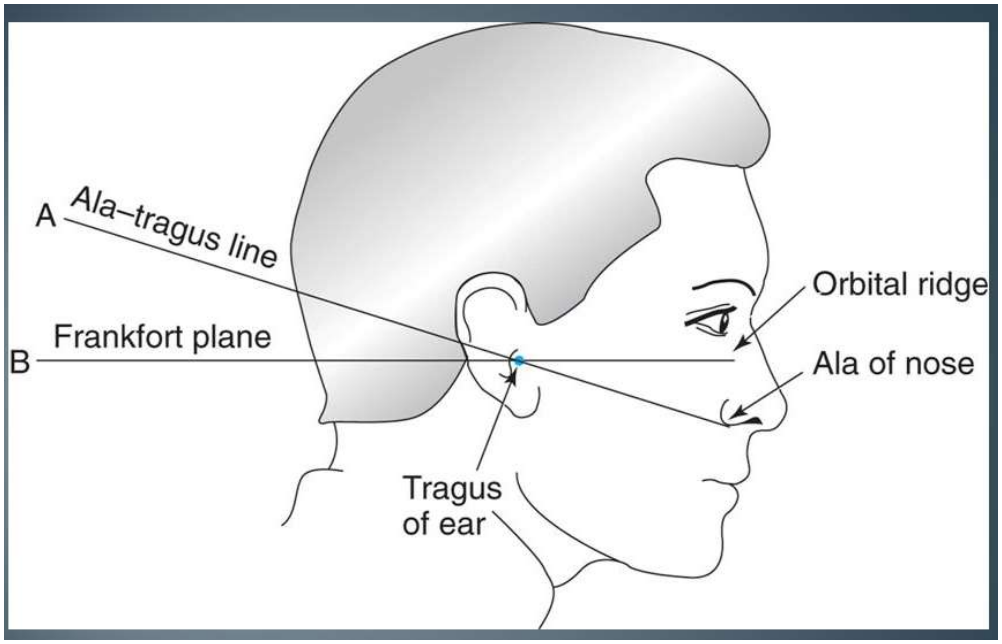

Figure (2) Frankfort plane[19]

The two recording electrodes were placed at the selected target muscle, while the reference electrode was placed on the sternocleidomastoid muscle located in the neck. The electrodes were placed on the skin and connected to the surface electromyography (sEMG) device via the attached electrode cable, while the sEMG device was connected to the laptop.

Preparation of Chewing Food:

Cotton rolls, soft food (banana) and hard food (carrot) were used during the muscle efficiency test by the patients to masticate or chew on. [21] The medium-sized cotton roll was used to bite into the mouth, and the patients could clench on it and then take the data. After that, remove the cotton rolls and ask the patient to clench on maximum intercuspation, and then read it. The muscle efficiency was tested with hard and soft food. The hard food (carrot) was sliced into pieces of 2 mm thickness, which were measured by a digital Vernier, and the soft food (banana) was sliced into small pieces, as shown in Fig. 3, so the patient could chew and record the muscle efficiency.

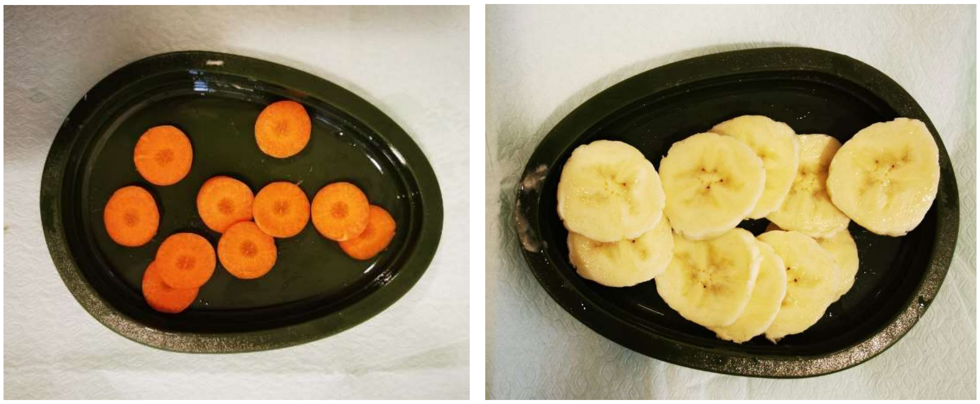

Figure (3) Hard food (sliced carrot) and Soft food (banana)

B. **Electrode placement:**

The system consists of three electrodes. For each muscle on both the right and left sides, two recording electrodes and one reference electrode were used for assessing muscle efficiency. This study measured the muscle efficiency of the masseter and temporalis muscles (Figure 4). The electrodes were positioned in an antero-superior location to the angle of the mandible, specifically targeting the masseter muscle. For the temporalis muscle, a line was traced from the superior ear line to the canthus of the eye, and the electrodes were placed above this line. [20]

Figure (4) Placement of the electrodes on the patient for the muscle efficiency test

(Masseter Muscle).

To locate the temporalis muscle, the researchers traced a line from the superior ear to the canthus of the eye. Following that, the electrodes were placed above this line by tactile perception of the location of muscle contraction, as seen in Figure 5.[20] Two recording electrode was placed on each of the specified muscle locations, while the reference electrode was placed on the sternocleidomastoid muscle located in the neck. via the electrode cable, the electrodes are positioned on the skin and attached to the sEMG device. The sEMG device is then connected to the laptop via a USB cable.

Figure (5) Electrodes placed on the Temporalis muscle.

C. **PC Software:**

A software (Bio-feedback Electrotherapy System pelvic floor version) version 2.1, which was provided with an sEMG device, was installed on the PC. To begin, enter the patient's information on the left side of the programme interface. Next, click on the sEMG evaluation button located in the upper middle section of the software, as shown in Figure 6.

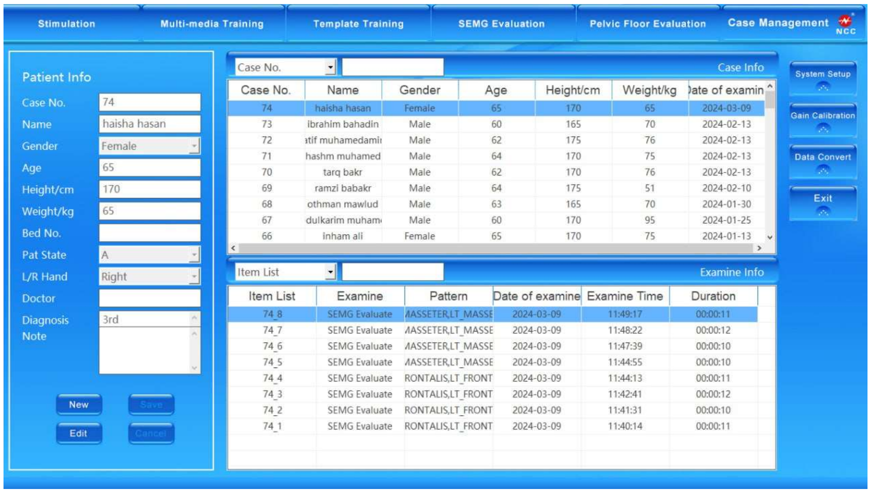

figure (6) Software of EMG (feedback electrotherapy system).

A new window was opened; in this window, the type of muscle is selected that is to be analyzed for muscle efficiency. Then the collect button on the lower right corner of the screen was clicked, and the sEMG device started to collect the muscle efficiency data (Fig. 7).

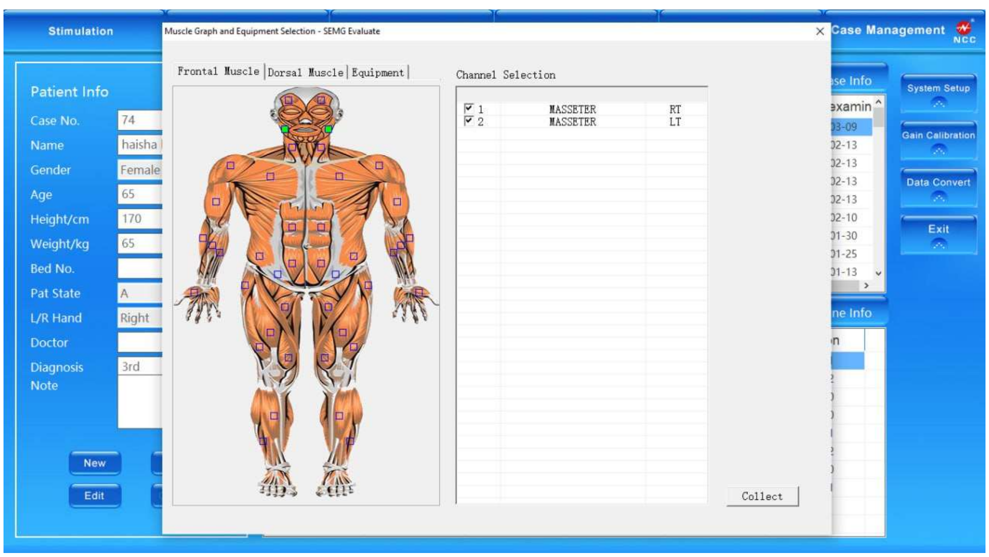

figure (7). muscle selection windows.

D. **Recording the muscular muscle Efficiency:**

Maximum and average muscle efficiency of masseter muscles (bilaterally) and temporalis muscles (bilaterally) were recorded (Fig. 8). During the first visit, after the insertion of the dentures, the muscle efficiency of both the temporalis and masseter muscles was measured by asking the patient to clench on the cotton rolls. and then the dentures were inserted, and the muscle efficiency was recorded four times: (1) during clenching on the cotton roll, (2) during maximum clenching on denture teeth, (3) while eating soft foods, and (3) while eating hard foods.

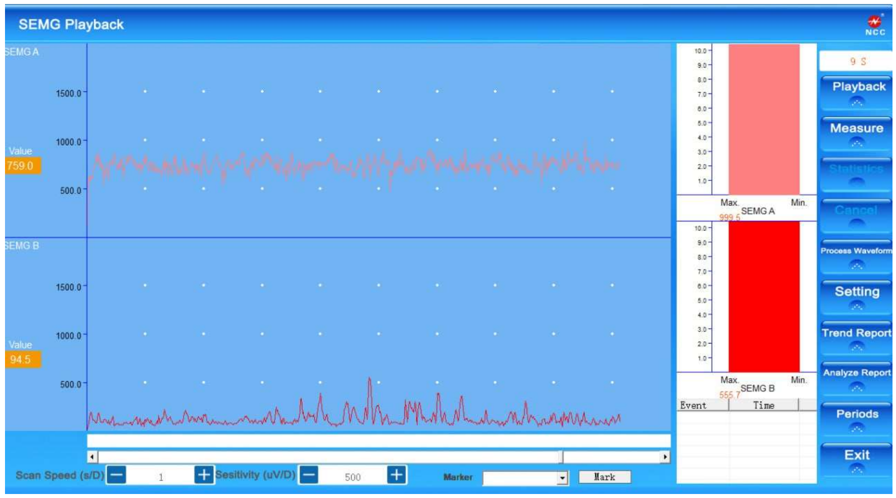

Figure (8) Recording the muscle efficiency.

This process was repeated for all patients in four different time intervals: (1) after one week of denture insertion; (2) one month after denture insertion; (3) six months post-denture implantation; and (4) one year after denture insertion. The above-mentioned procedures were performed for each patient and recorded the maximum and average muscle efficiency data as shown in figure 9.

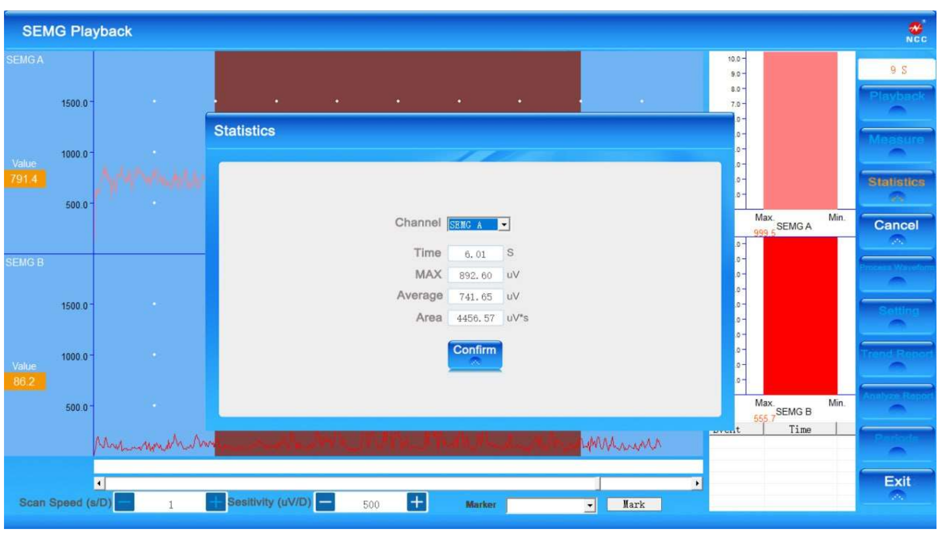

Figure (9) maximum and average muscle efficiency data.

Statistical analysis:

The acquired data were statistically analyzed utilizing SPSS (Statistical Package for the Social Sciences). One-way ANOVA was employed to identify the differences among the variables. The

Duncan test was employed to compare the mean values. The significant level was determined at ($P<0.05$).

Results

All patients completed the analysis without any dropouts, and during the follow-up period, the maintenance of the prosthesis and attachment was performed. The five groups concerning the activation of the Temporalis and Masseter muscles over various follow-up periods and muscle efficiency situations were compared. There was mostly significant difference in Temporalis and Masseter muscle activity between visits for both conventional complete dentures and implant supported overdentures at all visits of muscle efficiency testing during maximum intercuspation and eating soft and hard food after one week of denture insertion, 1 month, 6 months and one year.

Throughout all observation periods, implant-retained overdentures exhibited superior effectiveness of the Masseter and Temporalis muscles compared to traditional dentures.

The results of muscle efficiency of the right and left temporalis muscle with sEMG during the four visits of conventional complete denture and different types of ISOD are shown in Table 1.

Table (1) Comparison of five groups concerning the activity of the right and left Temporalis muscles. (microvolts) at different follow up periods.

Implant types	**Treatments**	**Factors**	Visits				P Value
			First	Second	Third	Fourth	
Two piece two ball	*Rt Temporalis	Max intercaspation	$175\pm59^{cd§}$	425 ± 305^{bc}	559 ± 47^{b}	995 ± 161^{a}	.003
		Eating soft foods (Banana)	315 ± 195^{d}	855 ± 477^{ab}	468 ± 56^{bc}	1601 ± 922^{a}	.068
		Eating hard foods (Carrot)	166 ± 29^{d}	646 ± 27^{a}	588 ± 115^{ab}	563 ± 51^{abc}	.000
	†Lt Temporalis	Max intercaspation	1061 ± 187^{a}	491 ± 331^{b}	463 ± 80.2^{b}	463 ± 80.2^{b}	.011
		Eating soft foods (Banana)	992 ± 428^{a}	408 ± 297^{b}	360 ± 86^{b}	473 ± 97^{b}	.067
		Eating hard foods (Carrot)	337 ± 267^{d}	453 ± 190^{c}	484 ± 91^{b}	1121 ± 544^{a}	.064

CD	Rt Temporalis	Max intercaspation	138 ± 55^{cd}	239 ± 226^{c}	1227 ± 769^{ab}	582 ± 431^{a}	.070
		Eating soft foods (Banana)	150 ± 70^{bcd}	169 ± 105^{bc}	683 ± 67^{a}	336 ± 313^{b}	.018
		Eating hard foods (Carrot)	165 ± 54^{bcd}	271 ± 62^{b}	837 ± 19^{a}	244 ± 136^{bc}	.000
	Lt Temporalis	Max intercaspation	135 ± 80^{d}	886 ± 278^{c}	1305 ± 395^{ab}	214 ± 88^{a}	.001
		Eating soft foods (Banana)	105 ± 11^{bcd}	231 ± 85^{bc}	1916 ± 536^{a}	303 ± 194^{b}	.000
		Eating hard foods (Carrot)	243 ± 63^{bc}	231 ± 180^{bcd}	647 ± 677^{a}	250 ± 117^{b}	.003
Two piece locator	Rt Temporalis	Max intercaspation	56 ± 58^{c}	463 ± 293^{c}	1036 ± 76^{ab}	1094 ± 197	.009
		Eating soft foods (Banana)	130 ± 18^{cd}	301 ± 284^{bc}	905 ± 132^{ab}	1347 ± 617^{a}	.000
		Eating hard foods (Carrot)	165 ± 18^{d}	733 ± 100^{c}	1248 ± 308^{ab}	1441 ± 285^{a}	.000
	Lt Temporalis	Max intercaspation	65 ± 37^{d}	477 ± 319^{c}	997 ± 74^{ab}	1086 ± 157^{a}	.000
		Eating soft foods (Banana)	337 ± 187^{d}	324 ± 349^{c}	1275 ± 313^{ab}	1341 ± 602^{a}	.018
		Eating hard foods (Carrot)	241 ± 28^{d}	562 ± 249^{c}	1273 ± 401^{ab}	1563 ± 328^{a}	.002
single piece ball	Rt Temporalis	Max intercaspation	202 ± 179^{a}	266 ± 220^{a}	204 ± 90^{a}	486 ± 255^{a}	.309
		Eating soft foods (Banana)	121 ± 6^{cd}	149 ± 22^{c}	203 ± 91^{ab}	456 ± 266^{a}	.069
		Eating hard foods (Carrot)	168 ± 9^{bc}	18 ± 6.8^{cd}	552 ± 207^{a}	509 ± 165^{ab}	.012

	Lt Temporalis	Max intercaspation	261±64^{a}	128±51^{b}	130±12^{b}	150±42^{b}	.024
		Eating soft foods (Banana)	153±24^{a}	123±59^{a}	183±162^{a}	243±151^{a}	.642
		Eating hard foods (Carrot)	160±61^{cd}	263±30^{bc}	403±211^{a}	318±79^{ab}	.161
Innovate implant	Rt Temporalis	Max intercaspation	187±59^{a}	289±297^{a}	161±58^{a}	319±325^{a}	.790
		Eating soft foods (Banana)	270±229^{a}	102±36^{a}	319±302^{a}	290±133^{a}	.577
		Eating hard foods (Carrot)	141±6^{a}	111±28^{a}	361±263^{a}	239±38^{a}	.174
	Lt Temporalis	Max intercaspation	95±8^{cd}	309±305^{bc}	1257±181^{a}	929±621^{ab}	.014
		Eating soft foods (Banana)	134±51^{b}	141±55^{b}	1821±339^{a}	182±87^{b}	.000
		Eating hard foods (Carrot)	211±88^{b}	205±41^{b}	656±65^{a}	506±348^{b}	.004

*Rt=Right,† Lt= Left,‡ CD= Complete Denture.

§Superscript letter with in the same row means different significant level. Significant level <0.05

In two pieces of ball and socket overdentures, the right temporalis muscle of maximum muscle efficiency was gradually increased in maximum intercuspation, and the differences were statistically significant in all the four visits. However, there were no significant alterations observed in the left temporalis muscle during maximum intercuspation, and there was a statistically significant difference between the two conditions.

The right temporalis muscle's maximum muscle efficiency during eating soft food (banana) increased in the second and fourth visits, and the differences in all four visits were statistically non-significant, while the left temporalis muscle's efficiency in the same condition decreased in the second and third visits with exhibiting no statistically significant differences among them.

On the other hand, the right temporalis muscle of maximum muscle efficiency in eating hard food (carrot) was more increased in the second visit and slightly decreased in the third and fourth visits, and the difference was statistically significant in all four visits and the P value was 0.000, while in the left temporalis it was gradually increased and there were more changes in the fourth visit, and the statistically non-significant differences were 0.00.

While in conventional complete dentures, the right temporalis muscle of maximum muscle efficiency was much more increased in the third visit with maximum intercuspation and statistically non-significant in all four visits, whereas in the left temporalis there were more changes in the second and third visits while decreasing in the fourth visit, and the differences were statistically significant between them.

The right temporalis muscle's maximum muscle efficiency during eating soft food (banana) was at a higher level in the third visit and decreased in the fourth visit, with statistically significant differences between the four visits, while the left temporalis muscle's efficiency in the same condition was at its highest level in the fourth visit, with statistically significant differences between them.

On the other hand, the right temporalis muscle of maximum muscle efficiency in eating hard food (carrot) was more increased in the third visit and slightly decreased in the fourth visit, with statistical significance in four visits, while the left temporalis muscle was gradually decreased in the second and third visits and increased in the fourth visit, with statistical significance differences in four visits.

Regarding the two pieces' implant and locator attachment overdentures of the right and left temporalis muscles of maximum muscle efficiency were much more increased in the third and fourth visits, with maximum intercuspation and statistical significance different in the four visits.

The right and left temporalis muscles of maximum muscle efficiency during eating of soft food (banana) were at higher levels in the third and fourth visits, and statistical significance was different in the four visits.

Then the right and left temporalis muscles of maximum muscle efficiency in eating hard food (carrot) were regularly increased in all the visits, and statistical significance was different between them.

In a single-piece implant with a ball and socket overdenture, the right temporalis muscle's maximum muscle efficiency was increased in the second and fourth visits with maximum intercuspation and statistically non-significant in the four visits, whereas in the left temporalis muscle in the same condition, there were less changes in the second, third, and fourth visits and statistical significance was different between them.

Right and left temporalis muscle of maximum muscle efficiency during eating of soft food (banana) were regularly increased in all visits and statistically non-significantly different in the four visits.

On the other hand, the right temporalis muscle of maximum muscle efficiency in eating hard food (carrot) had the highest level in the third and fourth visits and statistically significant differences in the four visits, while the left temporalis muscle gradually increased in the second and third visits and decreased in the fourth visit. Also, the differences in all four visits were statistically non-significant.

Regarding the innovative implant with locator attachments overdentures, the right temporalis muscle's maximum muscle efficiency increased in the second and fourth visits, with maximum intercuspation and statistically non-significant differences in the four visits, whereas the left temporalis muscle had the highest level in the third visit and statistically significant differences between them.

The right temporalis muscle of maximum muscle efficiency during eating of soft food (banana) had the highest level in the first and third visits and was statistically non-significantly different in the four visits, while the left temporalis muscle had the highest level in the third visit and was statistically different between them.

On the other hand, the right temporalis muscle of maximum muscle efficiency in eating hard food (carrot) had the highest level in the third visit, and the differences in all four visits were statistically non-significant, while the left temporalis muscle increased more in the third visit and decreased in the fourth visit, and statistical significance was different in the four visits.

The comparison of the right and left temporalis muscles during eating the hard food (carrots) in between all visits are shown in figures 10 and 11.

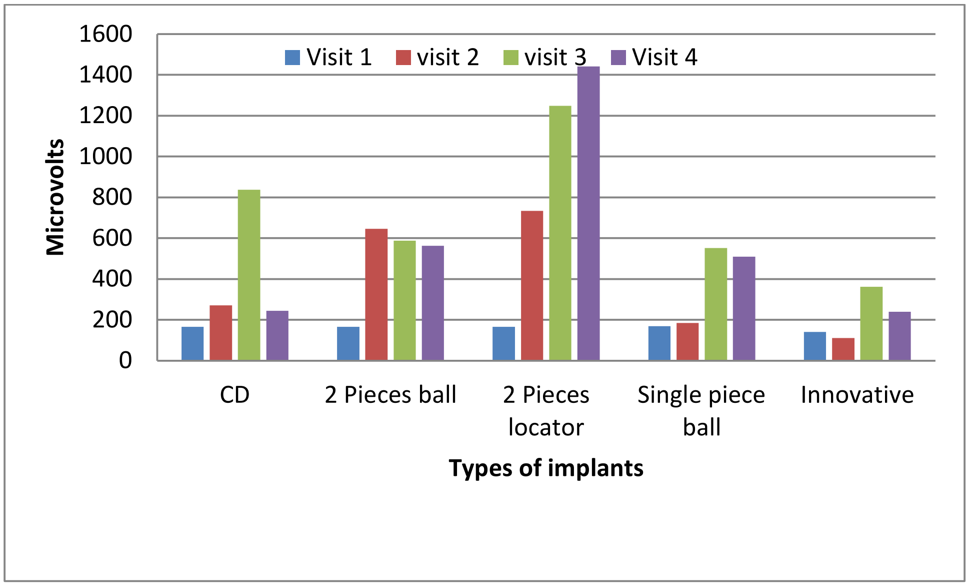

Figure (10) Right temporalis muscle eating hard food carrot

*CD= Complete Denture

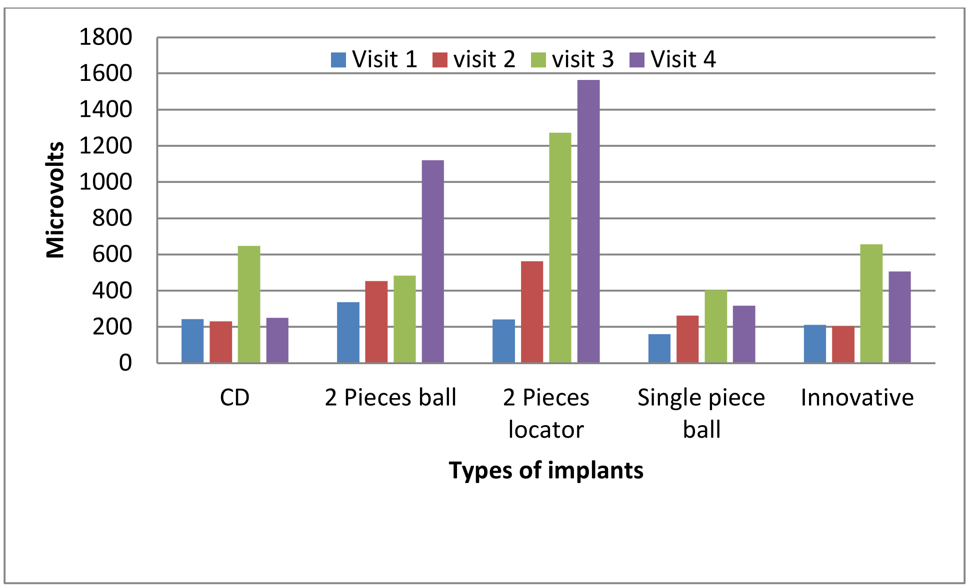

Figure (11) Left temporalis muscle eating hard food carrot

*CD= Complete Denture

Table (2) Comparison of five groups concerning the activity of the right and left Masseter (microvolts) at different follow up periods.

Implant types	**Treatments**	**Factors**	Visits				P value
			First	Second	Third	Fourth	
single piece ball	Rt Masseter	Max intercaspation	665±386^{ab}	255±286^{bc}	970±115^{a}	161±8^{d}	.013
		Eating soft foods (Banana)	309±132d	441±153bc	1080±132a	825±434ab	.019
		Eating hard foods (Carrot)	95±3d	732±217abc	883±172a	668±389ab	.017
	Lt Masseter	Max intercaspation	442±399^{d}	525±301^{c}	1064±70^{ab}	1340±483^{a}	.038
		Eating soft foods (Banana)	202±133^{d}	383±248^{c}	1299±61^{ab}	1406±237^{a}	.000
		Eating hard foods (Carrot)	186±170^{cd}	480±343^{c}	1332±60^{a}	1261±75^{ab}	.000
Two piece two ball	Rt Masseter	Max intercaspation	921±171^{a}	125±355^{c}	895±146^{ab}	286±174^{cd}	.005
		Eating soft foods (Banana)	803±116^{abc}	1038±735^{ab}	1614±366^{a}	314±37^{d}	.029
		Eating hard foods (Carrot)	653±523^{a}	1077±653 ^{a}	976±432 ^{a}	317±39^{a}	.265
	Lt Masseter	Max intercaspation	210±73^{c}	1472±568^{a}	1089±628^{ab}	189±5^{cd}	.013
		Eating soft foods (Banana)	259±105^{d}	1173±223^{abc}	1266±177^{ab}	1279±368^{a}	.002
		Eating hard foods (Carrot)	265±106^{c}	1459±361^{a}	689±818^{ab}	238±27^{cd}	.034
Two piece locator	Rt	Max intercaspation	104±10^{d}	704±179b^{c}	892±41^{ab}	1106±302^{a}	.001

	Masseter	Eating soft foods (Banana)	121 ± 72^{cd}	460 ± 221^{bc}	1117 ± 183^{ab}	1360 ± 701^{a}	.014
		Eating hard foods (Carrot)	382 ± 217^{d}	527 ± 112^{c}	1220 ± 264^{a}	1036 ± 204^{ab}	.003
	Lt Masseter	Max intercaspation	45 ± 23^{d}	1016 ± 661^{abc}	924 ± 56^{ab}	1138 ± 272^{a}	.021
		Eating soft foods (Banana)	100 ± 41^{d}	479 ± 287^{c}	1144 ± 158^{ab}	1000 ± 35^{a}	.000
		Eating hard foods (Carrot)	300 ± 217^{d}	435 ± 197^{c}	1348 ± 332^{a}	1081 ± 144^{ab}	.002
CD	Rt Masseter	Max intercaspation	166 ± 76^{a}	126 ± 69^{a}	447 ± 347^{a}	145 ± 71^{a}	.190
		Eating soft foods (Banana)	350 ± 200^{a}	250 ± 119^{a}	172 ± 57^{a}	264 ± 103^{a}	.467
		Eating hard foods (Carrot)	231 ± 58^{a}	256 ± 38^{a}	267 ± 37^{a}	267 ± 49^{a}	.757
	Lt Masseter	Max intercaspation	232 ± 171^{a}	185 ± 100^{a}	191 ± 104^{a}	192 ± 93^{a}	.960
		Eating soft foods (Banana)	312 ± 126^{bc}	530 ± 66^{a}	164 ± 49^{cd}	423 ± 155^{ab}	.017
		Eating hard foods (Carrot)	267 ± 49^{a}	267 ± 49^{a}	267 ± 49^{a}	267 ± 49^{a}	.079
Innovate implant	Rt Masseter	Max intercaspation	73 ± 7.234^{d}	393 ± 247^{bc}	925 ± 132^{ab}	967 ± 697^{a}	.053
		Eating soft foods (Banana)	212 ± 65.501^{c}	151 ± 108^{cd}	1449 ± 709^{a}	1014 ± 437^{ab}	.014
		Eating hard foods (Carrot)	303 ± 86^{cd}	196 ± 93^{c}	1270 ± 423^{a}	835 ± 599^{ab}	.026
	Lt	Max intercaspation	86 ± 14^{cd}	180 ± 14^{c}	1509 ± 751^{a}	1237 ± 220^{ab}	.004

	Masseter	Eating soft foods (Banana)	132±28[cd]	190±20[c]	1557±421[a]	1105±275[ab]	.000
		Eating hard foods (Carrot)	187±65[cd]	190±73[c]	1740±54[a]	1402±438[ab]	.000

*Rt=Right,† Lt= Left,‡ CD= Complete Denture.

§Superscript letter with in the same row means different significant level. Significant level <0.05

Masseter muscle

In a single-piece implant with a ball and socket overdenture, the maximum muscle efficiency of the right masseter muscle was increased in the third visit in the maximum intercuspation, whereas the left masseter muscle was gradually increased in all visits, with statistically significant variations between the right and left masseter muscles.

The right masseter muscle of maximum muscle efficiency during eating of soft food (banana) was increased in the second and third visits and decreased in the fourth visit, while the left masseter muscle was much more increased in the third and fourth visits and statistical significance was different in all the visits.

On the other hand, the bilateral masseter muscles of maximum muscle efficiency in eating hard food (carrot) increased more in the second and third visits and slightly decreased in the fourth visit, with statistical significance between them.

In two pieces of ball and socket overdentures, the right masseter muscle of maximum muscle efficiency was much more increased in the third visit with maximum intercuspation and statistical significance in the four visits, whereas in the left masseter there were more changes in the second visit while decreasing in the fourth visit and statistical significance between them.

The right masseter muscle of maximum muscle efficiency during eating of soft food (banana) was at a higher level in the second and third visits and decreased in the fourth visit, while the left masseter muscle was at the highest level in the second and third visits. There were also statistically significant differences between them.

On the other hand, the bilateral masseter muscles of maximum muscle efficiency in eating hard food (carrot) were more increased in the second visit and slightly decreased in the third and fourth visits, and statistically, there was no significance in all visits in the right masseter, while in the left masseter there were statistically significant differences in four visits.

Regarding the two pieces' implant and locator attachment overdentures the right masseter muscle of maximum muscle efficiency, which was much more regularly increased with maximum intercuspation and statistical significance in the four visits, while in the left masseter, the highest level in the second and fourth visits also had statistical significance between them.

Right and left masseter muscle of maximum muscle efficiency during eating of soft food (banana) were gradually increased in all visits, and statistically significant differences in the four visits,

Then the right and left masseter muscles of maximum muscle efficiency in eating hard food (carrot) were regularly increased in the second and third visits and slightly decreased in the fourth visit, with statistically significant differences between them.

In conventional complete dentures, the right masseter muscle's maximum muscle efficiency was increased in the third visit with maximum intercuspation and statistically non-significant in the four visits, whereas in the left masseter there were fewer changes in the second, third, and fourth visits and also statistically no significance between them.

Right and left masseter muscle of maximum muscle efficiency during eating of soft food (banana) was more increased in the second and fourth visits, and statistically no significant differences were found in four visits on the right side, while on the left side there were statistically significant differences between them.

On the other hand, the right and left masseter muscles of maximum muscle efficiency in eating hard food (carrot) were nearly the same level in all the visits and statistically non-significant in between them.

Regarding the innovative implants with locator attachment overdentures the right masseter muscle for maximum muscle efficiency in the second, third, and fourth visits were more increased with maximum intercuspation and statistical significance in the four visits, whereas the left masseter had the highest level in the third visit and statistical significance between them.

Right and left masseter muscle of maximum muscle efficiency during eating of soft food (banana) had the highest level in the third visit and slightly decreased in the fourth visit, with statistically significant differences in the four visits.

While the right masseter muscle of maximum muscle efficiency in eating hard food (carrot) had the highest level in the third visit and slightly decreased in the fourth visit, there were statistically significant differences between them.

The comparison of the right and left Masseter muscles during eating the hard food (carrots) in the four visits are shown in figures 12 and 13.

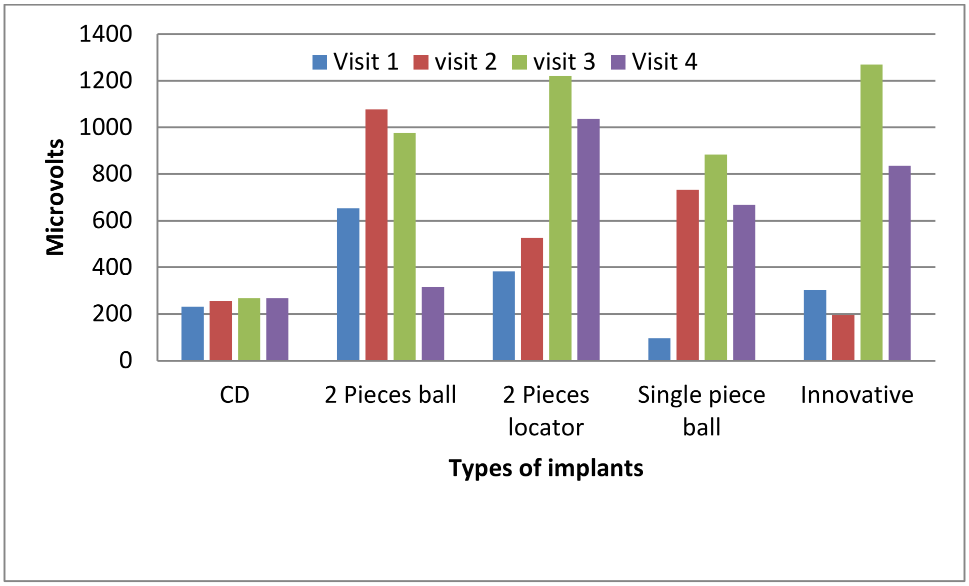

Figure (12) Right masseter muscle eating hard food carrot

*CD= Complete Denture.

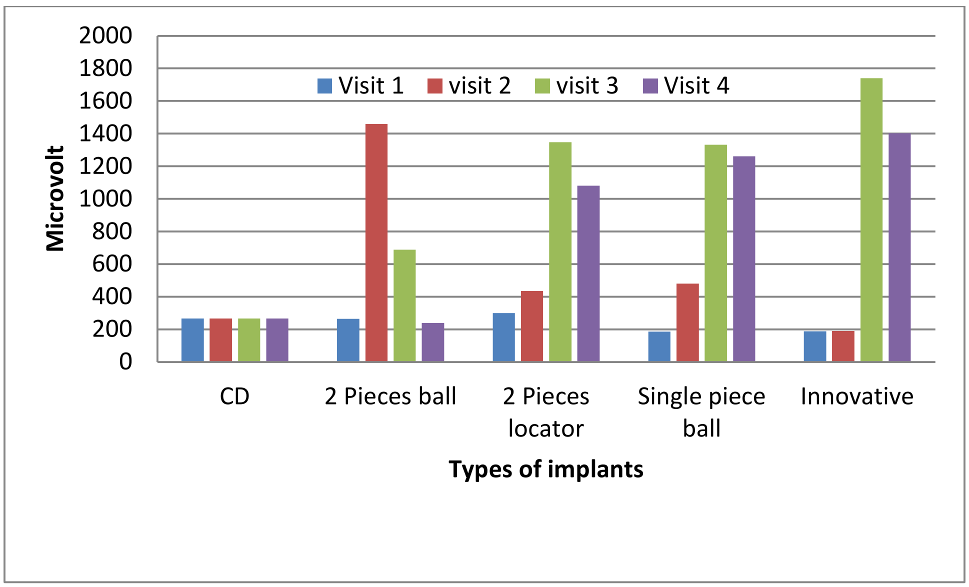

Figure (13) Left masseter muscle eating hard food carrot

*CD= Complete Denture.

DISCUSSION

The study design standardized patient-related variables that may affect surface electromyography (sEMG) activity. These factors include age, gender, muscular activity, neuromuscular control, and ridge anatomy. [21] The study's findings indicated that implant-retained and supported overdentures exhibited much greater temporalis and Masseter muscle activity compared to conventional complete dentures. This result is expected and in agreement with other prior studies. The enhanced muscle efficiency shown with ISODs in comparison to CCDs is agreed with the conclusions drawn by several authors, including. [26] This The enhanced stability and retention of overdentures might be attributed to the use of Osteointegrated implants. Masticatory function in individuals with CCD is well recognized to be compromised, resulting in reduced maximal voluntary biting forces and decreased levels of muscular effort during maximum clenching and mastication [25]

Denture instability likely hinders denture wearers from fully utilizing their jaw muscles, particularly while biting and eating on one side. [26]

Implant supported overdentures offer enhanced stability and retention for mandibular dentures, resulting in significant improvements in muscular activity and mandibular movements. This is primarily due to their connection with a more stable occlusion, leading to increased patient satisfaction and comfort. [27]

In addition, implants enhanced the functional condition of the masticatory system. They improved the control of the neuromuscular system and increased chewing efficiency by enhancing the support, stability and retention of the overdenture prosthesis to a level similar to that of those with healthy dentate persons. When implants were utilized, the muscles involved in chewing (temporalis and masseter muscles) were focused on their masticatory function, without the need for additional effort to maintain or hold the prosthesis in place. In addition, implant supported overdentures enhance chewing performance, improving patient satisfaction and reducing pain during chewing and biting force and can be improved.

The improved muscular activity that occurs as a result of increasing the retention and stability of dentures in the lower jaw is supported by several studies. [22], [28] This enhanced muscle activity is associated with an improved ability to effectively break down food while chewing. A study has revealed that the utilization of a steady overdenture has the ability to restructure the neuromuscular system, resulting in enhanced chewing function. According to [29] this not only enhances the force of the chewing movements, but also provides a lasting exercise impact and stimulates the chewing muscles more efficiently.

The enhancement of activity of the muscles of mastication can also be ascribed to the stimulation of periosteal mechanoreceptors due to bone deformation, enabling the majority of implant recipients to discern interocclusal thickness and sense stresses. This phenomenon is referred to as 'osseoperception'.

On the other hand, the utilization of implant locator attachment or ball and socket abutment contact with the denture for support and retention has been found to reduce soft tissue irritation and maintain the integrity of the alveolar bone. Although there are several benefits. It was interesting to discover that implant-supported overdentures with attachments significantly enhance sEMG activity in the temporalis and masseter muscles. This may be attributed to the prosthesis's insufficient retention and stability, resulting from the resilience of the attachments, which may shift during mastication. These movements may irritate the soft tissue and cause discomfort to the patient.

The locator attachments, as explained by, [30] consist of internal and external flanges. These flanges have two functions: they provide twofold retention and operate as guiding planes. Consequently, it provides enhanced comfort and contentment to the patient. Over time, there was a considerable rise in the activity of the temporalis and masseter muscles. This might be related to the enhanced neuromuscular adaptation to the dentures that happens gradually over time. Another study showed a similar discovery, where the authors identified a significant enhancement in masticatory function after a 6-month period of adjustment. This improvement was characterized by a considerable increase in maximum muscular contraction.

Overall, the muscle efficiency in the first visit was less active, which may be due to the patient's less accommodation with their dentures after one week, and in the second or third visits, the muscle activity increased, which may be due to the patient's accommodation with their dentures in long-term usage for one or six months and patient confidence with denture attachments. On the other hand, some patients decreased muscular efficiency in the fourth visit; this may be suspected to decrease the retention of the dentures and attachments due to the loss of rigidity of the plastic elements in the socket and locator systems.

CONCLUSION

This study concludes that implant-supported mandibular overdentures with locator attachment system enhance masseter and temporalis muscle activity more effectively than implant-retained ball and socket overdentures, and both of them provide better results than conventional complete dentures. The overdenture stability and retention afforded by the attachment systems are significantly more critical than the support of the dentures on the residual ridge type of prosthesis in enhancing muscle activity and patient satisfaction in those rehabilitated with implant overdentures.

Declaration of patient consent

The authors affirm that they have acquired the necessary patient permission papers. The patient(s) has/have provided approval for the publication of their photos and other clinical information in the journal. The patients acknowledge that their names and initials will remain unpublished, and reasonable steps will be undertaken to protect their identity; nevertheless, complete anonymity cannot be assured.

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Conflict of interest: None

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