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The effect of flexible acrylic resin on masticatory muscle activity in implant-supported mandibular overdentures: a controlled clinical trial

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Abstract

Background: It is not yet clear from the current literature to what extent masticatory muscle activity is affected by the use of flexible acrylic resin in the construction of implant-supported mandibular overdentures.

Objective: To compare masticatory muscle activity between patients who were provided with implant-supported mandibular overdentures constructed from flexible acrylic resin and those who were provided with implant-supported mandibular overdentures constructed from heat-cured conventional acrylic resin.

Methods: In this clinical trial, 12 completely edentulous patients were selected and randomly allocated into two equal treatment groups. Each patient in Group 1 received two implants to support a mandibular overdenture made of conventional acrylic resin. In Group 2, the patients received two implants to support mandibular overdentures constructed from "Versacryl" flexible acrylic resin. The maxillary edentulous arch for patients in both groups was restored by conventional complete dentures. For all patients, masseter and temporalis muscle activity was evaluated using surface electromyography (sEMG).

Results: The results showed a significant decrease in masticatory muscle activity among patients with implant-supported mandibular overdentures constructed from flexible acrylic resin.

Conclusion: The use of "Versacryl" flexible acrylic resin in the construction of implant-supported mandibular overdentures resulted in decreased masticatory muscle activity.

Keywords: flexible acrylic resin, muscle activity, implant-supported overdentures, electromyography

1. Introduction

The superiority of implant-supported overdentures (ISODs) over the conventional prosthodontic treatment by complete dentures is well documented in the literature (1, 2). Enhanced denture retention, better denture stability, more efficient chewing function, and improved patient satisfaction are some of the benefits that can be obtained from ISODs compared to complete dentures (3). While heat-cured conventional acrylic resin is the most popular denture base material, flexible acrylic resin can be used to achieve even force distribution, reduced localized pressure, and improved denture retention by close adaptation to the supporting tissues and engagement of soft-tissue undercuts. Moreover, the flexible acrylic resin possibly can absorb the impact forces during functional and para-functional movements (4-5). Electromyography (EMG) is defined as the graphic recording of the electrical potential of muscles. It has been the only tool used to assess the muscle activity of the stomatognathic system since it first was introduced by Robert Moyers in 1949. Over the years, clinicians and researchers have used electromyographic activity to evaluate the chewing function in denture wearers. The EMG can be considered as a reliable tool for the diagnosis of neuromuscular pathology of the stomatogmathic system and temporomandibular joint disorder (TMJ) (6, 7). The current literature shows that the EMG technique provides valid and quantitative data for the assessment of the functional condition of the masticatory muscles in rest condition, chewing, maximum muscle activation, bilateral symmetry of the contraction behavior of the jaw muscles, and also for the measurement of stomatognathic

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system reflexes (8). To date, it is not yet clear to what extent masticatory muscle activity can be affected by the use of flexible acrylic resin in the construction of mandibular ISODs. The aim of the present study was to compare masticatory muscle activity between patients who were provided with mandibular ISODs constructed from flexible acrylic resin and those who were provided with mandibular ISODs constructed from a rigid, heat-cured, conventional acrylic resin. The hypothesis that was examined was as follows: There is no significant difference in masticatory muscle activity between mandibular ISODs of conventional construction and mandibular ISODs made of flexible acrylic resin.

2. Material and Methods

2.1. Study setting

This was a controlled clinical trial. Twelve completely edentulous male patients whose ages ranged from 45 to 60 were selected from the out-patient clinic at the Fixed and Removable Prosthodontic Department, National Research Centre, Cairo, Egypt.

2.2. Inclusion criteria

All patients were evaluated before inclusion in this study through history, clinical, and radiographic examination. To be included in the study, the patient had to meet the following inclusion criteria:

1) Good physical and mental health.
2) The patient has been edentulous at least for five years with adequate inter-arch space to accommodate the attachment system.
3) Firm healthy alveolar mucosa free from inflammation or ulceration.
4) Sufficient mandibular alveolar bone of good quality and quantity to support dental implants. (Digital panoramic radiographs were used to assess the quality of the bone and to determine the possibility for installation of two dental implants in the symphyseal area.)

2.3. Exclusion criteria

The following were set as the exclusion criteria of the study:

1) Patients were excluded if they had diseases that might negatively influence implant installation and/or Ooseointegration (such as osteoporosis and diabetes).
2) The patient has a contraindication for the implant surgery (bleeding disorder, for example).
3) Patients with para-functional habits (e.g., clenching and bruxism).
4) Patients with TMJ disorders

2.4. Research ethics

The study protocol was approved by the Ethics Committee of the National Research Center, Cairo, Egypt. All patients were informed thoroughly about the study, and each patient was asked to sign a consent form. Only motivated and cooperative patients who accepted the periodic recall visits and agreed to sign the consent form were enrolled.

2.5. Patient grouping

Patients were randomly and equally divided into two treatment groups:

1) Group 1: Each patient in this group received conventional maxillary and mandibular complete dentures made of heat-cured acrylic resin. In the mandible, two implants were inserted in the symphyseal area and retained by ball-and-socket attachments.
2) Group 2: Patients in this group received the same type of treatment as the patients in group 1, but the mandibular overdentures were made of the flexible acrylic resin “Versacryl” (Keystone Industries GmbH, Sigen, Germany).

2.6. Prosthetic procedures

For all patients, complete upper and lower dentures were constructed in a conventional manner. Primary impressions were made using alginate impression material (Chromaclone, Ultradent Products, Inc., South Jordan, UT). Final impressions were made using rubber base impression material (Zhermack, Via Bovazecchino, Badia Polesine (RO) Italy). Jaw relation records were made using the wax wafer technique (Cavex Holland Bv, Haarlem, Noord-Holland, Netherlands). The maxillary cast was mounted on a semi-adjustable articulator (Hannau, Modd H, Teledyne, Buffalo, NY, USA) by using the maxillary face-bow record, while the mandibular cast was mounted by the centric jaw relation record. Modified anatomic acrylic resin artificial teeth (Acrostone Dental & Medical Supplies, Cairo,

Egypt) were used and set up according to the lingualized occlusion concept (9). Plaster indexes were made for the maxillary trial dentures for clinical remounting procedures. The waxed-up dentures were placed in flasks and processed into heat-cured acrylic resin (Acrostone Dental & Medical Supplies, Cairo, Egypt) using a long curing cycle (9 hr at 70 °C). However, for patients in group 2, the mandibular overdentures were made of flexible acrylic resin "Versacryl" (Keystone Industries GmbH, Sigen, Germany).

2.7. Surgical procedures

Preoperative digital panoramic radiographs were made to assess the proposed implant sites with the aid of a radiographic stent. The final processed dentures were duplicated into clear acrylic resin templates to be used as surgical stents. All patients received antibiotic prophylaxis 2 g/d of Amoxicillin Clavulanic acid 24 hr prior to surgery and until the fifth day postoperatively. Two root form endosseous implants (Zimmer Dental, Tapered Swiss Plus, Implant system, Warsaw, IN, USA) were installed in the mandibular canine areas for each patient after preparation of the implant bed using pilot, intermediate, and final drills.

2.8. Loading of the implants

The implants were allowed to osseointegrate for four months; then, ball and socket attachments (Zimmer, Inc. ImplantPart, Warsaw, IN, USA) were utilized to retain the lower dentures. The metal housings of the ball and socket attachments were picked up in the fitting surface of the lower dentures by self-cured acrylic resin. The direct pick-up technique allowed proper placement of the cap relative to the supporting ball. Also, it avoided the distortion of the caps during the heat curing of acrylic resin if they had been fixed to the denture before processing (10). Figure 1 shows the picked-up female housings in a Versacryl mandibular denture.

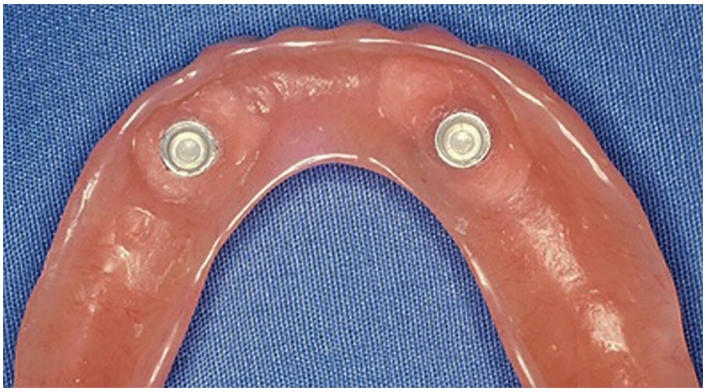

Figure 1. A picked-up female housings into a Versacryl mandibular denture

2.9. Follow-up of the patients

Patients were instructed concerning proper oral health and denture hygiene and asked to return for subsequent recall visits. At each review appointment, patients' complaints were recorded. The dental implants, the supporting tissues, the denture surfaces, and the occlusion and articulation of the dentures were examined. Then, the dentures were adjusted based on the findings of the clinical examination and the patients' complaints.

2.10. Evaluation of masticatory muscle activity

For all of the patients, masseter and temporalis muscle activity was evaluated using surface electromyography (sEMG) (Nihon Kohden, America, Inc., Foothill Ranch, CA, USA). The mean electromyographic amplitudes of both the masseter and temporalis muscles were recorded using surface electrodes during maximum clenching and chewing soft and hard food. During the EMG recording appointments, the patients were seated in an upright, relaxed position with their heads in the same line as their bodies. Before attaching the surface electrodes, the patient's skin was cleaned with alcohol at the corresponding areas of the masseter and temporalis muscles. Furthermore, we cleaned the lobule of the ear where the earth electrode had been placed. The inner sides of the electrodes were filled with Ten20 conductive EEG paste 32 (Weaver and Co., Aurora, CO, U.S.A.) and were fixed on the participant's skin using adhesive tape. Muscle activity was recorded during maximum clenching and when chewing equally-sized pieces of carrot as hard food and banana as soft food. Measurements were displayed and saved on a computer. The

records were obtained at denture insertion and at two, four, and six weeks after insertion of the denture. Figures 2 and 3 illustrate one of the patients during the evaluation of masticatory muscle activity using surface EMG.

Figure 2. Electromyography evaluation of the masseter muscle. The surface electrode is fixed to the masseter muscle and the earth electrode is placed on the lobule of the ear

Figure 3. Elecrtomyographic evaluation of the anterior temporalis muscles. The surface electrode is fixed to the anterior temporalis muscles and the earth electrode is placed on the lobule of the ear

2.11. Statistical analysis

Statistical analysis was performed with IBM SPSS statistical software, Version 20 for Windows. The independent samples t-test was used to study the difference between Versacryl ISODs and conventional ISODs for all tested variables. One-way ANOVA was used to study the effect of time on mean Electro-Myo-Gram (EMG) (mV) for the

patients in each group. Tukey's post-hoc test was used for pair-wise comparison between the means when the results of the ANOVA test were significant.

3. Results

Over the follow-up period, no patients withdrew from the study, no implant failures were observed, and only minor adjustments were needed for the constructed overdentures.

3.1. Effect of flexible acrylic resin on masseter muscle activity

1) Maximum clenching record: The results revealed a significant decrease in the mean EMG muscle activity for Versacryl dentures at denture insertion and four weeks record at p-value = 0.010 and < 0.010, respectively. At the two-week and six-week records, there was a decrease in the mean EMG muscle activity. However, this decrease did not reach a significant level.
2) Soft food record: The results indicated a significant decrease in the mean EMG muscle activity for Versacryl dentures at two-week and six-week records at p-values = 0.012 and 0.029, respectively. Also, an insignificant decrease of the mean EMG muscle activity between the two study groups was found at denture insertion and four-week records.
3) Hard food record: A significant decrease was found in the mean EMG muscle activity for Versacryl dentures at two-, four-, and six-week records at p-values = 0.014, 0.025, and < 0.001, respectively. However, an insignificant decrease in the mean EMG muscle activity between the two study groups was found at denture-insertion record.

3.2. Effect of flexible acrylic resin on temporalis muscle activity

1) Maximum clenching record: The statistical analysis demonstrated a significant decrease in the mean EMG muscle activity for Versacryl dentures at denture-insertion, two-, four-, and six-week records at p-value $\leqslant$ 0.001.
2) Soft food record: The results revealed a significant decrease in the mean EMG muscle activity for Versacryl at denture-insertion, two-, four-, and six-week records at p-value $\leqslant$ 0.001.
3) Hard food record: A significant decrease was found in the mean EMG muscle activity for Versacryl dentures at denture-insertion, two-, four-, and six-week records.

3.3. Effect of time on masseter muscle activity

1) Group 1 (Conventional ISODs): The statistical analysis did not identify any significant decrease in the EMG muscle activity for the clenching records between two weeks, four weeks, and six weeks following denture insertion. However, the data revealed a significant decrease in EMG muscle activity between denture-insertion and six-week records at p-value = 0.026 for the clenching records. For the soft food records, there was no significant difference in EMG muscle activity between the follow-up records (i.e., two-week, four-week, and six-week records). Similarly, with hard-food records, no significant decrease in EMG muscle activity was detected between the follow-up records.
2) Group 2 (Versacryl ISODs): There was an insignificant decrease in the EMG muscle activity for the clenching records over the follow-up period. With soft food records, a significant decrease in the EMG muscle activity was detected between the time of denture insertion and six-week records at p-value = 0.004. However, there was insignificant difference in the EMG muscle activity between two- and four-week records for the soft food. With hard-food records, no significant decrease in the EMG muscle activity was noted between the two-, four- and six-week records. However, the data indicated that there was a significant decrease in the EMG muscle activity between the time of denture insertion and the six-week records at p-value $\leqslant$ 0.001 for hard food.

3.4. Effect of time on temporalis muscle activity

1) Group 1 (Conventional ISODs): There was no significant decrease in the mean muscle activity between the two-, four- and six-week records for the clenching procedure. For the soft-food records, a significant decrease in the mean muscle activity was noted between denture-insertion record and six-week record at p-value = 0.001. Similarly, with hard-food records, there was a significant decrease in the mean muscle activity between the denture-insertion record and the six-week record at p-value = 0.003.

2) Group 2 (Versacryl ISODs): For clenching records, a significant decrease in the mean EMG muscle activity was recorded between the denture-insertion record and the six-week record at p-value $\leqslant$ 0.001. Also, the data showed that there was a significant difference between two-, four- and six-week clenching records. Furthermore, for the soft-food records, there was a significant decrease in the EMG muscle activity between the denture-insertion record and the six-week record at p-value = 0.001. The results were similar with hard-food records, i.e., a significant decrease in the mean muscle activity was noted between the denture-insertion record and the six-week records at p-value = 0.003.

4. Discussion

Although the heat-cured acrylic resin is the most popular denture base material, this study reported the use of flexible acrylic resin "Versacryl" to construct mandibular overdentures supported by two dental implants. The flexible acrylic resin first was introduced in 1950 as an alternative to conventional acrylic resin denture base material (11). It is a flexible, biocompatible, thermoplastic, denture-base material with unique physical and esthetic properties (12). The flexible acrylic can be adjusted simply by using warm water to soften the material so as to conform to the contours of the soft and hard tissues. Also, the flexible acrylic can be extended into undercut areas to mechanically retain the dentures. Furthermore, the softness of flexible acrylic provides a feeling of comfort to the patient (11). However, the flexible acrylic has some disadvantages and may lose its flexibility over time (4, 13). Many brands of thermoplastic or flexible denture materials are available in the market, such as Valplast (Valplast Int. Corp., Westbury, New York, USA), Flexiplast (Bredent, Senden, Germay), Flexite (The Flexible Company, Mineola, New York, USA), and Lucitone® FRS™ (DENTSPLY International, Woodbridge, Ontario, Canada). In this study, Versacryl (Keystone Industries GmbH, Sigen, Germany) was used as a thermoplastic material to construct mandibular overdentures supported by two dental implants. Versacryl has the physical properties of thermoplastic materials, as indicated by the manufacturer (5). Despite the relatively old age for the use of thermoplastic denture base materials, reports to evaluate its impact on masticatory muscle activity in patients wearing ISODs are scarce. Versacryl has a compressive or cushioning action. Under functional load, Versacryl absorbs the applied stress and minimizes the distortion of the supporting tissues. Also, it may reduce the fatigue of the masticatory muscles. This, in turn, may positively affect the health of the supporting tissues and result in a better masticatory muscle activity. The aim of the current study was to examine this hypothesis. The superficial masseter and anterior fibers of the temporalis muscle were selected to represent the masticatory muscle activity because they are the largest and strongest masticatory muscles and, thus, have a major role in mandibular movement. They also are accessible during EMG records (14). Surface electrodes were preferred over needle electrodes because they are less painful, which, in turn, would affect the EMG records. Surface electrodes allow evaluation of a wider area of the muscle (15). Overall, the findings of this study indicated that resilient Versacryl overdentures resulted in a significant reduction in the activity of the temporalis and masseter muscles. Chewing using the Versacryl overdenture was faster and required fewer chewing strokes. This may result in improvement of the masticatory function and preservation of the masticatory apparatus (4). The mean EMG values of masseter and temporalis muscles were gradually decreased from the time of implant placement until the end of the follow-up period. This may be attributed to the adaptability of the neuromuscular system to the overdenture treatment throughout the follow-up period. Consequently, the effort needed for mastication decreased with time (16). Previous studies indicated that treatment with ISODs improved the functional state of the masticatory apparatus and aided in establishment of better neuromuscular coordination by improving retention, support, and stability of the prosthesis, and, consequently, less effort had to be exerted by the muscles to control the prosthesis during function (17, 18). A limitation of this work is that only male patients were included. Also, this was a short-term study, and further studies are required to evaluate the long-term impact of flexible acrylic resin on masticatory muscle activity and oral comfort in patients wearing ISODs.

5. Conclusions

The use of flexible acrylic resin in the construction of ISODs resulted in improved masticatory muscle activity. Therefore, the hypothesis of no significant difference in masticatory muscle activity between mandibular ISODs of conventional construction and mandibular ISODs made of flexible acrylic resin was rejected.

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Conflict of Interest:

There is no conflict of interest to be declared.

Authors' contributions:
Both authors contributed to this project and article equally. All authors read and approved the final manuscript.

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