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Evaluation of Chewing Performance in Implant Supported Fixed Prosthesis

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Abstract

Objectives: A major aim of dental treatment amongst others is the restoration of function when masticatory performance is impaired due to tooth loss. The most promising and preferred approach among treatment methods offered to totally edentulous patients is to provide the patient with implant-supported complete arch-fixed prostheses (ISCAFP).

Material and Method: Patients rehabilitated in the prosthetic dental clinic with ISCAFDP and TBCAFDP were included in the study. In addition, individuals with ND were selected as the control group. Each group consisted of 12 individuals. The sieving analysis and surface EMG method was used to evaluate the chewing performances.

Results: There was no statistically significant difference in the chewing direction and the EMG results obtained during chewing cycles between patient groups (p<0.05). However, the interaction of the sieve-patient group was found to be statistically significant (p<0.05).

Conclusion: Patients using ISCAFP can apply chewing forces without hesitation due to the limitations of the control mechanism. Therefore; for ISCAFP, the fabricating procedures should be followed to distribute the force evenly. Objective evaluations of the masticatory function and the performance of implant-supported dentures will help clinicians for the best treatment planning for their patients.

Keywords: *Chewing performance, EMG, Implant-supported fixed prostheses, Masticatory performance*

İmplant Destekli Sabit Protezlerde Çiğneme Performansının Değerlendirilmesi

Özet

Amaç: Diş tedavisinin ana amaçlarından biri, diş kaybı nedeniyle oluşan çiğneme performansının rehabilitasyonudur. Tam dişsiz hastalara sunulan tedavi yöntemleri arasında en çok tercih edilen yaklaşımlardan biri, hastaya implant destekli tam ark sabit protezlerin (ISCAFP) uygulanmasıdır.

Gereç ve Yöntemler:

Çalışmamızda protetik diş tedavisi kliniğinde ISCAFDP (implant destekli tam ark sabit proteze sahip bireyler) ve TBCAFDP (Diş destekli tam ark sabit restorasyona sahip bireyler) ile rehabilite edilen hastalar çalışmaya dahil edildi. Ayrıca kontrol grubu olarak ND'li (doğal dentisyona sahip bireyler) bireyler seçildi. Her grup 12 kişiden oluşuyordu. Çiğneme performanslarını değerlendirmek için elek yöntemi ve yüzey EMG yöntemi kullanıldı.

Bulgular: Çiğneme yönü ve çiğneme siklusları sırasında elde edilen EMG sonuçları açısından hasta grupları arasında istatistiksel olarak anlamlı fark yoktu ($p<0.05$). Bununla birlikte, elek-hasta grubunun etkileşimi istatistiksel olarak anlamlı bulundu ($p<0.05$).

Sonuç: ISCAFP kullanan hastalar, kontrol mekanizmasının kısıtlılıkları nedeniyle çiğneme kuvvetlerini çekinmeden uygulayabilirler. Dolayısıyla; ISCAFP için, kuvveti eşit olarak dağıtmamızı sağlayan üretim prosedürleri izlenmelidir. İmplant destekli sabit protezlerde çiğneme fonksiyonunun ve performansının objektif değerlendirmeleri, klinisyenlerin hastaları için en iyi tedavi planlamasını yapmasına yardımcı olacaktır.

Anahtar Kelimeler: *Çiğneme performansı, EMG, İmplant destekli sabit protezler, Kas performansı*

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Introduction

A major aim of dental treatment amongst others is the restoration of function when masticatory performance is impaired due to tooth loss. A growing body of information was built up in the literature through studies reporting advances in dental implant technology, promising success rates of implant-supported fixed dental prostheses, and high survival rates over the past years. Patients' expectations of prosthetic approaches are important, too, because patients may demand not only the restoration of the function but wish to have an improved aesthetic appearance as well. The most promising and preferred approach among treatment methods offered to totally edentulous patients is to provide the patient with implant-supported complete arch-fixed prostheses (ISCAFP).[1]

Objective and reproducible laboratory tests need to be utilized to assess the effectiveness of fixed dental prostheses in ensuring the restoration of function or a favorable masticatory performance.[2] To determine masticatory performance, researchers asked individuals to chew test materials for a specified period [3], at different levels with a different number of chewing strokes [4-7], or until the material in the mouth became ready to be swallowed.[8,9,10] Although several methods are available to evaluate masticatory performance, the use of the multiple sieve method with using electromyography (EMG) has been observed to be the most reliable and efficient. Condensation silicones were used in different ways for the measurement of masticatory performance with polymerized samples.[8,11-15] Such studies reported a varying number of cubes and different chewing methods to measure masticatory performance.

Despite the patient-reported advantages of implants in improving the quality of life, satisfaction, and mastication, objective evaluations of the masticatory function and the performance of implant-supported dentures are not well represented in the literature.[16-19] The aim of the present study was to evaluate the masticatory efficiency and the activity of masseter muscles by comparing the EMG data results and sieving method outcomes of patients with Implant-Supported Complete-Arch Fixed Prostheses (ISCAFP) to those of patients with Tooth-Borne Complete-Arch Fixed Prostheses (TBCAFP) and Natural Dentition (ND). The null hypothesis was that

there would be no differences in the masticatory performance between the groups.

Material and Method

This is a cross-sectional study conducted at Department of Prosthodontics from Süleyman Demirel University Dentistry Faculty. Required permissions for the study were approved by the Ethics Committee, number of E-72867572/050/2473. This project was conducted by BAP-3847-D1-14.

Patients, who were rehabilitated with ISCAFDP and TBCAFDP in the prosthetic dental clinic, were included in the study. Individuals with ND were included in the control group. The adaptation time was applied to the prosthetic rehabilitation group in accordance with the information reported in the literature.[20]

Eligible patients were at 40-60 years of age, had a good general health status, were diagnosed with Class I maxillomandibular relationship, had received no diagnosis of neurological disorders previously, had a parafunctional habit, and had symptoms of temporomandibular dysfunction. The patients were examined clinically and underwent intraoral and extraoral evaluations.

The patients participating in the study were evaluated in three different groups:

1. Implant-Supported Complete-Arch Fixed Prostheses (ISCAFP)
2. Tooth-Borne Complete-Arch Fixed Prosthesis (TBCAFP)
3. Natural Dentition (ND)

Preparation of chewing material

Heavy polysiloxane impression material (Zetaplus; Zhermack, Rovigo, Italy) was used as chewing material. Standard cubes measuring 1cm^3 were obtained from the impression material. A plexiglass mold was used for this purpose.

Test protocol

The masticatory performance and the chewing ability of patients were evaluated using EMG. The EMG activity of the masseter muscle was recorded using a computerized device (EMG, Micromed S.L.R Mogliano Veneto (TV) Italy) and SystemPlus software (SystemPLUS version 1.02.1054 Mogliano Veneto (TV) Italy).

The evaluation of the chewing function was performed at two stages separately for the right and left sides. Patients were given

the silicone cube test material to be chewed. The EMG electrode was placed on the left masseter muscle. The patient was then told to chew the silicone cube material 40 times using only the maxillary and mandibular left dental arches and not to swallow the materials. Patients started to chew the material after the "start" command. EMG recordings were initiated to be recorded simultaneously. No time limits were used or a metronome was not used during the chewing action. The patient's chewing strokes were visually counted by the researcher. When the 40th stroke was made, the patient was given a "done" command. Then, and the EMG recording was stopped simultaneously by clicking the "stop" command of the software. Of the EMG measurements obtained from the masseter muscle, the maximum and minimum values of the potentials and the difference (amplitude) between the maximum and minimum values were calculated and recorded. Data were uploaded to the SPSS 17.0 (SPSS Inc, USA) software for statistical analysis. Results were tabulated.

After completing the chewing test for each side, an empty plastic disposable container and a bottle of 200 ml water were given to the patient. The patient transferred the shattered test material to the plastic container. Thus, small pieces of test material trapped in retentive areas were collected and transferred to the test container. This procedure was repeated until the patient felt or the researcher observed that no particles remained in the mouth. The researcher checked the oral cavity with a dental mirror and light. During all these procedures, it was ensured that the patient did not swallow. The patient rested for at least one day, then, the same test procedure was conducted on the opposite side.

After completing the chewing test, the materials were left to settle to the bottom of the container. The water in the plastic container was removed using a micropipette. All particles were transferred to a different water-filled container repeatedly to separate the saliva from the particles. Test particles were dried and transferred onto a blank sheet of white paper. Particles sticking together were separated with a brush. The sieves were put in order so that the sieve with the largest pore (8 mesh) would be at the top and the one with the smallest one (60 mesh) would be at the bottom. The remaining sieves were arranged

in the order of decreasing pore size (16, 30, and 45 mesh, respectively). The collecting container was placed under the sieve with the smallest pore size (60 mesh). Sieves of 8, 16, 30, 45, and 60 mesh are shown in Figure 1. The chewed silicone particles were transferred to the top sieve with the largest pore. Then, the assembly of sieves was placed on the vibrator and subjected to vibration for 2 minutes. After this sieving procedure, the test particles remaining in each sieve and the bottom collecting container were weighed on a sensitive scale. The comparison of the weights of particles, which were collected on each sieve, was used to determine chewing performance for each group. The total weight of particles on each sieve was recorded for the right and left sides for each material group. Then, the measurement results were uploaded to the SPSS 17.0 (SPSS Inc, USA) software for statistical analysis.

Figure 1. Sieves were used in this study.

In the statistical analysis of the study, the data obtained from measurements were analyzed by repeated variance analysis technique in factorial order. The group factor had three levels: Implant-Supported Complete-Arch Fixed Prostheses (ISCAFP), Tooth-Borne Complete-Arch Fixed Prostheses (TBCAFP), and Natural Dentition (ND). There was a direction factor as right and left. Repeated measurements were carried out at the levels of the direction factor. As a result of variance analysis, the "Tukey" test was used as a multiple comparison method to determine statistically significant differences.

Results

The mean EMG values were higher in the ISCAFP group compared to the other two study groups (Figure 2). However, the difference was not statistically significant. The analysis of variance showed that direction * patient group interaction was not statistically significant.

No statistically significant differences were found in the obtained EMG measurements between the study groups during the chewing cycles ($p<0.05$). Although there was not a statistically significant difference, the values obtained in all EMG measurements on both the right and

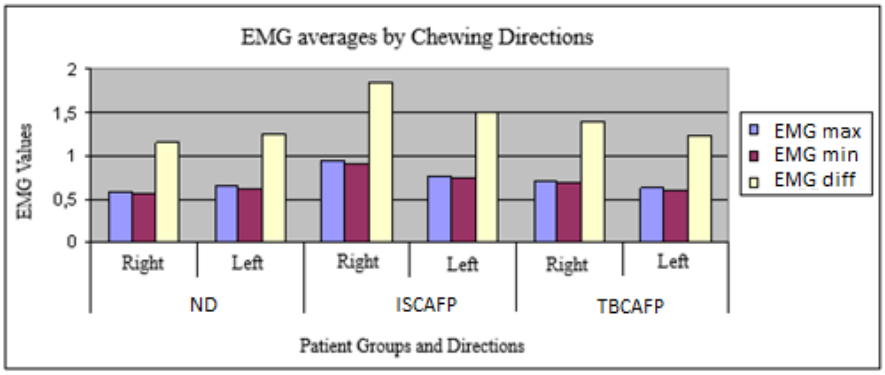

Figure 2. Mean values were obtained from EMG tests by the chewing directions of the study groups.

Table 1. Statistical data of the amount of matter remaining in the sieves in the group * direction * average amount remaining in the chewing materials taken from the patient groups.

	Chewing Direction	Amount of material remaining on 8 mesh ±SEmean	Amount of material remaining on 16 mesh ±SEmean	Amount of material remaining on 30 mesh ±SEmean	Amount of material remaining on 45 mesh ±SEmean	Amount of material remaining on 60 mesh ±SEmean	Amount of material in the collecting container ±SEmean
Full Dentition	**Right**	0,950± 0,146	0,842± 0,110	0,205± 0,039	0,22± 0,011	0,40± 0,018	0,26± 0,006
	Left	1,025± 0,167	0,767± 0,124	0,194± 0,050	0,20± 0,012	0,45± 0,018	0,27± 0,008
FAİS-FP	**Right**	0,882± 0,146	0,815± 0,110	0,158± 0,039	0,48± 0,011	0,61± 0,018	0,34± 0,006
	Left	0,673± 0,167	0,784± 0,124	0,258± 0,050	0,55± 0,012	0,60± 0,018	0,48± 0,008
NTS-FAP	**Right**	1,264± 0,146	0,642± 0,110	0,132± 0,039	0,19± 0,011	0,59± 0,018	0,25± 0,006
	Left	1,329± 0,167	0,602± 0,124	0,109± 0,050	0,21± 0,012	0,47± 0,018	0,25± 0,008

There were no statistically significant differences in the chewing direction or the average amount of chewing material remaining in the sieves ($p<0.05$). However, the interaction of the sieve-patient group was found to be statistically significant ($p<0.05$), (Table 1). The average amount of

material accumulated in each sieve differed from each other within the same patient group. The average amount of material remaining in each sieve differed between patient groups (Table2).

Table 2. The average data obtained on the amount of material remaining in the sieves in the group * sieve subgroups of the materials taken from the patient groups.

Patient Groups	Average amount remaining in 8 mesh sieve	Average amount remaining in 16 mesh sieve	Average amount remaining in 30 mesh sieve	Average amount remaining in 45 mesh sieve	Average amount remaining in 60 mesh sieve	Average amount remaining in the collecting container
Full Dentition	0,988 ± 0,143	0,804 ± 0,108	0,200 ± 0,041	0,021 ± 0,011	0,043 ± 0,017	0,026 ± 0,006
FAİSF	0,777 ± 0,143	0,800 ± 0,108	0,208 ± 0,041	0,051 ± 0,011	0,061 ± 0,017	0,041 ± 0,006
NTSFAP	1,296 ± 0,143	0,622 ± 0,108	0,121 ± 0,041	0,020 ± 0,011	0,053 ± 0,017	0,025 ± 0,006

A total of 2.35 g test material was used for the chewing test. After the test, particles were transferred into the container located at the bottom of the sieves. There were no statistical differences in the amount of the material collected in the bottom container among the groups. However, the amount of the material collected in the bottom container was larger in the ISCAFP group (Table 3).

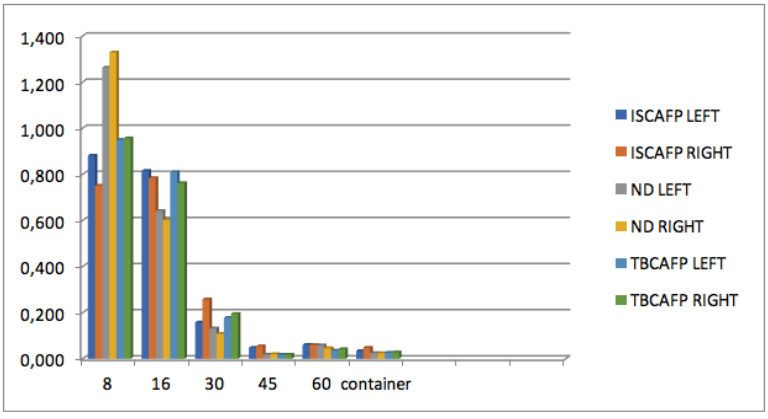

Figure 3. The average data was obtained on the amount of material remaining in the sieves taken from the patient groups.

Discussion

The main purpose of prosthetic treatments is to restore the chewing function of the patient, whose masticatory performance is impaired due to tooth loss. Masticatory performance is usually determined by the degree of crushing or shredding of a test material.

Several methods have been reported so far to evaluate masticatory performance. Such methods include the measurement of the chewed food with computer-aided programs, the analysis of the amount of sugar remaining in chewing gum, spectrophotometric analysis of color-changing food, the analysis of EMG parameters during the chewing test, and the measurement of bite forces. [20]

Chewing performance was first tested by the sieve analysis method by Gaudenz in 1901. Amongst the available methods for the assessment of chewing performance, the sieve analysis and surface EMG methods are observed as the most reliable and efficient.[10,11]

In this study, patients chewed a 1 cm^3 cube of dense polysiloxane impression material with 40 chewing strokes for each direction (right and left). The comfort of patients during the chewing was ensured so that they could chew naturally. It was observed that, when the metronome was used, patients panicked to follow the metronome's rhythm, and undesired mandibular movements occurred. Therefore, a metronome or a similar device was not preferred.[21]

Aras et al. studied particle size grading. In that study, patients with removable partial dentures and with natural teeth supported short arch fixed prostheses were compared. The study reported that the size of the particles was close to each other, and there were no very large and very small particles as outliers.[22,23] In this study, we observed a higher amount of chewing material, especially in the 45 and 60 mesh sieves and in the collection container at the most bottom in the ISCAFP group. However, the difference between the other groups was not statistically different.

When comparing a healthy natural tooth with a healthy implant, an implant's probing pocket depth has been reported to be approximately 0.5 mm deeper compared to that of a natural tooth. The pocket depths in the buccal and lingual implants are 0.5-1 mm less deep compared to their proximal counterparts. Since the abutment length and the

restoration margin of the implant can affect the probing pocket depth, it has been reported that the normal probing pocket depth may be different in different implant systems and in anterior-posterior regions.[23] Out of the 2.35 grams of material given to the patient, the weight of the material returned by the patient and the amount of material loss were calculated. Although no statistically significant differences can be found, patients with ISCAFP on both the right and left sides had the highest amount of lost material. Because pockets are deeper in implants compared to natural teeth, it may be suggested that the lost material can get stuck in implant pockets.

Many studies have shown that one of the methods that can objectively evaluate muscle activity during chewing is the analysis of EMG recordings.[24,25] EMG records of muscles during chewing provide data to calculate the energy, which is consumed by relevant muscles during the actions of eating or swallowing.[26-28] Therefore, we used EMG recordings from the masseter muscle in our study in order to evaluate the relationship between chewing performance and muscle activity and to compare the obtained data between the study groups.

In this study, we found that measured values obtained by EMG were highest both on the right and left sides in patients with ISCAFP compared to the two other study groups. Therefore, the null hypothesis was partially rejected.

Bersani et al. compared EMG values between patients with maxillary complete dentures and mandibular ISCAFP to patients with ND. EMG measurements were taken during resting, right and left lateral movement, protrusion, and maximum tooth clenching. Especially during protrusion and in the resting position, patients with maxillary complete dentures and mandibular ISCAFP showed markedly high EMG activity, while patients with ND showed higher values during maximum clenching. Bersani et al. have argued that in patients with maxillary complete dentures with mandibular ISCAFP, an increase occurs in the basal tone of the muscles. Therefore, an increase is observed in EMG values.[29] Furthermore, the lack of function of the periodontal ligament has been observed, which would normally affect the coordination of motor and sensory functions. Patients with ND showed low EMG values in postural positions and high EMG values in maximum tooth clenching positions. [30]

In another study, EMG values were compared between groups with ISCAFP, implant-supported overdentures, and ND. That study found that the muscular symmetry of the masseter muscles of the patients was similar across the groups. However, similar EMG measurements were obtained in all groups during standardized activities.[31]

The brain relies on information from sensory input from orofacial structures to control oral motor behaviors such as biting, chewing, speaking, and oral manipulation. Natural teeth are equipped with extremely sensitive tactile sensors – periodontal mechanoreceptors. These sensors, located in periodontal ligaments, provide information about tooth loads. Besides this information, high hold force levels are observed in patients who lack periodontal receptors (i.e., patients treated with dental prostheses that are supported only by the oral mucosa or patients with osseointegrated implants). Indeed, the mean hold force generated by patients, who lack periodontal receptors, are remarkably similar to those generated by dentulous subjects under periodontal anesthesia. Furthermore, in anesthetized subjects and patients lacking periodontal receptors, the morsel often escapes from incisal edges during mastication, indicating an impaired spatial control of the jaw action vector. Thus, in the absence of periodontal afferent information, patients show a marked impairment in controlling precise oral manipulation. Therefore, it may be suggested that periodontal receptors play an important role in the specification of the level, direction, and point of attack of forces used to hold and manipulate food between the upper and lower jaw teeth.[32,33]

In the study performed by Van Kempen et al., similar results were obtained patients groups with ISCAFP, implant-supported overdentures, and ND from EMG measurements taken during the exertion of the maximum bite force, exceeding the pre-implantation values within 3 months after successful prosthetic rehabilitation.[34] Gartner et al. have shown in their study that even one month is enough for patients to regain muscular coordination.[35]

In our study, EMG tests were scheduled on dates following the use of prostheses for at least one month. The obtained EMG data on those dates were similar to the results that

were obtained in previous studies. Regardless of the mechanism, the capacity of implants for providing sensory input is about eight times less compared to natural teeth.[32,36] Due to the lack of sensory feedback from the periodontal ligament, the values of patients with implants were higher in all EMG measurements taken from both the right and left sides.

Conclusion

Patients with ISCAFP can apply disproportionate chewing forces because of the deficient control mechanism. Although this seems to be favorable for breaking down the chewed material, it is unfavorable for the material used to restore the occlusal morphology, the framework material, and the abutment-implant units underneath. Furthermore, the supporting bone may be affected unfavorably, too. Therefore, fabricating procedures should be followed carefully to distribute the force evenly in the mouth when the restoration is performed with ISCAFP.

Further research through future long-term clinical trials is required to understand the phenomena of osseoperception. The long-term results of such studies may help researchers design optimized dental implants providing better masticatory outcomes and perform successful implant-supported restorations.

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