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Influence of Length of Occlusal Support on Masticatory Function of Free-End Removable Partial Dentures: Short-Term Adaptation

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Abstract

Purpose: To analyze masticatory function after a short adaptation period relative to occlusal support length reduction in free-end removable partial denture (RPD) wearers.
Materials and Methods: Twenty-three patients (55.2 $\pm$ 8.4 years) were rehabilitated with maxillary complete and mandibular free-end RPDs extending to the second molars. Five occlusal support length conditions were determined by removing artificial teeth from the RPDs: full occlusal support (control); occlusal support to the first molars, second premolars, and first premolars; and no occlusal support. To explore a probable short-term adaptation to occlusal support length reduction, participants wore their dentures at each condition for a period of 1 week before starting masticatory function assessment. For this purpose, masticatory performance, masticatory efficiency, chewing rate, selection chance, and breakage function were evaluated at each condition using the sieving method. Data were analyzed using repeated-measures ANOVA and post hoc Dunnett tests ($\alpha = 0.05$).
Results: Masticatory performance and masticatory efficiency for 2 to 4 mm particles under the condition of occlusal support to the first molars and second premolars were similar to control values ($p > 0.05$). Masticatory efficiency relative to particles smaller than 2 mm was also seen at the condition of support length to the first premolars ($p > 0.05$). Chewing rates showed adaptation only at the condition of support length to the first molars ($p > 0.05$). A similar trend was noted for the selection chance of 8-mm particles, and breakage function for 8- and 2.4-mm particles ($p > 0.05$).
Conclusion: After a 1-week adaptation period to free-end RPDs with occlusal support lengths reduced to the premolars, participants were able to achieve adequate masticatory function.

Prosthodontic management in partially edentulous patients should prioritize the replacement and maintenance of strategically important parts of the dental arch, such as the anterior and premolar regions, to ensure bilateral occlusal support and masticatory function.[1] However, no well-defined recommendations for the management of free-end partially edentulous arches are available,[2] being that patients' perception of masticatory function due to missing posterior occlusal pairs may be a critical factor in making decisions about treatment.[3] Moreover, therapeutic approaches for such patients should also be based on individual assessments that consider periodontal health, occlusion, temporomandibular status, and parafunctional habits, which are especially important when occlusal support has been largely or completely lost.[4] Then, not only the timing of reduced arch rehabilitation, but also the appropriate length of artificial arches remain unclear.[5]

Al-Ali et al[6] found decreased masticatory efficiency in implant-retained overdenture wearers after the reduction of occlusal support length (OSL). Yanagawa et al[7] also observed a decreased food-mixing ability when the length of the food platform in Kennedy Class II removable partial dentures (RPDs) was reduced to 10 mm. Other studies[8–10] have suggested that oral rehabilitation may be restricted to the restoration of occlusal support to the premolar level. These studies have proposed that cantilever-fixed or implant-supported partial dentures may achieve greater patient comfort and acceptance than free-end RPDs. Decreased masticatory function may be related to alteration in the ability to select and break food produced by decreases in the available chewing surfaces[11] after the immediate reduction of OSL.[6,7] However, the present authors believed that different results would be obtained after a period of adaptation to the reduced OSL.

Periodontal afferent nerves are important for the control of mastication, send information about spatial changes of tooth loads to food particles, and encode in detail the temporal changes in force that occur immediately after contact with food.[12-14] During mastication, food particles are rhythmically selected and placed in available breakage sites.[15,16] Therefore, the proportion of comminuted particles increases after each masticatory cycle and decreases when other whole food particles are successively selected from new mouthfuls.[17] Although this cyclical process is altered when teeth are lost,[18] adaptation of masticatory muscles through neural changes on the primary motor and somatosensory cortexes was shown in rats 1 week after incisor removal.[19-21] Evidence for oral adaptation remains limited,[22,23] particularly in RPD wearers, but compensation for decreased comminution capacity might be achieved by different chewing rates or mandibular and soft-tissue movements.[24-26] This may generate alternative patterns of bolus control, increasing the selection chance, and breakage of food particles between chewing surfaces.[27]

Improvement in masticatory performance with fabrication of bilateral free-end RPDs can be influenced not only by prosthetic factors such as retention, stability, and support,[28] but also by physiological features such as reduced texture perception,[29] number of remaining natural teeth,[30] and lower transmission of muscle strength through artificial teeth.[31] Moreover, little is known about how these patients adapt their oral function to new oral environments.[32,33] Patients' functional requirements can vary considerably,[34] and each treatment should be adjusted to the patient's individual requirements and adaptation ability.[1] Thus, the aim of this study was to analyze masticatory function adaptation to reduced OSL in free-end RPD wearers by evaluating masticatory performance and efficiency, chewing rate, selection chance, and breakage function 1-week postinsertion of the prostheses.

Materials and methods

This clinical paired study involved a sample of 23 participants (5 males, 18 females; mean age 55.2 ± 8.4 years) with edentulous maxillae and Kennedy Class I mandibles. Test power calculation of the sample number was verified using SAS Power and Sample Size software version 3.1 (SAS Institute, Cary, NC). Analysis was accomplished considering a repeated measures design and significance level of 5%. This achieved a statistical power higher than 0.80. The sample allowed 114 degrees of freedom to the total data, and 88 degrees of freedom to the residue on ANOVA.

Inclusion criteria were maxillary edentulism and Kennedy Class I partial edentulism in the mandible. The presence of all incisor and canine mandibular teeth was also required. Patients with neuromuscular disease, or who presented with symptoms of temporomandibular diseases, parafunctional habits, xerostomia, severe periodontal disease, or severe bone resorption of residual ridges quantified by clinical examination and visual inspection of plaster casts, were excluded. The Ethics Committee of Piracicaba Dental School, State University of Campinas approved the research protocol; written consent was obtained from all volunteers.

Table 1 Optocal artificial test material components

Proportion	Material	Manufacturer
58.3%	Polydimethylsiloxane putty	Optosil Comfort, Heraeus Kulzer GmbH & Co., KG, Germany
7.5%	Toothpaste	Colgate-Palmolive, Co., Osasco, Brazil
11.5%	Vaseline®	Rioquímica, São José do Rio Preto, Brazil
10.2%	Dental plaster powder	Asfer, Indústria Química Ltda., São Caetano do Sul, Brazil
12.5%	Alginate powder	Jeltrate, Dentsply Indústria e Comércio Ltda., Petrópolis, Brazil
20.8 mg/g	Activador universal	Optosil Xantopren, Heraeus Kulzer GmbH & Co., KG, Hanau, Germany

Patients were rehabilitated with new maxillary conventional complete dentures and Kennedy Class I RPDs in the mandible after receiving periodontal and dental care of the remaining teeth from a single operator. RPDs were planned according to individual anatomical characteristics, including lingual plates or lingual bars as major connectors and circumferential or bar clasps as direct retainers. All frameworks were processed using Co-Cr cast metal. The artificial teeth (Dentsply Industria Ltd., Petropolis, Brazil) were mounted on wax occlusion rims on the RPD frameworks. Heat-cured acrylic resin (Dental Vipi, Pirassununga, Brazil) was used to process the denture bases. Occlusal support was established to the second artificial molars; bilateral balanced occlusion was obtained. Masticatory function measurements began 2 months after insertion of the new dentures for masticatory performance, masticatory efficiency, chewing rate, selection chance, and breakage function tests.

Masticatory performance, masticatory efficiency, and chewing rate measurements

Optocal artificial test food was prepared by mixing the components listed in Table 1 in a ceramic mortar.[35] Cubes of Optocal were prepared in metallic molds, measuring 5.6 mm on each edge, and completely polymerized in a stove for 16 hours at 65°C. Each participant chewed a portion of 17 Optocal cubes (~3 cm^3, 3.7 g) using 20 habitual chewing strokes counted by the examiner.[36] Comminuted particles were expectorated on a paper filter set on a glass container, followed by mouth rinsing with 200 ml of water to recover all material. The comminuted particles were dried at room temperature for 1 week, and then vibrated in a sieving machine (Bertel Indústria Metalúrgica,

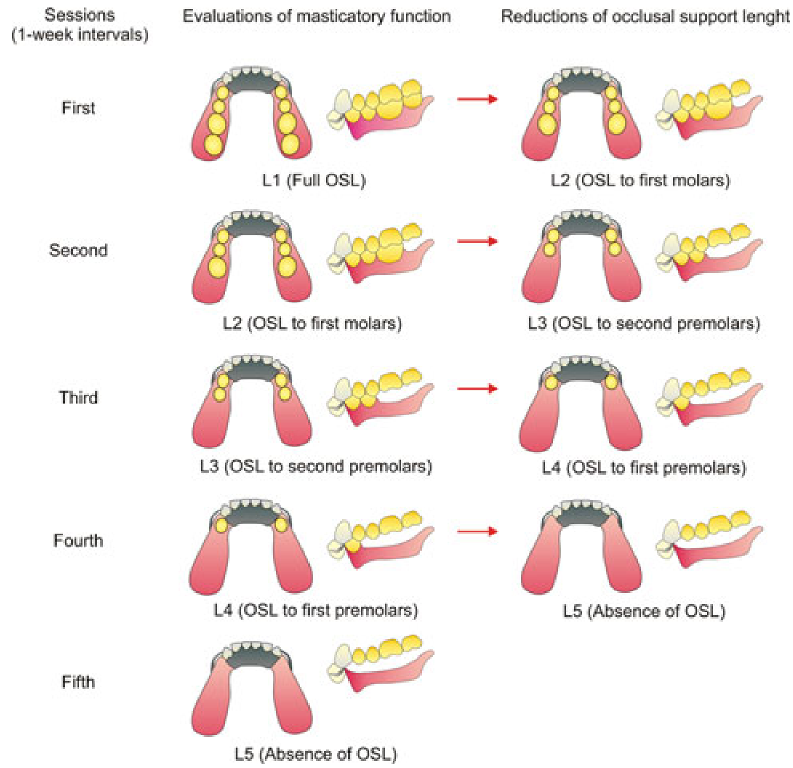

Figure 1 Occlusal support length (OSL) conditions and evaluation periods of masticatory function.

Caieiras, Brazil) using a sieve stack ranging from 5.6- to 0.5-mm mesh. Materials retained on each sieve and in the bottom pans were weighed on a 0.001-g analytical balance (Mark; BEL Engineering, Milan, Italy). Masticatory performance was determined by median particle size (X_{50}) calculated using the Rosin-Rammler cumulative function.[36] To investigate the behavior of comminuted coarse, medium, and fine Optocal particles,[37] masticatory efficiency was calculated as the percentage weight of the fractioned material that passed through the 4-, 2.8-, and 2-mm meshes.[38] The number of masticatory cycles performed per minute was defined as the chewing rate.[39]

Selection chance and breakage evaluations

Three sizes of Optocal cubes[35] (8.0-, 4.8-, and 2.4-mm edge sizes) were prepared as described earlier.[40] Each patient received 3 8.0-mm cubes, 12 4.8-mm cubes, and 68 2.4-mm cubes simultaneously, and was asked to make pseudo-chewing movements to obtain a natural dispersion of all cubes in the mouth and to produce saliva.[17,40-42] Thereafter, each participant was instructed to chew the particles for one real masticatory cycle.[41] The comminuted material was recovered, and the nondamaged (nonselected) particles were separated from the damaged and broken (selected) particles by visual inspection.[42] The selection chance of each particle size was calculated by dividing the weight of selected particles by the total weight of damaged and nondamaged particles. After sieving and weighing, breakage function was calculated by employing a cumulative distribution function, which determined the degree of fragmentation (r).[40-42]

Occlusal support length and evaluation periods

All masticatory function variables were first evaluated at baseline in participants using the new prostheses with a full OSL extending to the second molars (L1, control). The OSLs of the mandibular RPDs were then reduced to the first molars (L2) by removing artificial second molars using a low-speed cylindrical tungsten bur (Maxi Cut; Edenta, São Paulo, Brazil). Each patient was given 1 week to adapt to this new condition. Afterward, all masticatory function variables were again evaluated with the OSL reduced to the second premolars (L3) and then the first premolars (L4), followed by no occlusal contact (L5), with a 1-week adaptation period between each evaluation (Fig 1).

Statistical analysis

Parametric analysis was employed according to the additivity model, homogeneity of variances, and normality of residuals by guided data analysis with SAS statistical software (SAS Institute). No outliers were detected in the sample. Median particle size values were transformed to square values, and square root transformation was applied to masticatory efficiency and breakage function data for 2.4-mm cubes. Chewing rate and selection chance data were transformed to base-10 logarithms. One-way repeated-measures ANOVA and post hoc Dunnett tests were used to analyze variables. Correlation of masticatory performance and efficiency values were determined by Pearson's correlation test. Two-tailed tests were used performing a 5% significance level.

Table 2 Masticatory performance, masticatory efficiency, and chewing rate values (mean ± standard deviation)

Occlusal support length	Masticatory performance (mm)	Masticatory efficiency (%) 4-mm mesh	2.8-mm mesh	2-mm mesh	Chewing rate (cycles/min)
L1 (full support)	5.46 ± 0.64	20.43 ± 13.36	8.68 ± 6.58	3.75 ± 3.22	82.21 ± 14.68
L2 (to first molars)	5.51 ± 0.77	20.58 ± 15.52	8.63 ± 7.33	3.91 ± 3.93	85.38 ± 18.49
L3 (to second premolars)	5.64 ± 0.49	16.39 ± 10.46	6.84 ± 4.77	3.10 ± 2.45	88.08 ± 18.03*
L4 (to first premolars)	6.08 ± 0.48*	10.21 ± 9.10*	4.29 ± 4.63*	2.23 ± 2.76	90.22 ± 17.46*
L5 (none)	6.25 ± 0.39*	6.95 ± 5.29*	3.12 ± 2.75*	1.47 ± 1.64*	89.22 ± 18.88*

*Significant difference among occlusal support lengths ($p < 0.05$).

Table 3 Selection chance and breakage function values according to cube size (mean ± standard deviation)

	Selection chance			Breakage function (r)		
Occlusal support length	8 mm	4.8 mm	2.4 mm	8 mm	4.8 mm	2.4 mm
L1 (full support)	0.90 ± 0.16	0.41 ± 0.01	0.07 ± 0.02	0.39 ± 0.10	0.19 ± 0.08	0.05 ± 0.03
L2 (to first molars)	0.87 ± 0.17	0.34 ± 0.07*	0.05 ± 0.01*	0.39 ± 0.08	0.15 ± 0.08*	0.04 ± 0.03
L3 (to second premolars)	0.65 ± 0.12*	0.23 ± 0.07*	0.03 ± 0.01*	0.32 ± 0.10*	0.09 ± 0.06*	0.02 ± 0.02*
L4 (to first premolars)	0.45 ± 0.19*	0.15 ± 0.06*	0.02 ± 0.01*	0.23 ± 0.10*	0.06 ± 0.05*	0.01 ± 0.02*
L5 (none)	0.33 ± 0.10*	0.05 ± 0.06*	0.00 ± 0.01*	0.11 ± 0.10*	0.02 ± 0.03*	0.00 ± 0.00*

*Significant difference among occlusal support lengths ($p < 0.05$).

Results

Masticatory performance (mm) and efficiency (%) results according to each OSL are presented in Table 2. Reduction of the comminuted median particle size was similar for patients who chewed using dentures under the control, L2, and L3 conditions ($p > 0.05$); however, masticatory performance decreased after additional tooth removal ($p < 0.05$) compared with the control conditions. The same trend was observed for masticatory efficiency, but values differed ($p < 0.05$) for particles smaller than 2 mm only when participants chewed using RPDs without occlusal support (L5). Compared with the control condition (L1), chewing rate values were higher ($p < 0.05$) at all OSLs except the L2 condition. Median particle sizes (mean for the entire sample = 5.79 ± 0.64 mm) were correlated with masticatory efficiency with coarse (mean = 14.92 ± 12.40%; r = –0.865), medium (mean = 6.31 ± 5.82%; r = –0.823), and fine (mean = 2.89 ± 3.00%; r = –0.769) particles ($p < 0.0001$).

Selection chance and breakage function data (Table 3) for 8-mm cubes showed no difference ($p > 0.05$) between L2 and L1 OSLs. In addition, no difference in breakage function was noted between these OSLs for 2.4-mm cubes. Selection chance for 4.8- and 2.4-mm cubes and breakage function for 4.8-mm cubes were lower ($p < 0.05$) than control values at all OSLs (Table 3).

Discussion

Median particle sizes and masticatory efficiency were similar to those under control conditions in patients wearing RPDs with OSLs reduced to the premolars. This suggests masticatory adaptation to the loss of the molars. Aras et al[31] also reported similar masticatory performance in patients with arches reduced to the premolars and those rehabilitated with free-end RPD wearers after an 8-week adaptation period. Masticatory function adaptation probably occurred because molar function was compensated for by the premolars.[16] This assumption is supported by the high correlation observed between masticatory performance and masticatory efficiency for coarse particles (4-mm mesh). Masticatory efficiency results for medium particles (2.8-mm mesh) showed the same tendency, but represented less than 10% of masticatory efficiency within a higher dispersion, indicating irregular comminution. The percentage of particles smaller than 2 mm was even lower and showed the least correlation with median particle size. Therefore, the theory that artificial molars function analogously to natural teeth may be considered more important for comminuting smaller particles[5] because medium and coarse particles were affected mainly by premolars.[16] Larger particles were found to have a higher correlation with median particle size values.[38]

Bite force might be another factor contributing to masticatory function adaptation after loss of the first and second molars. Shinogaya et al[33] found that bite force increased at the premolars when molar occlusal surfaces were experimentally removed. This change could represent a compensatory mechanism to increase masticatory performance in patients wearing RPDs with reduced OSLs. Similarly, Ikebe et al[30] found that the preservation of occlusal contacts in bilateral premolars was a key predictor of occlusal force. Moreover, in patients lacking molar support, mastication could be adapted to shift the preferred chewing region to the premolar level.[32] Although this study did not evaluate bite force or preferred chewing side in patients using RPDs before and a week after OSL reduction, these factors could have contributed to the results.

A possible adaptation in chewing rate was observed for only the L2 OSL. The capacity to select particles during mastication may have been reduced in participants without artificial first molars or premolars. In those cases, the smaller number of Optocal particles compressed between the available occlusal surfaces may have facilitated mandibular movement to maximum intercuspal positions and increased the chewing rate, probably because of reduced occlusal phase duration.[25] This assumption is supported by Buschang et al[39] and Yoshida et al,[26] who observed that patients with higher chewing rates had reduced masticatory performance and poorer food-mixing ability, respectively.

The selection chance results suggested masticatory function adaptation at L2 OSLs for 8-mm particles. This finding may indicate that proprioceptive information encoded from the tongue, lips, and cheeks[12] enhanced placement of food particles between occlusal surfaces.[37] However, unlike the masticatory performance and efficiency results, the other conditions showed no improvement in selection chance results, possibly because the one-chew experiment did not allow compensation with additional masticatory cycles; this is an inherent limitation of this test. On the other hand, patients probably had more difficulty selecting smaller particles, as suggested by differences found between the control and L2 OSL conditions for 4.8- and 2.4-mm particles. This hypothesis was based on Engelen et al's study,[27] which determined that the perception of steel spheres with diameters less than 6 mm was not correlated with Optocal median particle size.

Analysis of breakage function also suggested adaptation at the L2 OSL for 8- and 2.4-mm particles. This result may be explained by the increase in force applied to the food. Although bite force may increase on the remaining teeth with reduced OSLs, the total bite force was lower due to the presence of fewer occluding teeth.[30] This may also explain the poor results in the other conditions. Furthermore, the selection of fewer particles limits the possibility of breakage function adaptation,[15] and comminution of larger particles is expected.[16] Breakage function was higher for 2.4-mm cubes than for 4.8-mm cubes under the L2 condition, probably due to the alteration in food particle manipulation during the one-chew experiment.

The adaptation of masticatory function to reduced OSL shown in this work could also be explained by considering the presence of natural mandibular anterior teeth in the studied patients. Whereas anterior teeth are used during initial food intake to manipulate and split the food into smaller pieces, posterior teeth are typically used during rhythmical chewing when jaw muscles produce strong axial and horizontal forces to grind food.[13] Periodontal afferents of teeth encode information about the directions of forces applied to individual teeth, which is important for the sensorimotor regulation of mastication.[18] Periodontal afferents of anterior teeth are more sensitive than posterior afferents to lower loads[14] and can regulate masticatory function in conjunction with the tongue and soft tissue,[11] thereby enabling adaptation in patients with reduced OSL. In contrast, because the role of artificial or natural posterior teeth is mainly mechanical,[24] the comminution capacity of the molars can be compensated by artificial or natural premolars. Furthermore, the new oral motor behaviors adopted by patients after tooth loss could determine neuroplastic changes in the facial sensorimotor cortex, establishing adaptive events learned gradually.[21]

The discussion of masticatory function adaptation should also include the role of craniofacial morphology. Patients with dolichofacial pattern, or long face syndrome, may have more difficulty in adaptation due to their unfavorable mechanical characteristics.[34] This condition may include a steep mandibular plane angle or hyperdivergent growth, excessive height of the maxilla, long anterior lower face height with open bite tendency, and lip incompetence, and is often associated with Class II malocclusion. Besides, 1-week assessments may be limited for adaptation inferences; however, previous studies in animals[19,20] and humans[22,23] have shown positive results to functional adaptive challenges. Thus, since oral rehabilitation using the shortened dental arch concept is still discussed, a short-term reversible treatment could be useful to understanding adaptation processes. To clarify these issues, this study may be complemented by further longitudinal research examining periodontal, muscular, and temporomandibular joint status in posterior partially edentulous patients. Reduction of occlusal surface area may also be measured.[7] However, as the size of the artificial teeth was different among patients, this variable was not included. In addition, considering that a paired design was employed and participants were compared with themselves, the effects of this confounder was minimized. This topic may be considered a methodological restriction; therefore, other studies in patients presenting similar arch dimensions may be necessary to improve the study. Within the limitations of this study, participants appeared to adapt masticatory function to OSL reduction to the artificial premolars, despite the structural importance of RPD molars.[16] These results can be applied to food with lower or similar hardness and similar texture to the test food used in the masticatory function analysis.

Conclusion

After a 1-week period, the examined patients were able to adapt their masticatory function to the removal of the second and first artificial molars from mandibular distal extension RPDs. Therefore, despite reduction of OSL to premolars, participants experienced significant improvements in masticatory performance and efficiency, as well as on the capacity to select and break the test foods. Similar values to the control conditions were noted.

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