Comparison of Masticatory Function Between Subjects with Three Types of Dentition

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Purpose: The aim of this study was to evaluate the effect of an oral rehabilitation program on masticatory performance and ability as a function of the number of masticatory cycles. Subjects with a mandibular fixed implant-supported prosthesis (ISP), complete dentures (CDs), or a natural dentition (ND) were evaluated. ***Materials and Methods:*** Masticatory performance was tested with an artificial test food (Optocal). Optocal was provided to subjects in two portions of 17 cubes and collected after both 20 and 40 masticatory cycles. The particles were collected on stacks of eight sieves. The geometric mean diameter of the chewed particles was calculated using the sieves. Questionnaires were used to assess masticatory ability before and after the fixed mandibular rehabilitation program. The geometric mean diameter of the chewed particles was compared by two-way analysis of variance followed by the Tukey test ($P < .05$). ***Results:*** The geometric mean diameter for all groups was lower after 40 cycles versus 20 cycles. When compared to the ND group, masticatory performance for the CD and ISP groups was 12% and 28% after 20 cycles and 31% and 61% after 40 cycles, respectively. The data for the masticatory ability of the ISP group before and after fixed mandibular rehabilitation were compared by the McNemar test ($P < .05$), and showed that 100% of these subjects were satisfied with their chewing capacity after fixed mandibular rehabilitation. ***Conclusions:*** These results quantify the differences in masticatory function among different types of dentition. Greater masticatory function for fixed mandibular rehabilitation versus CDs was demonstrated. *Int J Prosthodont 2009;22:399–404.*

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One major reason for dental treatment is the maintenance of oral function. This is particularly difficult in patients who are missing teeth[1] since chewing ability is related to the number of remaining natural teeth.[2] Edentulism is a chronic condition. Patients seek treatment for this condition to restore esthetics and oral function so that they can eat and speak more easily and feel better about themselves.[3] For many years, complete dentures (CDs) were the only choice of treatment for edentulous patients, and they still are when financial costs are involved.[4,5] However, masticatory function with CDs is reduced when compared to dentate patients.[6–8] Treatment with dentures is associated with anatomic and psychologic problems,[9] and direct and indirect sequelae have been linked to the use of CDs.[10] Residual ridge resorption and mucosal reactions (direct) and severe modifications in masticatory function (indirect) are commonly associated with the use of CDs.[10] Residual ridge resorption causes a deterioration of denture retention, especially in the mandible,

chewing and speech difficulties, and also leads to the fear that the denture may come loose, resulting in a state of tension and insecurity.[9] On the other hand, osseointegrated implants and rehabilitation of edentulous patients with fixed prostheses have shown substantial improvement in masticatory performance, as well as in the subjective chewing experience.[11,12]

The definitions of the terms used in this study are important because a number of similar terms, such as masticatory ability, masticatory efficiency, or masticatory performance, have been used interchangeably for masticatory function.[13] In this article, masticatory performance was defined as the particle size distribution of food when chewed for a given number of strokes,[6,14] while masticatory ability was used to represent an individual's own assessment of his/her masticatory function.[15]

The aim of this study was to quantitatively compare the masticatory performance of subjects rehabilitated with fixed mandibular implant-supported prostheses (ISPs) to subjects with CDs and subjects with a natural dentition (ND) as a function of the number of chewing cycles. The masticatory ability of the individuals with fixed mandibular ISPs before and after mandibular rehabilitation was also compared. The hypotheses of this study were that *(1)* an increase in chewing cycles improves masticatory performance and *(2)* a fixed mandibular ISP improves masticatory performance as compared with CDs.

Materials and Methods

Patient Selection

This study was approved by the Institutional Review Board of the Federal University of Uberlândia for the use of human subjects in research. Written informed consent was obtained from each subject after a full explanation of the research project. Three groups of subjects participated in this study. The control group was composed of 15 subjects with an ND (six females and nine males; range: 20 to 28 years). The inclusion criteria for the ND group were a complete ND with the presence of all second molars, no prior orthodontic treatment, and no signs or symptoms of traumatic occlusion, periodontal disease, or temporomandibular dysfunction. The second group had 21 subjects rehabilitated with CDs in both arches (eight females and 13 males; range: 40 to 76 years). The third group had 16 individuals with mandibular fixed ISPs and a nonspecific maxilla (five females and 11 males; range: 55 to 80 years). The patients from the CD group had already used their prostheses for 3 to 48 months; mandibular ISPs were also in use 3 to 48 months before the tests began. Rehabilitations prior to implant treatment were partially or totally removable prostheses, which were in use for at least 2 years. The majority of the patients (12 in total) in the ISP group received immediate loading of the implants. The exclusion criteria for the CD and ISP groups were any signs or symptoms of temporomandibular dysfunction. Patients in the control group were undergraduate dental students at the School of Dentistry, Federal University of Uberlândia. The patients for the CD and ISP groups originated from the same dental school. All patients were selected according to the aforementioned inclusion and exclusion criteria.

Objective Analysis of Masticatory Performance

Masticatory performance of all subjects was determined by chewing cubes of Optocal (Bayer)[16] for 20 and 40 continuous and sequential cycles. Optocal is an experimental artificial test food based on Optosil (Bayer), a condensation silicone impression material. Preparation of Optocal was previously described by Slagter et al.[16] All ingredients of Optocal were weighed on a digital laboratory scale (Micronal-B 1600) and then agglutinated. After being weighed, the cubes were prepared in molds with an edge size of 5.6 mm.[17] After setting, the samples were stored in an electrical stove for 16 hours at 65°C to ensure complete polymerization.[16,17] The cubes were then removed from the molds and a Shore A durometer (Woltest) was used to monitor the hardness of the Optocal until it reached 30 to 35 Shore A units.

During the experiments, subjects were seated comfortably and upright in a dental chair and were given instructions to chew normally. The test food was provided in two portions of 17 cubes (approximately 3 cm^3), collected after 20 and 40 masticatory cycles, and counted by the examiner. The chewed particles were then expectorated into a 300-mL plastic cup. The subject was asked to rinse his or her mouth carefully with water, which in turn was also expectorated into the cup. Finally, the examiner confirmed that no pieces of the test portion were left in the oral cavity. Chewed particles were immediately sieved on a stack of eight sieves (Bertel Indústria Metalúrgica), with apertures decreasing from 5.6 mm to 0.5 mm.[17] These particles were placed on the upper part of the stack of sieves and were washed with 1,000 mL of water for 30 seconds. Then, the sieves were placed on a dental laboratory vibrator (Vibramold) set at one-half speed for 2 minutes.[18–20] The chewed particles of each sieve were collected and placed on individualized rigid plastic recipients (1 cm in height and 2 cm in diameter) with the name of the patient and the number of chewing cycles. These particles were dried in an electrical stove for 3 hours at 60°C.[21] After drying, the particles of each recipient were weighed on an analytic scale accurate to 0.0001 g (Sauter).

Quantification of Masticatory Performance

Based on the weight of the Optocal retained on each sieve, the geometric mean diameter (GMD) of the chewed particles was calculated from the means of the weighted geometric means[22] using Excel spreadsheets (Microsoft). The smaller the GMD, the better the masticatory performance.

For quantification of the reduction of the particles during mastication, it was necessary to know the maximum GMD value of the particles. For this reason, a situation in which all particles remained intact after the chewing cycles and then retained on the first sieve (5.6 mm) was simulated. In doing so, it was found that the maximum value of the GMD of the particles was 6,660 µm. The mean reduction value was obtained as the difference between the value of the GMD of the group and 6,660 µm.

To compare the masticatory performance of the CD and ISP groups in relation to the control group (ND), the reduction of the particles of this group was considered to be 100%.

The ISP group was analyzed as if the opposite arch (maxilla) would result in a different masticatory performance. The ISP group was splint into two groups based on the type of maxillary rehabilitation received (ie, fixed and removable prostheses).

Subjective Analysis of Masticatory Ability for the ISP Group

A visual analog scale (VAS)[23] and the Geertman questionnaire[24] were used to conduct a subjective analysis of the individuals who had received fixed mandibular prostheses.

The VAS was applied to the patients' evaluation of their actual masticatory ability and the masticatory ability they thought existed with their previous mandibular dentition or prosthesis (the patients were asked to remember how they felt before fixed placement of the mandibular prosthesis). The individual variables assessed by the VAS included: general satisfaction with chewing ability, satisfaction with mandibular and maxillary prostheses, and satisfaction with the stability of the prostheses. The VAS was open-ended and 10 cm in length. The subjects were asked to draw a vertical line anywhere across the horizontal line at the point that best represented their perceptions, in which 0 indicated complete dissatisfaction and 10 indicated total satisfaction. Individuals that marked more than 5 cm on the VAS were considered satisfied. Actual and previous masticatory abilities were marked separately.

Immediately after the chewing tests, patients were interviewed using the Geertman questionnaire with respect to any difficulties in chewing Optocal and pain and loss of retention of the maxillary, as well as the mandibular, prosthesis.[24] After the subjects had completed the chewing tests and answered these questionnaires, they were asked to name a natural food that they thought resembled Optocal.

The correlation between masticatory performance and the VAS answers for the ISP group was also verified.

Statistical Analysis

Parametric tests were used for the objective analysis since the data followed a normal distribution. The differences between the three groups were analyzed by factorial analysis of variance and the Tukey test. Analyses of the different types of opposite arches for the ISP group were completed using the Student *t* test. For the subjective analysis of the ISP group, data were analyzed by the nonparametric McNemar test using Excel. The nonparametric Spearman correlation test was used to verify the correlation between masticatory performance and VAS answers. These tests were performed using SPSS (SPSS) and the statistical significance level was set at 5%.

Results

After 40 cycles the particle size was reduced in all three groups when compared to 20 cycles ($P < .05$) (Fig 1). The particle size was smaller in the ND group than in the other two groups after both 20 and 40 cycles ($P < .05$). However, no statistically significant differences existed between the ISP group after 20 chewing cycles and the CD group after 20 and 40 chewing cycles, whereas the ISP group had smaller particles after 40 cycles. After 40 strokes, the ISP group did not have significant differences from the ND group after 20 chewing cycles (Fig 1). The reduction in particle size in comparison to the ND group (100%) was 12% and 28% after 20 cycles and 31% and 61% after 40 cycles for the CD and ISP groups, respectively. The Student *t* test showed no statistically significant differences when the ISP group was divided into two groups according to type of maxillary rehabilitation ($P < .05$) (Fig 2).

Regarding the subjective analysis obtained from the VAS questionnaire answered by the ISP group, Table 1 shows the responses before and after mandibular rehabilitation. For questions 1, 3, and 4, the McNemar test showed a statistically significant difference ($P < .05$). Results of the Geertman questionnaire are summarized in Fig 3. During the mastication of Optocal, one patient reported difficulties and another complained about pain in the mandible. None of the mandibular prostheses felt loose. Nevertheless, five individuals reported that the maxillary prostheses felt loose while chewing Optocal (Fig 3). Based on the stated hypotheses, it

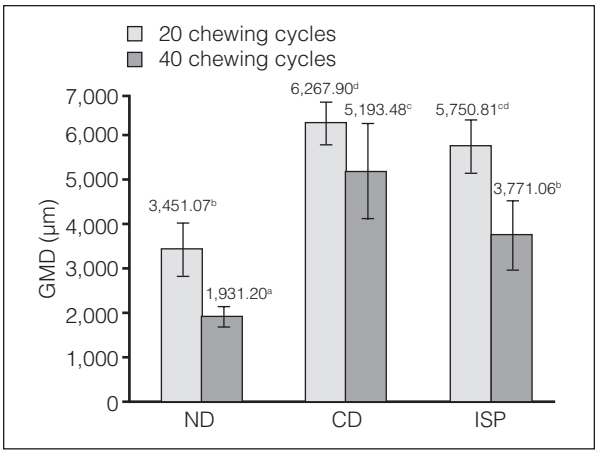

Fig 1 GMD of the chewing particles for the ND, CD, and ISP groups after 20 and 40 chewing cycles (mean ± SD). Different letters denote statistically significant differences.

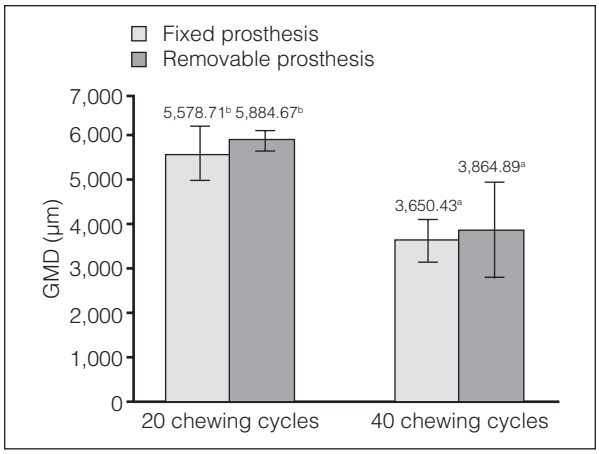

Fig 2 GMD of the chewing particles for the ISP group with fixed or removable prostheses after 20 and 40 chewing cycles (mean ± SD). Different letters denote statistically significant differences.

Table 1 Answers to VAS Questions Before and After Mandibular Rehabilitation

VAS questions	Before ISP n (%)	After ISP n (%)
1 – General satisfaction with chewing ability	4 (25)	16 (100)*
2 – Satisfaction with maxillary prosthesis	10 (62)	15 (94)
3 – Satisfaction with mandibular prosthesis	3 (19)	16 (100)*
4 – Satisfaction with stability of the prosthesis	5 (31)	16 (100)*

*Statistically significant difference ($P < .05$).

was possible to observe that *(1)* an increase in chewing cycles improved masticatory performance, at least for the ND and ISP groups, and *(2)* the ISP group was able to improve masticatory performance when compared to the CD group.

No statistically significant correlation was found between masticatory performance and VAS answers for the ISP group ($P < .05$). When asked to name a natural food that they thought resembled Optocal, 75% of subjects in the ISP group compared Optocal to meat.

Discussion

The differences between the ages in the control group (ND) and the test groups (CD and ISP) reflect the difficulty in finding full dentate individuals in all age ranges. According to Ikebe et al,[25] reduction of occlusal force is not a natural effect of aging, and maintaining a reasonable number of healthy natural teeth and occlusal support is the best guarantee for good masticatory ability with increasing age. Despite the differences in ages, the control group was kept as a model of full masticatory function. Carlsson and Lindquist[12] demonstrated that masticatory performance among individuals with ISPs did not change over time. Ongoing investigations have also observed similar results with CDs and ISPs as long as the prostheses were considered satisfactory. Based on these findings, immediate and conventional (after 4 months healing) loading was performed in the ISP group.

Both natural and artificial foods have been used as test materials in experiments determining masticatory performance.[6,26] To avoid variations in consistency, the experiments were performed using Optocal,[16] which is based on a dental impression material known as Optosil. Optocal presents a lower fracture resistance than Optosil, which makes it more suitable for masticatory performance tests in completely edentulous subjects.[16,17] Some authors[27] have reported on the hardness of CutterSil (Heraeus Kulzer), a condensation silicone impression material, by means of a type A durometer. In this study, Optocal hardness was used until it reached 30 to 35 Shore A units for masticatory performance tests, which most of the patients compared to cooked meat.

The multiple sieve method[17,18,20,21,28–32] was used because it provides a more accurate result and more detailed information on masticatory performance than the single sieve method.[33] The Rosin-Rammler equation[21] facilitates analysis of the larger amount of data

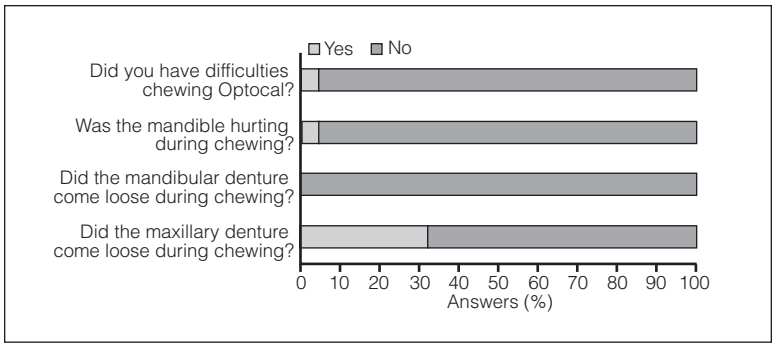

Fig 3 Answers to the Geertman questionnaire before and after placement of the ISPs.

obtained by the multiple sieve method, but does not adequately describe the particle size distribution unless a certain degree of size spread within the distributions has been reached.[21] For this reason, this study used the weighted geometric mean[22] to represent the GMD of the chewed particles for the studied groups based on the fact that the apertures of the sieves decrease at a constant rate from 5.6 mm to 0.5 mm. It also took into consideration the percentage of weight of the chewing particles on each sieve.[34] The method used to calculate the GMD resulted in saving time and a significant reduction in the probability of errors during calculations.

While this is not an interventional study, the data infer that the placement of an ISP in the mandible was followed by a marked improvement in masticatory function, demonstrated not only by the patient's own evaluation (Table 1), but also by the objective tests of masticatory performance after 40 chewing cycles (Fig 1). Since the VAS and Geertman questionnaire were applied retrospectively, the authors needed to rely on the patient's memory for this subjective analysis. All patients presented good physical and mental health, which allowed for participation in this study. This improvement is in accordance with other studies.[12,35]

No correlation was found between the objective and subjective analyses of masticatory performance and the VAS answers. Results were consistent with those studies reporting no correlation between masticatory performance and masticatory ability tests.[36] For most patients it was more important to feel comfortable with a stable mandibular denture than be able to objectively chew as a dentate subject. According to Gunne et al,[36] this lack of correlation between the objective and subjective evaluation may be related to the fact that edentulous patients prefer soft foods that are easier to masticate. Also, according to the Geertman questionnaire, the subject that recalled difficulty while chewing Optocal had a GMD of 2,964 μm after 40 cycles; the one that reported pain presented a GMD of 3,981 μm after 40 cycles. Likewise, the five individuals who reported that the maxillary prostheses came loose while chewing Optocal had a mean GMD of 3,417 μm after 40 cycles. Even though these patients had related problems during mastication of Optocal, they all had satisfactory GMDs.

Another study limitation was related to the various types of maxillary rehabilitations used in the patients in the ISP group. Deficiencies in retention and stability are the most common complaints of denture wearers in relation to chewing, with complaints generally central to mandibular prostheses.[37] However, when mastication was assessed, the type of maxillary rehabilitation, whether fixed or removable, did not influence the masticatory performance results of the subjects in the ISP group (Fig 2). Similar results were also demonstrated when comparing the masticatory performance of individuals rehabilitated with implant-supported overdentures or fixed ISPs in the mandible, regardless of the maxilla.[12] On the other hand, these data should be interpreted with caution due to a limited number of subjects in each subset of the ISP group. Besides the various antagonists, the participants of this research were between 20 and 80 years of age, although some authors have indicated that age per se does not appear to influence chewing efficiency directly.[15,38,39]

Conclusion

The results of this study demonstrate that the three groups had better results regarding masticatory performance after 40 chewing cycles, suggesting that individuals should execute more chewing cycles to achieve better masticatory performance. The maintenance of masticatory function is important not only for the intake of food, but also for the improvement in quality of life.[40,41] According to this paper's research limitations, it appears that the rehabilitation of edentulous patients with mandibular fixed ISPs improved their masticatory function. The improvement was equivalent to 61% of the masticatory performance of subjects with an ND, while improvement with CDs was in the 31% range.

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