

Original Article

## Masticatory function after unilateral distal extension removable partial denture treatment: intra-individual comparison with opposite dentulous side

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Due to large individual differences of masticatory function, an inter-individual comparison between denture patients and complete dentate people would be insufficient. This cross-sectional study aimed to evaluate patients' masticatory performance (determined by Mixing Ability Index, MAI) and bite force (determined by maximum bite force, MBF) after removable partial denture (RPD) treatment by comparing those of the RPD replaced side with those of their own opposite dentulous side, and to evaluate influence of bite force on masticatory performance in different dentitions. Subjects included patients with unilateral distal extension RPDs (n=28). Apart from the RPD replaced area on one-side, all subjects had intact dentitions. Both masticatory parameters were evaluated separately on each chewing side. MAIs and MBFs obtained from the RPD replaced side ( $0.65 \pm 0.50$  and  $220 \pm 155$  N, mean  $\pm$  SD) were significantly lower than those from the dentulous side ( $1.06 \pm 0.64$  and  $450 \pm 268$  N; Wilcoxon signed-ranks,  $P < 0.001$ ). MBF significantly influenced MAI in both RPD replaced (Univariate linear regression;  $R^2=0.17$ ,  $P < 0.001$ ) and dentulous sides ( $R^2=0.51$ ,  $P < 0.001$ ). After RPD treatment, masticatory performance and bite force of RPD

replaced side were lower than those of their own dentulous side. The influence of the bite force on masticatory performance in RPD replaced side was less significant than that in the dentulous side.

**Key words:** Mastication, Masticatory performance, Bite force, Kennedy class II, Unilateral distal extension RPD

### Introduction

Rehabilitation of missing dentitions with removable partial dentures (RPDs) is often utilized to improve patients' masticatory function. However, even if all missing teeth have been replaced, the masticatory function is usually improved to a lesser extent than that of the previous complete dentition. However, within our knowledge, this faith has been rarely confirmed by an intra-individual study. The transition of patients' masticatory function when switching from a complete dentate to RPD replaced condition remains unclear.

In the past, most studies employed masticatory performance and/or bite force as the objective measurements in evaluating masticatory function. Denture patients were reported as handicapped and have less masticatory performance<sup>1-10</sup> and bite force,<sup>8-12</sup> than people with natural dentitions. In inter-individual comparisons, masticatory performance and bite force of denture patients were about one-half to one-sixth those of dentate subjects, depending mainly on type of dentures and numbers and distribution of remaining teeth.<sup>5-7,10,11</sup>

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From the above-mentioned studies, it is logical to assume that the masticatory function after complete dentition state was impaired after transformation to partial and/or complete denture state. On the other hand, most studies reported a wide range in the masticatory performance of denture patients,<sup>4,9,13-15</sup> and also people with natural dentitions,<sup>16-18</sup> within groups of subjects with similar state of dentitions. These may be explained by the influence of various human physiological factors (e.g. bite force, oral sensorimotor function, masticatory pattern, etc.) on masticatory performance.<sup>19-25</sup> Hatch et al suggested that masticatory performance is the outcome of complex interrelationships among physiological and contextual variables, leading to a difference in masticatory performance between individuals.<sup>23</sup> Bite force showed a similar pattern as the masticatory performance; within groups with identical characteristics, the bite force ranged widely in denture patients<sup>8,9,11,26,27</sup> and people with natural dentitions.<sup>8,9,11,17</sup> Therefore, the patients' masticatory function after denture treatment should not be determined only by studies employing an inter-individual comparison.

The present cross-sectional study intended to evaluate patients' masticatory function after RPD treatment by comparing that of the RPD replaced side with that of their own opposite dentulous side. All patients who attended the study had a unilateral partially posterior edentulous area replaced with distal extension RPD, opposing a complete natural dentition, while the maxillary and mandibular dentitions were intact on the opposite side of the mouth. Intra-individual comparisons of masticatory performance were performed on each side. By eliminating inter-individual variables, the patients' masticatory function after RPD treatment could be evaluated with this more valid approach.

In dentate people, determinants of masticatory performance are bite force and numbers of functional tooth units, i.e. pairs of occluding posterior teeth.<sup>23</sup> Greater bite force and more occluding posterior teeth facilitate better food breakage. On the other hand, Fontijn-Tekamp et al. reported significant but low correlation between bite force and masticatory performance in overdenture and complete denture patient groups.<sup>8</sup> However, the influence of bite force on masticatory performance of patients using dentures, especially RPD, has rarely been studied. The role of bite force in masticatory performance of RPD patients after all missing teeth are replaced remains unclear.

Aims of this study were to evaluate (1) patients' masticatory function after RPD treatment by comparing that of the RPD replaced side with that of their own opposite

dentulous side, (2) influence of bite force on masticatory performance in RPD replaced and dentulous sides, and (3) relationship between masticatory performance and bite force in intra-individual difference between the RPD replaced and dentulous sides.

## Materials and methods

### Subjects

Twenty-eight subjects (9 males and 19 females), who attended the Removable Prosthodontics clinic, Tokyo Medical and Dental University for maintenance were included. The mean age of subjects was  $60.5 \pm 6.2$  years. All subjects had either a maxillary (12 subjects) or mandibular (16 subjects) partially posterior edentulous area, equal to Kennedy class II modification 0, replaced with unilateral distal extension removable partial dentures (RPD) up to artificial second molar (mean restored  $2.3 \pm 0.7$  teeth, range 2-4 teeth). None of them complained about discomfort or pain at the experiment time. At the time of data collection, the dentures had been worn for at least 6 months (mean  $11.1 \pm 3.8$  months). Except for the RPD replaced area, subjects had complete natural dentitions (included restored or fixed prosthetic teeth) to the second molars. They presented with one RPD replaced area opposing a complete dentition, on one side of the mouth (RPD replaced side) and complete maxillary and mandibular dentitions on the opposite side of the mouth (dentulous side). Table 1 shows the characteristics of subjects participated in this study. Patients were excluded if abutment teeth had greater than grade 1 mobility (more than +19 Periotest value) evaluated by Periotest<sup>®</sup> (Siemens, Bensheim, Germany), and if they had any signs or symptoms of temporomandibular joint disorders. The protocol was reviewed and approved by the Ethics Committee for Human Research of the Tokyo Medical and Dental University.

**Table 1.** Subject characteristics participated in the study.

Replaced arch	Numbers of replaced teeth			Total
	2	3	4	
Maxilla	9	1	2	12
Mandible	13	2	1	16
Total	22	3	3	28

Prior to inclusion, written informed consent was obtained from all subjects after a full explanation of the study.

**Denture design**

Patients with 2 missing teeth (first and second molars) were replaced with unilateral design distal extension RPDs,<sup>28</sup> while patients with 3 or 4 missing teeth (from second or first premolar to second molar) were replaced with bilateral design distal extension RPDs.<sup>29</sup> The denture designs used in this study are shown in Table 2.

**Masticatory performance**

Mixing Ability Index (MAI) was obtained from a chewing test with a standard two-colored wax cube to determine masticatory performance.<sup>30</sup> The MAI is calculated from the degree of color mixing and shape deformation of the chewed wax. Details of the technique,<sup>30</sup> as well as its reliability and concurrent validity to the original comminuted sieving method,<sup>31</sup> have been described previously. Subjects were asked to chew a wax cube for 10 strokes separately on one side. The mean of 3 actual tests represented the MAI of each side. The Intraclass Correlation Coefficients (ICC) for the test-retest consistency of the RPD replaced side and dentulous side, determined after the test was performed again at one month in 12 randomly selected subjects, were 0.95 and 0.92 respectively.

**Bite force**

Bite force was determined by maximum bite force (MBF), which was assessed unilaterally using a force transducer, Occlusal Force Meter (GM-10, Nagano keiki, Tokyo, Japan). To assess MBF of the RPD replaced side, the force transducer was positioned on the occlusal surface of the artificial first molar; while on the dentulous side, it was positioned on that of the

mandibular natural first molar. Subjects were seated upright in a dental chair and were trained before the actual test to create confidence. The highest value out of 3 tests, with a one-minute rest between tests, represented the MBF for each side. The ICC for the test-retest consistency of both sides with one-month interval was 0.95 (n=12).

**Statistical Analysis**

Wilcoxon signed-ranks test was performed to test the effect of chewing sides (RPD replaced side / dentulous side) on MAI and MBF respectively. The univariate linear regression analysis was performed to test the influence of the MBF on MAI of each chewing side respectively. Intra-individual difference of MAI ( $\Delta$ MAI) and that of MBF ( $\Delta$ MBF) between both sides were obtained as paired data from each subject. Then, Pearson correlation coefficient was used to examine relationship between the  $\Delta$ MAI and the  $\Delta$ MBF. Additionally, the effects of replaced arches (maxilla / mandible) and numbers of replaced teeth on the MAI and MBF were tested with independent t-test (replaced arches) and with one-way analysis of variance (numbers of replaced teeth), respectively. All tests were two-tailed, with a significance level at  $P < 0.05$ . Data were analyzed using SPSS version 10.0J (SPSS Japan Inc., Tokyo, Japan).

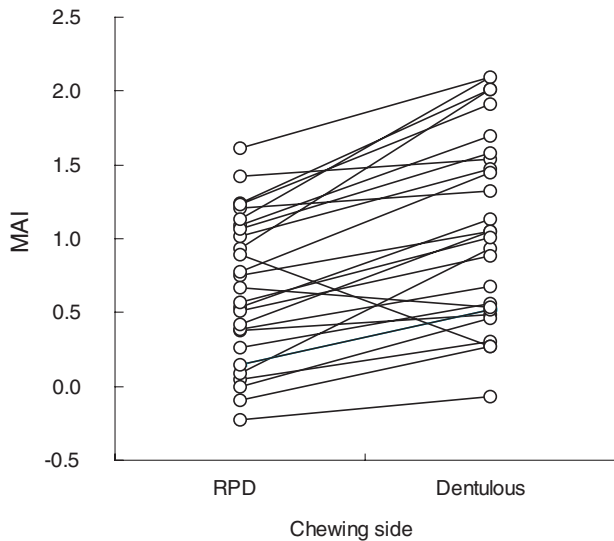
**Results**

The MAIs and MBFs on the RPD replaced and dentulous sides are shown in Figures 1 and 2 respectively. The mean MAI of the RPD replaced side ( $0.65 \pm 0.50$ , mean  $\pm$  SD) was significantly lower ( $P < 0.001$ ) than that of the dentulous side ( $1.06 \pm 0.64$ ). The mean MBF obtained from the RPD replaced side ( $220 \pm 155$  N) was also significantly lower ( $P < 0.001$ ) than that obtained from the dentulous side ( $450 \pm 268$  N).

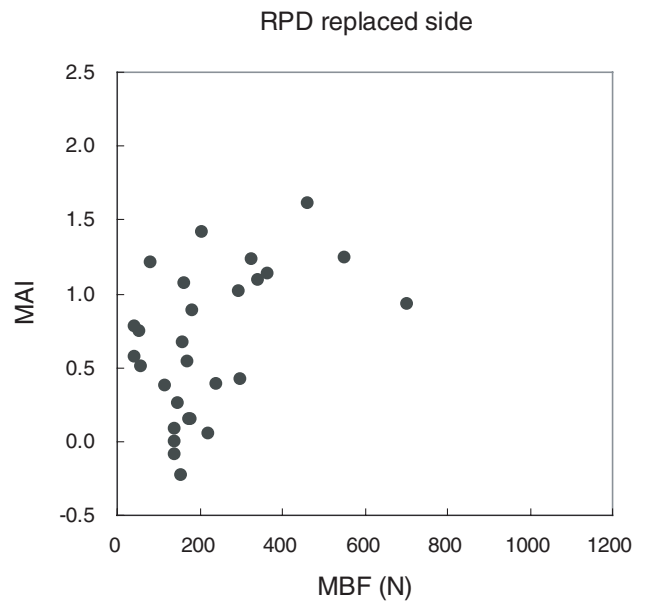
From univariate linear regression analyses, influence of the MBF on MAI in the RPD replaced side (adjusted  $R^2=0.17$ ,  $P < 0.001$ ; Figure 3) was significant, but lower than that in the dentulous side (adjusted  $R^2=0.51$ ,  $P < 0.001$ ; Figure 4). Moreover, no significant correlation was found between  $\Delta$ MAI and  $\Delta$ MBF ( $r=0.31$ ,  $P=0.10$ ; Figure 5). In the RPD replaced side, MAI and MBF of patients with maxillary RPDs were not significantly different compared to those of patients with mandibular RPDs (Table 3). Similar results were found among patients with different numbers of replaced teeth (Table 4).

**Table 2.** Numbers of replaced teeth and their corresponding denture designs

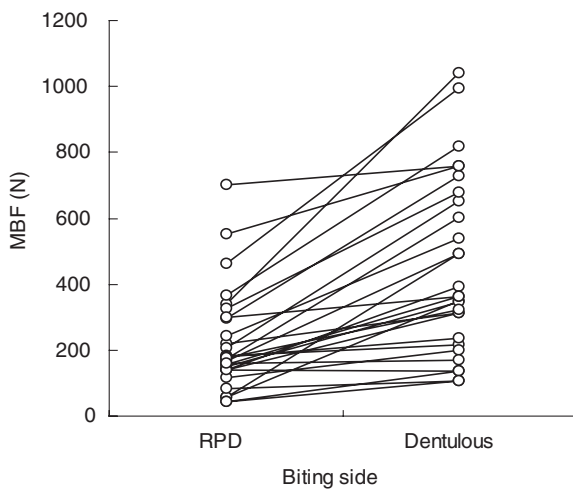
Numbers of replaced teeth	Denture designs
2	Unilateral design, a Back-action clasp and mesial occlusal rest on the second premolar, an embrasure hook on the first premolar and canine
3	Bilateral design, a Back-action clasp and mesial occlusal rest on the first premolar, an embrasure clasp on the opposite premolars or the second premolar and the first molar
4	Bilateral design, a cast or wrought-wire retentive clasp arm and a cingulum rest on the canine, an embrasure clasp on the opposite premolars or the second premolar and the first molar



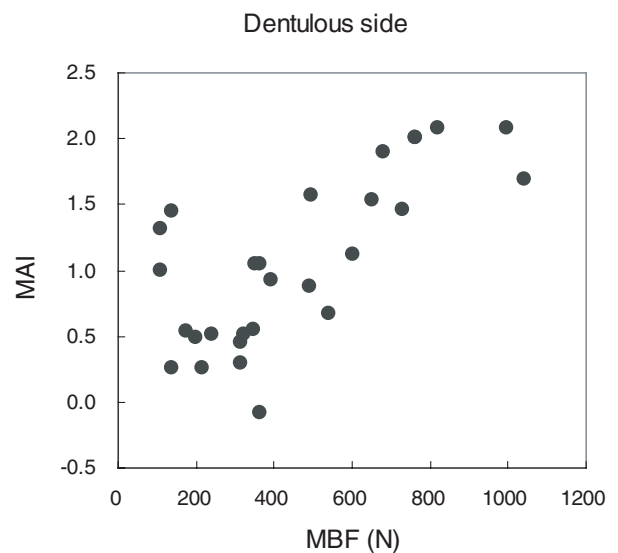
**Figure 1.** Mixing Ability Indexes (MAI) obtained from the removable partial denture replaced side (RPD) and the dentulous side (Dentulous).



**Figure 3.** Scattered plot between Mixing Ability Indexes (MAI) and maximum bite forces (MBF) in removable partial denture replaced side.



**Figure 2.** Maximum bite forces (MBF) obtained from the removable partial denture replaced side (RPD) and the dentulous side (Dentulous).

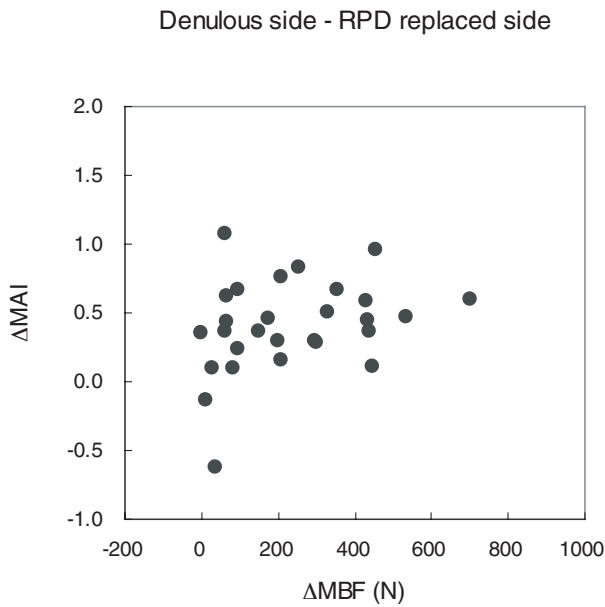


**Figure 4.** Scattered plot between Mixing Ability Indexes (MAI) and maximum bite forces (MBF) in dentulous side.

**Discussion**

To evaluate patients' masticatory function after denture treatment, the masticatory performance and the bite force, determined by the MAI and the MBF respectively, were separately assessed and were intra-individually compared between the RPD

replaced and dentulous sides. In this study, the test of chewing and biting on the dentulous side simulated the test in the condition before missing teeth. This simulation enables intra-individual comparison of masticatory function between the condition before missing teeth and that after RPD treatment. When individual differences among subjects were eliminated, the present study



**Figure 5.** Scattered plot between intra-individual differences of Mixing Ability Indexes ( $\Delta$ MAI) and intra-individual differences of maximum bite forces ( $\Delta$ MBF).

**Table 3.** Means and standard deviations of Mixing Ability Indexes (MAI) and maximum bite forces (MBF) of patients with RPDs on maxilla and mandible.

Replaced arches	MAI	MBF (N)
Maxilla	0.53 $\pm$ 0.50	170 $\pm$ 79
Mandible	0.73 $\pm$ 0.49	252 $\pm$ 184
<i>P</i>	0.30	0.18

**Table 4.** Means and standard deviations of Mixing Ability Indexes (MAI) and maximum bite forces (MBF) of patients with different numbers of replaced teeth.

Numbers of replaced teeth	MAI	MBF (N)
2	0.76 $\pm$ 0.49	240 $\pm$ 170
3	0.18 $\pm$ 0.24	135 $\pm$ 16
4	0.30 $\pm$ 0.32	159 $\pm$ 17
<i>P</i>	0.07	0.48

confirmed findings of past studies indicating impaired masticatory performance<sup>1-10</sup> and bite force<sup>8-12</sup> in denture patients.

van der Bilt et al. previously reported that masticatory performance was improved by posterior tooth replacement with RPDs.<sup>32</sup> They demonstrated that the masticatory performance after posterior tooth replacement improved to approach the level of the complete dentate control group. However, such a conclusion was based on inter-individual comparisons between denture patients and people with complete dentition. Many longitudinal studies reported improvement of masticatory performance after RPD treatment, however all of their baseline data were obtained from partially edentulous condition, just before the treatment.<sup>13,32-34</sup> None of these studies reported findings that were derived from the complete dentition state. The results of the present study suggest that, after RPD treatment, the masticatory function of RPD replaced side does not reach the level of patients' own opposite dentulous side. Although the subjects of this study presented with mildly deteriorated conditions such as one partially posterior edentulous area with 2-4 missing teeth, impaired masticatory function was also observed after denture treatment.

A significant influence of bite force on masticatory performance was found in both dentulous and RPD replaced sides, although the latter showed lower coefficient. Estimated from the  $R^2$  value, in dentulous side, the bite force could explain fifty-one percent of the individual difference in masticatory performance. This result is consistent with findings of a previous study indicated that bite force had an important influence on masticatory performance of dentate people.<sup>23</sup> In the RPD replaced side, bite force could explain only seventeen percent of individual difference of masticatory performance. This result was similar to findings reported in patients wearing overdentures.<sup>8</sup> Additionally, no significant correlation was found between the differences in masticatory performance and bite force in the RPD replaced and dentulous sides. This might be due to a low correlation between bite force and masticatory performance in the RPD replaced side. These findings suggest a significant, but small, contribution of the bite force on masticatory performance in RPD replaced side compared to that in dentulous side.

As mastication has been defined as the combined process of fragmentation, selection of food particles, and mixing of food bolus,<sup>35,36</sup> the retention and stability of dentures could affect the selection process of food

particles and in turn, reduce masticatory performance in denture patients. Although we included only patients with qualified dentures, these denture factors could certainly affect masticatory performance in the RPD replaced side. And thus, these factors might reduce contribution of the bite force on masticatory performance. It is also possible to consider that RPD replaced arches (maxilla / mandible) and numbers of replaced teeth may affect the MAI and MBF of denture patients. In this study, although patients who were replaced 2 teeth (first and second molars) tended to show higher MAI and MBF than those who replaced more than 2 teeth, the significant effect of numbers of replaced teeth and RPD replaced arches was not found. One explanation for this result may be small numbers of subjects with more than 2 replaced teeth (6 subjects) were included, comparing to those with 2 replaced teeth (22 subjects). This may be a limitation of subject distribution. And thus, the effect of numbers of replaced teeth on masticatory function after denture treatment cannot be concluded by the present study.

Studies in complete denture patients suggested that impaired oral sensorimotor function decreases masticatory performance.<sup>7,25</sup> Oral sensorimotor function possibly plays an important role in mastication of PRD patients as well. In addition, the condition of residual ridge and mandibular movement might affect their masticatory performance. Thus, further studies are necessary to find other anatomical and functional factors associated with masticatory performance in patients using RPDs.

### Conclusion

Within the limitations of this cross-sectional intra-individual study, after rehabilitation of Kennedy class II edentulous areas with unilateral distal extension RPDs, patients' masticatory performance and bite force of the RPD replaced side are lower than those of their own opposite dentulous side. Influence of the bite force on masticatory performance of the RPD replaced side is less than that of the opposite dentulous side.

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