Masticatory Performance, Maximum Occlusal Force, and Occlusal Contact Area in Patients with Bilaterally Missing Molars and Distal Extension Removable Partial Dentures

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Purpose: The aim of this study was to compare the masticatory performance, maximum occlusal force, and occlusal contact area of subjects with bilaterally missing molars, treated either with the shortened dental arch (SDA) concept or with distal extension removable partial dentures (RPDs), during a 1-year follow-up. ***Materials and Methods:*** This study included three groups of 10 subjects each, in which SDA and RPD groups displayed bilateral molar loss in the mandible. Subjects with complete natural dentition (CD) served as the control group. Masticatory performance was evaluated by the multiple sieve method. Standard cubes (edge length: 8 mm, 0.9 g) shaped from a high viscosity polysiloxane molding material (Zetaplus, Zhermack) were used as the test food. Maximum occlusal force (N) and occlusal contact area (mm^2) were evaluated using dental prescale films. ***Results:*** No statistically significant differences regarding masticatory performance between the groups or evaluation periods were demonstrated. In the RPD group, masticatory performance with and without prostheses showed no significant differences. SDA patients showed significantly lower contact area and occlusal force than both the CD and RPD groups ($P < .05$). ***Conclusion:*** SDA can be an alternative to distal extension RPDs with respect to masticatory performance in subjects with bilaterally missing molars in one dental arch, despite remarkable reductions in maximum occlusal force and occlusal contact area. *Int J Prosthodont 2009;22:204–209*

Different therapeutic concepts for the prosthetic rehabilitation of patients with bilaterally missing molars have been proposed. One option is replacement with a tooth-supported cantilever fixed partial denture (FPD).[1] An implant-supported FPD is another treatment alternative, but local and systemic factors as well as financial concerns may limit the application of implants.[2–4] Moreover, with both treatment options, posterior occlusion is usually restricted to the first molar region.[3,5–7] A commonly used treatment modality when many teeth are missing includes restoration with a distal extension removable partial denture (RPD).[8–11] However, RPDs, in the absence of meticulous oral hygiene measures, may accelerate the progression of caries and destruction of the periodontal tissues.[10,12,13] The contribution of RPDs to oral comfort and function in many partially dentate patients may also be questioned.[7,10,12] Finally, in patients with missing posterior teeth, the shortened dental arch (SDA) concept, as first suggested in 1981 by Käyser, provides that molars are not replaced and compromised dentition is restored to the second premolars.[14]

Sufficient masticatory function is one of the goals of prosthodontic rehabilitation in partially dentate patients. A full complement of teeth has been stated as a prerequisite for a healthy masticatory system and satisfactory oral function.[7] The number of functional tooth units (ie, pairs of occluding natural teeth) and occlusal force are the two major factors affecting masticatory

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performance. In recent years, clinical observations confirmed by research findings have demonstrated that the minimum number of teeth needed to satisfy functional and social demands varies individually and depends on a combination of local and systemic factors such as periodontal condition of the remaining dentition, age of the patient, physiologic occlusal activity, and adaptive capacity of the tissues. Thus, the SDA concept is increasingly recognized as a treatment alternative to RPDs that can meet the patient's aspirations, especially for middle-aged and elderly patients with a history of compromised oral health.[6,7,12,14] However, SDA treatment is still considered controversial by many clinicians because adverse effects may be associated with the non-replacement of posterior teeth, including insufficient masticatory function.[2] Limited information evaluating masticatory performance in SDA patients in well-defined groups could be identified by the authors.[15] Few studies concerning chewing functions in SDA and distal extension RPDs are based on subjective tests performed by interviewing subjects as to their own assessment.[16] Furthermore, there are inadequate data indicating an improvement in masticatory performance with the restoration of posterior occlusal units with RPDs.[17,18]

The purpose of this study was to investigate the effect of two treatment options, SDA and distal extension RPDs, on the masticatory performance of subjects displaying similar posterior tooth loss in the mandible during a 1-year follow-up period, and evaluate the role of maximum occlusal force and occlusal contact area on masticatory performance.

Materials and Methods

Subjects

Forty participants with bilaterally missing molars in the mandible were recruited from a pool of 90 patients attending the Prosthodontic Clinics of Ankara University, Faculty of Dentistry for the rehabilitation of their missing teeth, problematic natural teeth, or for a routine check-up procedure. All patients had complete natural dentition in the opposing dental arch. They were briefly informed about treatment alternatives (free-end RPDs, restoration of missing teeth with implants, or treatment according to the SDA concept) and the study protocol. Fifteen patients accepted the rehabilitation of their mandible according to the SDA concept. Most of these patients had been previously treated with distal extension RPDs but could not use them. Restoration of missing molars with implants was contraindicated due to anatomic and/or financial limitations. However, five patients could not complete all evaluation sessions due to personal reasons.

Of the 40 participants, some were already wearing RPDs in the mandible and wanted to be treated with new prostheses. A number of these patients who fulfilled the inclusion criteria were included in the RPD group. Others preferred implant therapy for the restoration of their missing molars. A few of them, though not using an RPD, did not want to participate in the study.

All subjects were required to be over the age of 45 years, in good health, have an Angle class 1 relationship between the dental arches, and an acceptable state of hard and soft tissues of the residual ridge. Exclusion criteria eliminated patients with any signs or symptoms of temporomandibular disorders, severe periodontal diseases around the remaining teeth, parafunctional habits, and severe attrition on the anterior teeth. Therefore, the study was designed to include three groups of 10 patients each with balancing for gender and age.

Time of edentulousness differed between 4 and 9 years for the experimental groups. In the first group (SDA group, four males and six females; mean age: 56 years, age range: 45 to 66 years), the primary aim of treatment was focused on the rehabilitation of natural teeth and edentulous posterior areas were left unrestored. The second group (RPD group, five males and five females; mean age: 54 years, age range: 45 to 68 years) received conventional distal extension RPDs fabricated using cast metal (BEGO USA) frameworks that incorporated rests, retainers, and a rigid connector. The dentures were finished with a heat-cured acrylic resin (QC-20, Dentsply). Semi-anatomic teeth were used and an occlusal scheme conforming to the patient's existing occlusion (canine protected, group function, or mutually protected articulation) was employed. Ten subjects (complete natural dentition [CD] group, five females and five males; mean age: 48 years, age range: 46 to 66 years) with a complete natural dentition who fulfilled the inclusion criteria participated in this study as the control group. The study protocol was approved by the Research Ethical Committee at Ankara University, Faculty of Dentistry. The patients signed consent forms after receiving a thorough explanation about the experimental rationale, clinical procedures, and possible risks.

Masticatory Performance

Masticatory performance was evaluated by a multiple sieve method on the basis of median particle size of the fragmented particles.[19] Standard cubes (edge length: 8 mm, 0.9 g) were shaped from a high viscosity polysiloxane molding material (Zetaplus, Zhermack) due to its brittle structure after polymerization and used as the test food. Tests were performed in two sub-runs to obtain enough material for sieving and to

reduce experimental scatter.[11] In each sub-run, the patient chewed three cubes bilaterally for 60 cycles. After chewing, the collected particles from two trials were dried and weighed to determine total sample mass and then passed through a stack of up to five sieves, with apertures ranging from 4.75 mm to 300 μm (US Sieve Standard) and a bottom plate. The amount of test food on each sieve (mass retained on sieve) and on the plate were weighed to the nearest one-hundredth of a gram. Test food retained on each sieve was used to calculate the cumulative weight percentage with the following formula:

$$\text{Weight percent} = \frac{\text{Mass retained on a sieve} \times 100}{\text{Total sample mass}}$$

Cumulative weight percentage data was used to draw a cumulative arithmetic curve with the help of a computer program (Excel, Microsoft Office 2000), which was necessary to receive information about the median particle size. The median particle size by weight is the aperture size of a theoretical sieve through which 50% of the weight of the comminuted food can pass. Therefore, shifting toward smaller median particle size corresponds to a better chewing performance.[19] To determine the median particle size for each subject, a plot was constructed of aperture size (x-axis) versus the 50% point (y-axis) on the cumulative arithmetic curve.

The masticatory performance of the SDA group was evaluated following rehabilitation and after 6 and 12 months. In patients wearing RPDs, elimination of functional problems and discomfort may take several weeks because acrylic resin absorbs water and results in minute changes in size and occlusion of the denture. Furthermore, to learn chewing satisfactorily with new dentures takes 6 to 8 weeks. So, in the current study, masticatory performance of patients in the RPD group was measured following an adaptation period of 8 weeks. In this group, an intraindividual comparison of masticatory performance with and without dentures was also made. Masticatory performance testing was applied to the control group only once.

Maximum Occlusal Force and Occlusal Contact Area

Maximum occlusal force (N) and occlusal contact area (mm^2) were evaluated using horseshoe-shaped pressure-sensitive films (Dental Prescale 50H, R type, Fujifilm), which show color variation and area depending on the amount of applied pressure within a range of 5 to 120 MPa. Each patient was seated in a dental chair with the head upright and in an unsupported natural position. The patient was instructed to bite the pressure-sensitive film placed between the maxillary and mandibular dentition with maximum clenching in the intercuspal position for 3 seconds.[20,21] The imprints on the films were analyzed by a computerized image scanner (Occluzer FPD705, Fujifilm) designed for the film. The scanner was connected to a personal computer on which the software designed for the film was installed. The system automatically estimated the amount of occlusal pressure and area of contact by measuring the color density and area data. At the same time, the occlusal force was calculated by multiplying the contact area by the pressure. This test was performed once at the first evaluation period in all the groups.

Statistical Analysis

For analysis of masticatory performance, a two-way repeated-measures analysis of variance (ANOVA), with evaluation period and treatment modality as the two factors, was used to determine the significance of each factor. In the RPD group, masticatory performance with and without dentures within each evaluation period was compared with the nonparametric Friedman test, while the difference between evaluation periods was analyzed using the nonparametric Wilcoxon test. The Kruskal-Wallis test was used to evaluate the differences among SDA, RPD, and CD (control) groups with regard to maximum occlusal force and occlusal contact area. A probability level of $P < .05$ was considered significant.

Results

Masticatory Performance

Masticatory performance results for CD, SDA, and RPD groups at each evaluation period are shown in Fig 1. Repeated-measures ANOVA showed no significant differences for the treatment groups, evaluation periods, and group and time interactions. The smallest median particle size, though not statistically significant, was determined for the CD group, followed by the SDA and RPD groups. In RPD patients, insertion of distal extension RPDs did not improve masticatory performance (Table 1). Also, no significant improvements in masticatory performance were established with the use of RPDs over time.

Maximum Occlusal Force and Occlusal Contact Area

Table 2 describes the results related to maximum occlusal force and occlusal contact area of the CD, SDA, and RPD groups. The SDA group demonstrated significantly lower occlusal force and occlusal contact area values compared with the CD and RPD groups ($P < .05$).

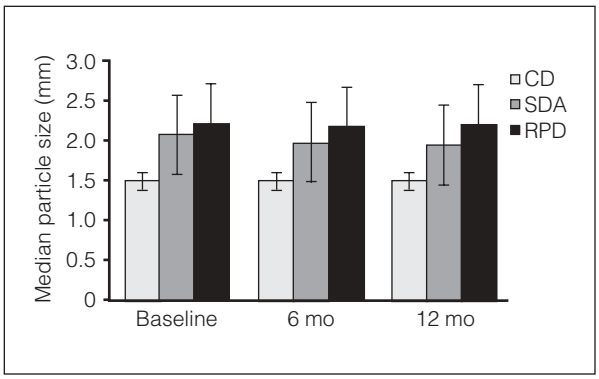

Fig 1 Median particle size (mm) of the CD, SDA, and RPD groups. CD = complete natural dentition (control); SDA = shortened dental arch; RPD = bilateral distal extension removable partial denture; n = 10 (each group).

Table 1 Median Particle Size (mm) of the RPD Group With and Without Dentures

Evaluation period	With denture median (min–max)	Without denture median (min–max)
Baseline	2.4 (1.6–3.5)	2.17 (1.5–3.1)
6 mo	2.1 (1.8–3.5)	2.05 (1.4–3.1)
1 y	2.0 (1.6–3.5)	2.04 (1.4–3.3)

Table 2 Mean, Median, and SD Values of Maximum Occlusal Force (MOF) and Occlusal Contact Area (OCA)*

	MOF (N)			OCA (mm^2)		
Groups	Mean	SD	Median (min–max)	Mean	SD	Median (min–max)
CD (n = 10)	872.62[a]	219.75	735.00 (683.40–1,153.10)	22.00[a]	5.91	17.50 (16.70–30.20)
SDA (n = 10	408.81[b]	289.54	292.40 (118.20–869.60)	9.61[b]	7.34	5.80 (2.40–22.40)
RPD (n = 10)	708.8[a]	313.89	575.60 (362.50–910.30)	16.31[a]	9.94	7.10 (7.10–36.10)

*Mean values followed by different letters in the same column are statistically different ($P < .05$).

Discussion

The present study was conducted on a relatively small sample size for several reasons. Initially, for studies of masticatory performance with different types of prosthetic restorations, it is important to eliminate cofounding factors as much as possible. Therefore, special care was given to achieve a homogenous age, gender, and dental state distribution among the study groups. Another reason for reducing sample size was the policy of the Turkish public dental health system, which affords RPD treatment at 2- to 4-year intervals. Thus, most patients fulfilling the inclusion criteria refused SDA treatment and wished lost teeth to be replaced with RPDs whether they wore them or not. Finally, some of the subjects who had approved of the study protocol did not return at the 6- or 12-month follow-up sessions. In related literature, though the studies included larger sample groups, they were not, in general, normalized with respect to the number and localization of missing teeth, opposing occlusion, gender, and age. Therefore, despite the stated limitations, optimal standardization of the study groups in the present study may provide an advantage for the reliability of the results.

Impaired masticatory function has been suggested to be one of the main concerns of a reduced dental arch. Thus, the correlation between dental arch length and masticatory ability has been frequently evaluated through interviews with patients assessing their own chewing functionality. Objective masticatory function (defined as masticatory performance), though limited, has also been measured for patients with different lengths and symmetries of the SDA.[4]

An early study[22] compared patients' perceptions related to masticatory efficiency in 43 SDA subjects with the findings from 54 patients who had complete dentitions. The results indicated that while masticatory function and food selection were affected for SDA patients, the perceived reduction was within acceptable limits. Another study[5] evaluated the impact of the loss of posterior teeth on the efficacy of mastication by gradually removing posterior teeth from implant-retained copy overdentures in 10 edentulous patients. Thus, a complete dental arch was converted to a SDA with premolars, an extremely SDA without postcanine occlusal support, and to a broken dental arch with missing second premolars. Masticatory performance results demonstrated significant differences between the complete dental arch and other experimental conditions, with subjects becoming more inefficient in breaking apart test food as the number of teeth decreased. A more recent study[13] assessed the masticatory abilities of Tanzanian subjects with SDAs compared to those of adults with complete dental

arches. It was concluded that an SDA with intact premolar regions and at least one occluding pair of molars provided acceptable chewing ability. In contrast, masticatory ability was severely impaired when the subjects had a reduced number of occluding premolars and/or asymmetric arches, especially with hard foods. In the current study, SDA patients established masticatory performance measurements comparable to those of the CD group. This was a finding somewhat conflicting with the results of former investigations and can be explained in several ways. Initially, most of the studies referred to were conducted using chewing ability tests based on subjective perceptions, while the current study was performed using an objective masticatory performance test which has been defined as a more accurate and repeatable assessment modality than the chewing ability analysis.[11,23–25] Secondly, former studies included a diverse subject population with varying dental status, age, and gender. Study groups in this study were very similar regarding these criteria, apart from the difference in treatment concepts. Finally, in the intraindividual studies mentioned above, where technical restorative alternatives were interchangeable, adaptation periods between each restorative model were inadequate. All these variations might have produced the differences observed between our findings and those of other investigations. Moreover, in this study no significant differences in the masticatory performance of SDA patients were detected between follow-up sessions. This finding may be attributed to the fact that the patients had been edentulous without dentures for 4 to 9 years and therefore had functionally adapted to the reduced dental arch situation.[26]

The replacement of posterior teeth with a bilateral distal extension RPD is another treatment option.[2,27] A clear correlation between compromised dentition and the real need for prosthetic treatment with distal extension RPDs has not been established. Studies evaluating masticatory efficiency in partially edentulous patients before and after RPD treatment demonstrated improvements with the insertion of dentures.[4,11,28] In contrast, Witter et al[16] assessed the masticatory ability of subjects with either untreated SDAs or restored with RPDs and concluded that distal extension RPDs in the mandible did not contribute to oral comfort, including mastication. In this study, RPD patients demonstrated masticatory performance measurements that did not significantly differ from those of the SDA group. Also, in this group, insertion of the prosthesis did not remarkably increase masticatory performance when compared to values recorded without dentures. These results seem to confirm the findings of former studies that suggest that the restoration of missing posterior teeth with distal extension RPDs does not lead to concomitant improvements in masticatory function.[6,14] The presence of functional tooth units, adjacent to RPDs, is important to preserve a patient's masticatory performance.[11,18] Therefore, existence of functionally occluding premolars in the RPD and SDA groups in the current study might have also increased the masticatory performance to a level close to that of the CD group. A number of studies have reported that when bilateral RPDs are used to restore shortened mandibles, not only did the patients prefer not to wear them, there were also indications of adverse effects on the remaining teeth such as increased incidence of caries and periodontal breakdown.[10,12] These implications, together with the results of this study, suggest that SDA treatment may be an alternative to bilateral distal extension mandibular RPDs regarding masticatory capacity for middle-aged patients who have symmetrically located four functional units.

Occlusal force and amount of occlusal contact area of postcanine teeth are the main factors in determining masticatory functions.[5,18,29] In this respect, significant correlations have been reported between masticatory performance and maximum occlusal force for subjects with natural dentition, shortened arches, and dentate arches.[18] In the current study, CD and RPD groups demonstrated occlusal force and occlusal contact area values compliant with masticatory performance measurements. These findings are in agreement with those of previous studies. On the contrary, SDA patients established masticatory performance close to that of the RPD and CD groups despite remarkable reductions in their occlusal force and occlusal contact area. This may, in part, be attributed to the existence of functionally occluding premolars in SDA and RPD patients participating in the current study. Thus, SDA patients, when shifting their chewing platform to premolars and anterior teeth, might have performed masticatory functions comparable to those of the control group even though they had significantly lower occlusal force and occlusal contact area. Likewise, functionally occluding premolars in RPD patients might have produced the relatively high occlusal force and acceptable mastication, conflicting with the suggestion that denture wearers are seriously handicapped regarding both occlusal force and masticatory performance. Therefore, the existence of functional tooth units may be a key factor in the preservation of masticatory function. Mastication is one of the most complex functions of the human body. Therefore, apart from loss of postcanine teeth, occlusal contact area, and occlusal force, a variety of factors such as body size, sensory feedback, swallowing threshold, and saliva control the masticatory process.[25] These factors might have also affected the masticatory performance in the current study.

Conclusions

Within the limitations of this study, no statistically significant differences could be detected between SDA and RPD groups comprising middle-aged patients with bilaterally missing molars in the mandible. Therefore, SDA treatment may be an acceptable alternative to distal extension RPDs in these patients.

SDA patients established masticatory performance levels close to those of the CD and RPD groups despite remarkable reductions in their maximum occlusal force and occlusal contact area. Therefore, a variety of factors besides occlusal force and occlusal contact area seem to affect the quality of mastication.

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