

Effect of Dental Rehabilitation on Masticatory Function Following Jaw Reconstruction

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Purpose: This study examined the effect of dental implant rehabilitation on masticatory function following jaw reconstruction. **Materials and Methods:** Patients who received dental rehabilitation after jaw reconstruction with a fibular or iliac bone flap from 2012 to 2018 were examined for masticatory efficiency, electromyographic (EMG) activity of the masticatory muscles, and the distribution of occlusal force. The masticatory efficiency was measured by a spectrophotometer. The asymmetry index of the masticatory muscle was calculated by EMG measurement, and the asymmetry index of the occlusal force was calculated by T-scan analysis. **Results:** A total of 32 patients were examined, 13 with implant-retained fixed dental prostheses, 9 with implant-retained removable dental prostheses, and 10 with removable dental prostheses. Masticatory efficiency was significantly lower in the removable dental prosthesis group (2.29 ± 0.19) than in the implant-retained removable dental prosthesis (2.45 ± 0.03 , $P < .05$) and implant-retained fixed dental prosthesis groups (2.45 ± 0.03 , $P < .05$). Moreover, the asymmetry index of the masticatory muscle while chewing and clenching was significantly higher in the removable dental prosthesis group (0.099 ± 0.046 and 0.107 ± 0.042 , respectively) than in the implant-retained removable dental prosthesis (0.032 ± 0.019 and 0.035 ± 0.021 , respectively; $P < .01$) and implant-retained fixed dental prosthesis groups (0.038 ± 0.021 and 0.046 ± 0.023 , respectively; $P < .01$). The asymmetry index of the occlusal force was also significantly higher in the removable dental prosthesis group than in the implant-retained removable dental prosthesis (0.38 ± 0.08 , $P < .01$) and implant-retained fixed dental prosthesis groups (0.36 ± 0.11 , $P < .05$). **Conclusion:** The results of this study suggest that dental implant prostheses have a greater effect on masticatory function following jaw reconstruction, improving masticatory efficiency, EMG activity of the masticatory muscles, and occlusal force. *Int J Oral Maxillofac Implants* 2022;37:494–500. doi: 10.11607/jomi.9337

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Restoration of masticatory function is an important consideration of jaw reconstruction. A revascularized bone free flap is generally used in jaw

reconstruction to improve appearance and recover oral function^{1,2}; however, the recovery of masticatory function depends largely on the prosthetic rehabilitation employed.³ Dental rehabilitation after jaw reconstruction is particularly challenging since the reconstructed bone lacks keratinization and attached soft tissue, resulting in an unstable and nonfunctional prosthesis.⁴ Dental implants have therefore been widely used to restore masticatory function, with promising results.⁵

Differences in masticatory function also exist between removable dental prostheses and implant-supported prostheses. For example, a previous study of edentulous patients revealed that those with implant-supported prostheses demonstrated a higher level of masticatory efficiency and maximum voluntary occlusal force than those with removable dental prostheses.⁶ Meanwhile, further studies found that implant-retained fixed dental prostheses performed better than implant-retained removable dental prostheses in terms of esthetics, masticatory function recovery, and implant survival.^{7,8} The differences in masticatory function following jaw reconstruction with an implant-supported

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prosthesis and removable dental prosthesis have also been examined, revealing conflicting results. For example, Ciocca et al⁹ compared the differences in masticatory efficiency and health-related quality of life between implant-supported prostheses and removable dental prostheses but revealed no significant differences. Meanwhile, Roumanas et al¹⁰ found that both removable dental prostheses and implant-supported prostheses improved masticatory function to the pre-operative functional level, although restoration on the defective side was significantly greater in the implant-supported prosthesis group than in the removable dental prosthesis group.

Dental implant rehabilitation of reconstructed bone involves either a fixed or removable prosthesis. However, comparative analyses of implant-retained fixed dental prostheses and implant-retained removable dental prostheses following jaw reconstruction are lacking. The primary aim of this study, therefore, was to evaluate the effect of dental implant rehabilitation on masticatory function following jaw reconstruction with a removable dental prosthesis, implant-retained fixed dental prosthesis, and implant-retained removable dental prosthesis.

MATERIALS AND METHODS

Ethical Approval

This research was conducted in accordance with the tenets of the Declaration of Helsinki and approved by the institutional ethics committee of Peking University School and Hospital of Stomatology (PKUS-SIRB-202055065) and registered on the Chinese Clinical Trial Registry (Registration number: ChiCTR2000034964; <http://www.chictr.org.cn/listbycreator.aspx>). All patients provided written informed consent to participate in the study.

Patients

Patients referred to the Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China, for jaw resection and rehabilitation between May 2012 and November 2018 were enrolled in this study. Inclusion criteria were as follows: (1) the patient received a fibular or iliac bone free flap for jaw reconstruction; (2) one or more molars were lost due to the jaw defect; (3) the patient received a removable dental prosthesis, implant-retained fixed dental prosthesis, or implant-retained removable dental prosthesis; and (4) the patient was willing to undergo the masticatory function test. Exclusion criteria were: (1) the patient underwent radiotherapy; (2) the patient had missing teeth that were not caused by a jaw defect; (3) the patient underwent dental prosthesis rehabilitation

for < 6 months; and (4) poor prosthesis stability when clenching and chewing.

Patients were divided into one of the following three groups according to their type of prosthesis: the removable dental prosthesis group, implant-retained fixed dental prosthesis group, and implant-retained removable dental prosthesis group (Fig 1). The masticatory efficiency, electromyographic (EMG) activity of the masticatory muscles, and distribution of occlusal force were then measured in all patients in the double blind method.

Masticatory Efficiency

Masticatory efficiency was measured with a colorimetric method by chewing capsules, which was described by Escudeiro Santos et al.¹¹ The capsules were made with plastic casings (0.2 mm) in an oval shape (50 mm × 35 mm) and contained 250 mg of standardized fuchsin violet granules following unified standards. The tester was not told the patient characteristics. Then, the patients were asked to chew the capsules with habitual chewing movements for 20 seconds, and no additional information was provided to the patients.

The beads were identified, and the triturated content was placed in a beaker, dissolved in 5 mL of water, and constantly stirred for approximately 30 seconds. The optical density of fuchsin solution intensity was then measured using a 752 UV-Vis spectrophotometer as optical density. The results were used to directly reflect masticatory efficiency. The masticatory efficiency with the prosthesis was measured in each group along with the masticatory efficiency without the prosthesis in the removable dental prosthesis and implant-retained removable dental prosthesis groups. The change in masticatory efficiency with and without the prosthesis was then calculated as follows using the obtained results:

Change in masticatory efficiency (%) = (the masticatory efficiency with prosthesis – the masticatory efficiency without prosthesis)/the masticatory efficiency without prosthesis.

Electromyographic Analysis

EMG activity was examined using a standardized masticatory test and recorded using electromyography (Meb-5508; Nihon Kohden). Briefly, bipolar surface electrodes were placed over the masseter and temporalis muscles on both sides during the masticatory performance test. Analysis of EMG activity during clenching was performed by placing two 10-mm-thick cotton rolls on the mandibular second premolars and first molars.¹⁰ EMG activity during chewing was measured while chewing sugarless gum.¹² Muscle activity was then assessed using the mean amplitude results. EMG activity of the non-defective temporal muscle, defective temporal muscle, nondefective masseter muscle, and defective masseter

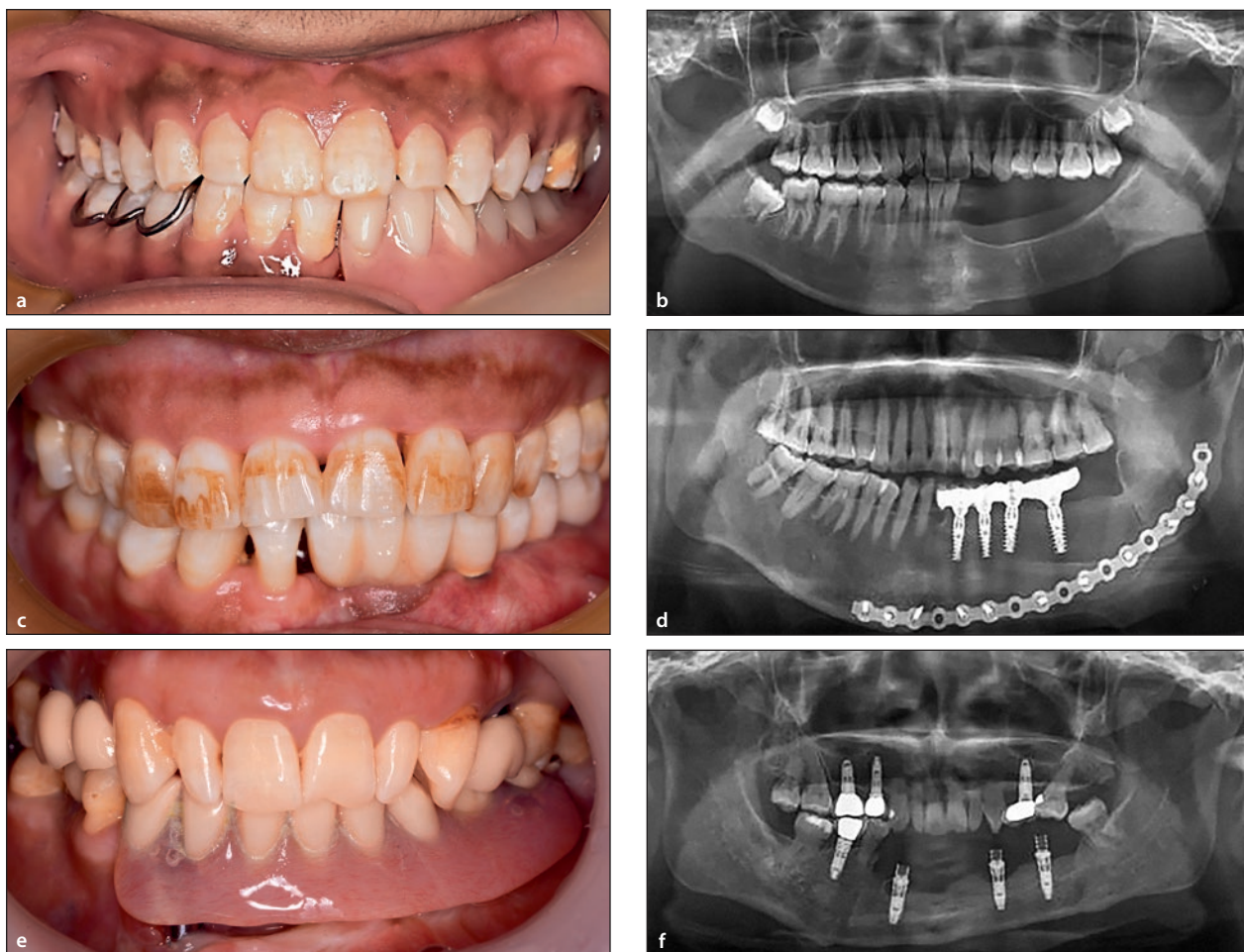


Fig 1 Intraoral views and panoramic radiographs of prostheses. (a and b) Removable dental prosthesis. (c and d) Implant-retained fixed dental prosthesis. (e and f) Implant-retained removable dental prosthesis.

muscle were measured and recorded, respectively. Then, the asymmetry index of bilateral masticatory muscles was calculated as follows:

Asymmetry index of masticatory muscle (%) = (nondefective muscles – defective muscles) / (nondefective muscles + defective muscles).

Distribution of Occlusal Force

The distribution of occlusal force was evaluated as described previously using a T-Scan III system (Tekscan).¹³ The positions of implants and missing teeth and the width of the maxillary central incisor were recorded, and the mandibular occlusal plane was adjusted so it was parallel to the ground. The sensor was then placed between the maxillary and mandibular teeth, and the patient was asked to occlude naturally until reaching intercuspal occlusion and then to remain like that for approximately 1 second. Then, the occlusal force on the nondefective side and occlusal force on the defective side were measured and recorded, respectively. The asymmetry index of the occlusal force was calculated as follows:

Asymmetry index of occlusal force (%) = (nondefective side – defective side) / (nondefective side + defective side).

Statistics and Data Analysis

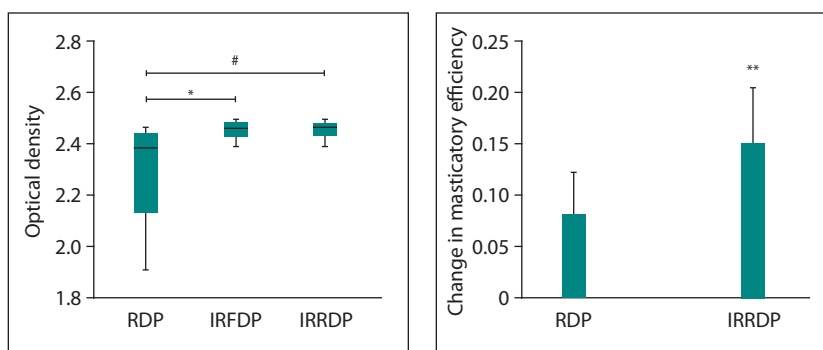
The masticatory efficiency, EMG activity, and distribution of occlusal force results were analyzed using SPSS software version 20.0 (SPSS). All results are expressed as mean \pm SD. Differences between the three groups were determined using an independent sample *t* test. Chi-square analysis was used to determine the effects of sex, the site of reconstruction, and the type of graft on prosthesis type; analysis of variance was used to analyze the effect of age. The significance was set at $P < .05$.

RESULTS

A total of 32 eligible patients were included in the study. They consisted of 19 male patients and 13 female patients, ranging in age from 17 to 76 years, with a median age of 34 years. Of these, 13 patients belonged to

Fig 2 (Left) Boxplot of masticatory efficiency as determined by optical density in the three study groups (RDP = removable dental prosthesis; IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis). * $P < .05$ vs IRRDP, # $P < .05$ vs IRFDP.

Fig 3 (Right) Change in masticatory efficiency in the implant-retained removable dental prosthesis and removable dental prosthesis groups. RDP = removable dental prosthesis; IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis. ** $P < .01$ vs IRRDP.



the implant-retained fixed dental prosthesis group, 9 to the implant-retained removable dental prosthesis group, and 10 to the removable dental prosthesis group. The median follow-up time was 17 months. During the follow-up period, all dentures remained stable and functional. Patient characteristics of each group are shown in Table 1. Prosthesis type showed no significant correlation with sex, age, site of reconstruction, or type of graft ($P < .05$).

Masticatory efficiency as determined by optical density was 2.45 ± 0.03 in the implant-retained fixed dental prosthesis group, while in the implant-retained removable dental prosthesis group, the efficiency with the prosthesis was 2.45 ± 0.03 , while that without the prosthesis was 2.13 ± 0.08 . In the removable dental prosthesis group, the masticatory efficiency with the prosthesis and without the prosthesis was 2.29 ± 0.19 and 2.12 ± 0.24 , respectively. Overall, the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups had a significantly higher masticatory efficiency than the removable dental prosthesis group ($P < .05$), and there was no significant difference between the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups (Fig 2). In addition, the change in

Table 1 Patient Characteristics

	IRFDP	IRRDP	RDP
Total participants	13	9	10
Male	7	7	5
Female	6	2	5
Age (y)	31.15 ± 9.94	47.56 ± 11.94	41.70 ± 19.90
Site of reconstruction			
Maxilla	5	3	3
Mandible	8	6	7
Vascularized bone flap			
Fibula	8	7	7
Iliac bone	5	2	3

IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis; RDP = removable dental prosthesis.

masticatory efficiency was higher in the implant-retained removable dental prosthesis group (0.15 ± 0.05) than in the removable dental prosthesis group (0.08 ± 0.04 , $P < .05$, Fig 3).

EMG activity and asymmetry index of masticatory muscle are shown in Tables 2 and 3. The asymmetry index of masticatory muscle was significantly lower in the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups than in the removable dental prosthesis group when clenching and chewing ($P < .01$). Moreover, there was no significant difference between the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups (Figs 4 and 5). EMG activity was higher when chewing than clenching in both the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups; however, there was no significant difference in the asymmetry index of masticatory muscle between chewing and clenching.

The distribution of occlusal force and asymmetry index of the occlusal force in three groups are shown in Table 4. The asymmetry index of the occlusal force was significantly higher in the removable dental prosthesis group than in the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups, and there were no significant differences between the latter two groups (Fig 6).

DISCUSSION

Restoration of masticatory function is a key feature of jaw functional reconstruction and is largely dependent on the type of dental prosthesis used. At present, implant-supported prostheses and removable dental prostheses are most commonly used in patients who undergo jaw reconstruction. However,

Table 2 EMG Activity of the Nondefective and Defective Muscles and Asymmetry Index of Bilateral Masticatory Muscles While Clenching (Mean ± SD)

Study group	Nondefective muscles	Defective muscles	Asymmetry index
RDP	406.20 ± 63.33	330.00 ± 64.36	0.107 ± 0.042
IRFDP	421.31 ± 58.54	386.00 ± 65.96	0.046 ± 0.023
IRRDP	424.33 ± 70.65	397.22 ± 79.32	0.035 ± 0.021

IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis; RDP = removable dental prosthesis.

Table 3 EMG Activity of Nondefective and Defective Muscles and Asymmetry Index of Bilateral Masticatory Muscles While Chewing (mean ± SD)

Study group	Nondefective muscles	Defective muscles	Asymmetry index
RDP	451.10 ± 72.67	374.30 ± 81.27	0.099 ± 0.046
IRFDP	489.54 ± 61.29	455.77 ± 68.97	0.038 ± 0.021
IRRDP	493.67 ± 90.18	465.56 ± 98.78	0.032 ± 0.019

IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis; RDP = removable dental prosthesis.

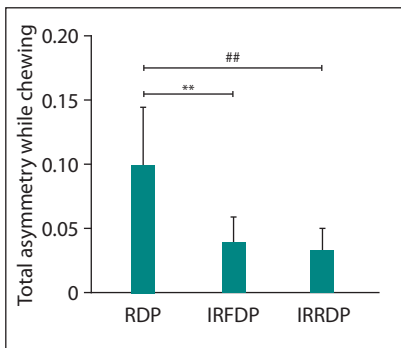


Fig 4 Asymmetry index of bilateral masticatory muscles in the three study groups while chewing. RDP = removable dental prosthesis; IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis. ***P* < .01 vs IRFDP, ##*P* < .01 vs IRRDP.

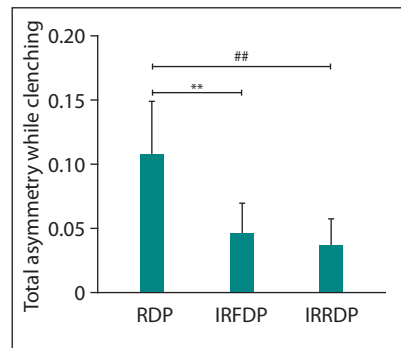


Fig 5 Asymmetry index of bilateral masticatory muscles in the three study groups while clenching. RDP = removable dental prosthesis; IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis. ***P* < .01 vs IRFDP, ##*P* < .01 vs IRRDP.

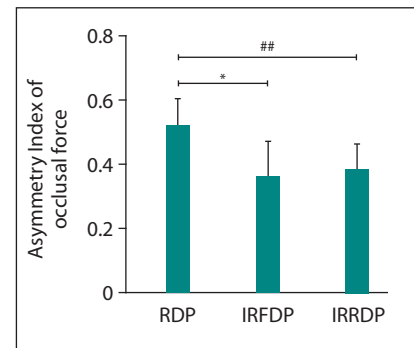


Fig 6 Asymmetry index of occlusal force in the three study groups. RDP = removable dental prosthesis; IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis. **P* < .05 vs IRFDP, ##*P* < .01 vs IRRDP.

Table 4 Distribution of Occlusal Force on the Nondefective and Defective Sides and Asymmetry Index of Occlusal Force (Mean ± SD)

Study group	Nondefective sides	Defective sides	Asymmetry index
RDP	0.76 ± 0.04	0.24 ± 0.04	0.52 ± 0.09
IRFDP	0.68 ± 0.06	0.32 ± 0.06	0.36 ± 0.11
IRRDP	0.69 ± 0.04	0.31 ± 0.04	0.38 ± 0.08

IRFDP = implant-retained fixed dental prosthesis; IRRDP = implant-retained removable dental prosthesis; RDP = removable dental prosthesis.

with the development of technology, implant restoration is becoming more widely applicable to functional reconstruction of the jaw, showing good retention and stability.¹⁴

In this study, the differences in masticatory efficiency, EMG activity of the masticatory muscles, and the distribution of occlusal force between implant-retained fixed dental prostheses, implant-retained removable dental prostheses, and removable dental prostheses were analyzed. Masticatory function varies from person to person and is largely affected by sex, age, height, and weight.¹⁵

Thus, when comparing variables between different dental prostheses, it is also important to consider these individual differences. In this study, the impact of individual differences was effectively reduced by comparing changes in masticatory efficiency, the asymmetry index of bilateral masticatory muscles, and the asymmetry index of occlusal force between the three groups.

Masticatory efficiency is an important indicator of masticatory function. Previous studies suggest that masticatory efficiency in edentulous patients can be effectively restored with implant-supported prostheses, with implant-supported prostheses performing better than removable dental prostheses.^{6,16,17} Studies also suggest that both implant-supported prostheses and removable dental prostheses can improve masticatory function and provide satisfactory masticatory efficiency in patients who undergo jaw reconstruction.^{6,16–18} In this study, both implant-supported prostheses and removable dental prostheses improved masticatory efficiency, with significantly higher results in the implant-supported prosthesis groups than in the removable dental prosthesis group, which is consistent with previous studies.^{9,10,19} In addition, no significant differences in masticatory efficiency were observed between the implant-retained

fixed dental prosthesis and implant-retained removable dental prosthesis groups. However, this result may have been affected by the limited number of cases, with further analyses of the differences between implant-retained removable dental prostheses and implant-retained fixed dental prostheses required in the future.

The method used to measure masticatory efficiency can also affect the findings. The sieve method is the most widely used. In this method, the weight of chewed test particles is determined after they pass through single or multiple sieves with different-sized apertures. The results can therefore be easily affected by the speed of the running water and the mesh size.²⁰ However, with technologic advances, new test methods are emerging, such as image analysis,²¹ the two-color mixing ability test,²² and chemical analysis,²³ although they have yet to be applied clinically largely due to their complexity and limitations in the necessary instruments and equipment. The colorimetric method is straightforward and affected by relatively few influencing factors and is also awaiting clinical approval. However, the results can be affected by the test materials, which are not always fully collected after chewing.²⁴

The EMG of masticatory muscles measures the energy consumed over a period of time, which can provide an estimate of the total energy consumed by muscles during mastication and clenching.²⁴ EMG activity is also an important indicator of masticatory function, and some studies suggest that the EMG of masticatory muscles can provide important information on functional reconstruction results.²⁵ Thus, EMG activity is also widely used to reflect masticatory function. Some studies have found that EMG activity is higher in edentulous patients with implant-supported prostheses than with removable dental prostheses.^{17,24,26} Meanwhile, Fueki et al²⁷ analyzed EMG activity in nine patients after mandibular reconstruction with a fibula flap, comparing the differences between removable dental prostheses and implant-supported prostheses. The results revealed significantly higher EMG activity in the implant-supported prosthesis group than in the removable dental prosthesis group. Similar results were also obtained in this study, whereby EMG activity was greater in the implant-retained fixed dental prosthesis and implant-retained removable dental prosthesis groups than in the removable dental prosthesis group during both clenching and chewing. This is thought to be because of the higher retention ability and greater stability of implant-supported prostheses, which improve occlusal function and stimulate masticatory muscle activity.²⁶ In addition, EMG activity of the masticatory muscles was higher when chewing than when clenching on both the defective and nondefective side. Karkazis²⁸ suggested that the absence of a periodontal membrane around dental implants causes a reduction in sensory

function during mastication after jaw reconstruction, resulting in an increase in EMG activity during chewing.

In terms of the distribution of occlusal force, analysis of the asymmetry index of the occlusal force revealed greater restoration with the implant-supported prosthesis than with the removable dental prosthesis, but no significant differences between implant-retained fixed dental prostheses and implant-retained removable dental prostheses. Similarly, Müller et al⁶ found that the occlusal force was significantly greater in edentulous patients with an implant-supported prosthesis than with a removable dental prosthesis, and with an implant-retained fixed dental prosthesis compared with an implant-retained removable dental prosthesis. This difference may have been caused by various factors, including age, sex, maxillofacial structure, and patient psychology, all of which can result in large individual differences. Therefore, these individual differences in occlusal force should be considered when evaluating the function of different dental prostheses.¹⁵ In this study, the T-Scan III system was used to measure the distribution of occlusal force, and the asymmetry index of the occlusal force was used to reflect the improvement following dental rehabilitation, thus reducing the effect of individual differences.²⁹ In addition, compared with edentulous patients, the patients in this study all underwent jaw reconstruction with a bone free flap, which can also affect occlusal force.³⁰ Further studies with a larger number of patients are therefore required to further understand the differences in masticatory function between implant-retained removable dental prostheses and implant-retained fixed dental prostheses.

CONCLUSIONS

The results of this study suggest that dental implant prostheses have a greater effect on masticatory function following jaw reconstruction, improving masticatory efficiency, EMG activity of the masticatory muscles, and occlusal force. Moreover, no differences in masticatory function were observed between implant-retained fixed dental prostheses and implant-retained removable dental prostheses.

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