

Evaluation of the Alteration of Occlusal Distribution in Unilateral Free-End and Intermediate Missing Cases

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The present study aimed to evaluate the effect of implant prostheses on the occlusal force and area as well as the distribution of occlusal loading in unilateral free-end and intermediate missing cases. Fourteen healthy subjects (7 free-end missing cases in the first and second molars and 7 intermediate missing cases in the first molar region) were included. Six months after the implant prosthesis was placed, an occlusal evaluation was performed with or without the implant superstructure by using Dental Prescale film and an occluder device. In free-end missing cases, the total occlusal force and area, implant-side occlusal force and area, and implant-side occlusal force and area of the residual natural teeth were significantly affected by the implant prostheses. In intermediate missing cases, the implant-side occlusal force of the residual natural teeth was significantly affected by the implant prostheses. In free-end missing cases, the proportions of implant-side occlusal force, non-implant-side occlusal force, and implant-side occlusal force of the residual natural teeth relative to the total occlusal force were significantly affected by the implant prostheses. In the intermediate missing cases, the proportion of the implant-side occlusal force of the residual natural teeth relative to the total occlusal force was significantly affected by the implant prostheses. The proportion of the occlusal area was also significantly affected. In free-end missing cases, implant prostheses significantly increased the occlusal force and area, which resulted in the proper occlusal distribution. In intermediate missing cases, an implant prosthesis may only improve the same-side occlusal loading of the natural teeth.

Key Words: dental implant, occlusal force, implant prosthesis

INTRODUCTION

Implant-supported fixed dental prostheses are a preferred treatment for replacing missing teeth in partially and completely edentulous patients due to their high predictability and success rate.¹⁻⁴ The aim of treatment is to restore the esthetics and function of the tooth. Occlusion plays an important role in the functional and biological aspects of the implant prosthesis. A stable, well-maintained occlusion can reduce mechanical and biological complications and therefore increase the longevity of the prosthesis.⁵

Measuring the occlusal force is often necessary to (1) assess the function of the jaw-closing muscles and (2) compare the muscle activity between subjects in various experimental situations.^{6,7} The loss of occlusal support due to missing posterior teeth increases the remaining occlusal region's loading and incidence of temporomandibular disorders.^{8,9} It is difficult to produce a fixed prosthesis to restore missing posterior teeth and achieve patient satisfaction with functional reconstruction by

using the traditional method.¹⁰ Dental implant treatment enables the use of fixed dentures that provide a satisfactory result for patients. Some investigators have suggested that the evaluation of the occlusal contact area, occlusal pressure, occlusal force, and masticatory efficiency can be useful for assessing masticatory function.¹¹ Fontijn-Tekamp et al reported on the occlusal force with implant-supported or retained over-dentures with follow-up periods beyond 1 year.¹² They reported that patients with mandibular implant-related over-dentures have a significantly higher occlusal force than those with complete dentures. However, few reports have analyzed functional reconstruction by using dental implant prostheses for natural dentition.^{13,14}

The present study aimed to evaluate alteration of the occlusal force by implant prostheses in unilateral free-end and intermediate missing cases.

MATERIALS AND METHODS

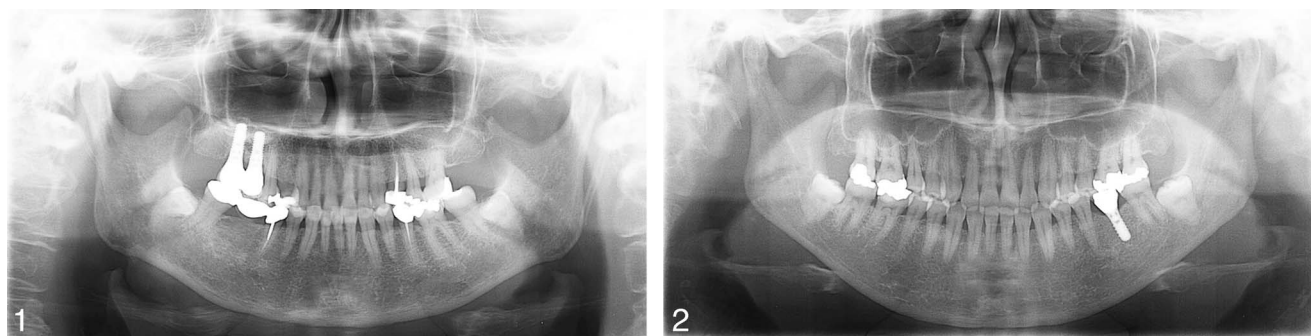
Patients who received dental implant therapy to reconstruct unilateral free-end missing 1st and 2nd molars (Figure 1) or intermediate missing 1st molars (Figure 2) were included, and they were treated from January 1, 2012, to December 31, 2014. Inclusion criteria were as follows: (1) patients who had undergone tooth extraction at least 3 months before implant

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FIGURES 1 AND 2. **FIGURE 1.** Panoramic radiograph of a free-end missing case. Dental implant treatment was applied at 2 and 3. **FIGURE 2.** Panoramic radiograph of an intermediate missing case. Dental implant treatment was applied at 19.

placement; (2) those with a proper maxillary-mandibular relationship; (3) patients without periodontal problems; (4) those without a history of alcohol, smoking, and drug abuse; (5) patients without clinical or radiographic evidence of pathology; and (6) those without a history of radiation or ablative surgery for orofacial tumors. Exclusion criteria were as follows: (1) patients with any systemic disorders that could complicate the hard and soft tissue healing of osseointegrated implants, (2) those with musculoskeletal problems that could possibly affect masticatory function, and (3) patients with a soft or major hard tissue graft before or in conjunction with implant placement. All patients provided informed consent, and this study was approved by an ethics committee.

All implants were placed according to manual and standard procedures, and they were inserted in the same direction of the adjacent natural tooth. Fourteen patients (5 men and 9 women, average age 61.4 years) were included, and 21 teeth were replaced. Porcelain-fused metal crowns were cemented on the straight abutment of the implant 3–6 months after implant placement. The occlusal contact of the implant prosthesis was defined as near contact when the articulating paper (0.035 × 6 mm) between the teeth could be pulled out with resistance.¹⁴ All patients achieved comfort and sufficient occlusal reconstruction. No indications of pain or temporomandibular disorders were associated with our implant therapy. Patients’ characteristics are presented in the Table.

TABLE					
Overview of 14 patients treated with an implant-supported prosthesis					
Sex	Age	Position	Opposing Tooth Situation	Applied Implant	
Free end missing case					
F	69	2,3	Natural tooth PFM	16: Straumann Tissue level RN/TE $\phi 4.1 \times 10$ mm	17: Straumann Tissue level RN/TE $\phi 4.1 \times 10$ mm
M	55	30,31	Natural tooth FMC metal inlay	46: Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	47: Straumann Tissue level RN/SP $\phi 4.1 \times 8$ mm
M	71	14,15	Natural tooth FMCr fixed partial denture	26: Spline Twist $\phi 3.75 \times 11.5$ mm	27: Spline Twist $\phi 3.75 \times 10$ mm
M	63	30,31	Natural tooth FMC	46: Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	47: Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm
M	70	18,19	Natural tooth	36: Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	37: Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm
F	72	18,19	Natural tooth FMC	16: Straumann Tissue level WN/TE $\phi 4.8 \times 10$ mm	17: Straumann Tissue level WN/TE $\phi 4.8 \times 10$ mm
M	66	30,31	Dental implant PFM	46: Spline Reliance Cylinder $\phi 4.0 \times 10$ mm	47: Spline Reliance Cylinder $\phi 4.0 \times 10$ mm
Intermediate missing case					
F	62	19	Natural tooth	Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	
F	72	30	Natural tooth PFM	Straumann Tissue level WN/TE $\phi 4.8 \times 10$ mm	
F	54	19	Natural tooth FMCr	Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	
F	57	30	Natural tooth	Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	
F	66	14	Natural tooth FMCr	Straumann Tissue level WN/TE $\phi 4.8 \times 10$ mm	
F	64	30	Natural tooth	Straumann Tissue level WN/TE $\phi 4.8 \times 10$ mm	
F	47	3	Natural tooth metal inlay	Straumann Tissue level RN/SP $\phi 4.1 \times 10$ mm	

Follow-up evaluation and measurements

Six months after implant prosthesis placement, specifically designed films (Dental Prescale, Fuji Film Corp, Tokyo, Japan) were used to determine the maximum occlusal force with or without the implant prosthesis. The Dental Prescale consists of two paper sheets and numerous microcapsules that contain red dye. When a patient is asked to occlude as forcefully as possible on the paper sheets, these microcapsules rupture, discharging the red dye and staining one of the paper sheets. The density of the color is proportional to the degree of pressure applied. All measurements were performed with the subject seated with the head upright, looking forward and in an unsupported natural head position. Then the tooth contact area and density of the color that indicated the occlusal pressure were measured with the Occluzer (FPD705, Fuji). The occlusal force was also measured with this apparatus. Each patient was measured with or without the implant superstructure. The following items were measured: total occlusal force and total occlusal area, implant-side occlusal force and area, implant-side force and area of the residual natural teeth, non-implant-side occlusal force and area, proportion of each value to the total occlusal force, and the total occlusal area.

Statistical analysis

Data were analyzed with a paired *t*-test or Wilcoxon signed-rank test after conducting a normality test. Statistical differences were analyzed between the values obtained with and without an implant prosthesis. *P*-values < .05 were considered statistically significant. Statistical analyses were performed by using a commercial computer program (PASW Statistics, IBM Corp, Armonk, NY).

RESULTS

Occlusal force

In free-end missing cases, the total occlusal force, implant-side occlusal force, and implant-side force on the residual natural teeth demonstrated statistically significant differences with and without the implant prosthesis 6 months after placement (*P* = .0027, .0032, and .022, respectively). In cases with intermediate missing teeth, the implant-side occlusal force demonstrated statistically significant differences 6 months after implant prosthesis placement (*P* = .043; Figure 3).

Occlusal area

In free-end missing cases, the total occlusal area, implant-side occlusal area, and implant-side area of the residual natural teeth were significantly different with and without the implant 6 months after placement (*P* = .0039, .0051, and .0429, respectively; Figure 4).

Proportion of each occlusal force

In free-end missing cases, proportions of the implant-side occlusal force, non-implant-side occlusal force, and implant-side force of the residual natural teeth relative to the total

occlusal force were significantly different with and without the prosthesis 6 months after placement (*P* = .018, .018, and .018, respectively). In cases with intermediate missing teeth, the proportion of the implant-side occlusal force of the residual natural teeth relative to the total occlusal force was significantly different 6 months after implant prosthesis placement (*P* = .018; Figure 5).

Proportion of each occlusal area

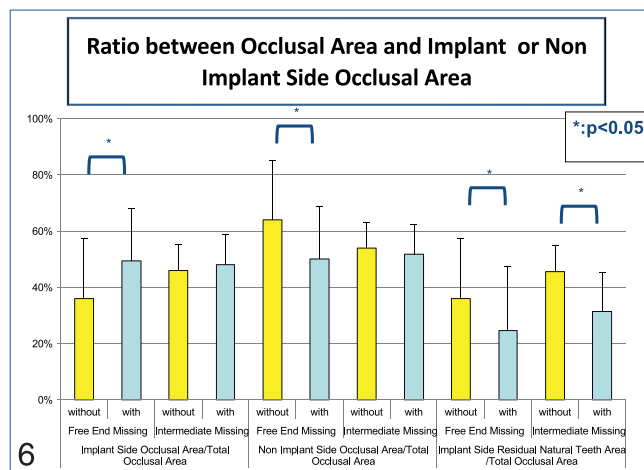
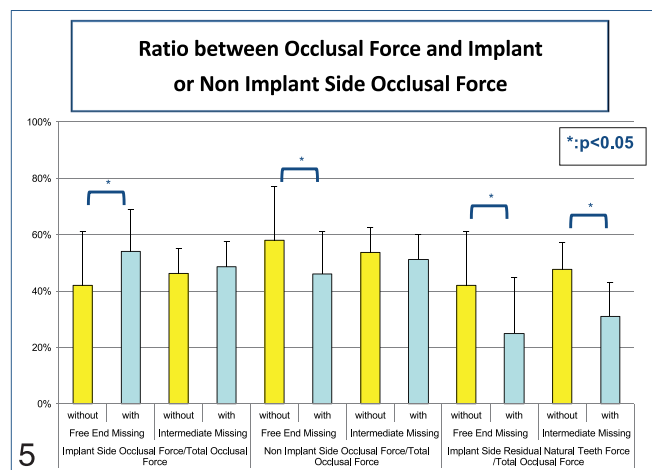
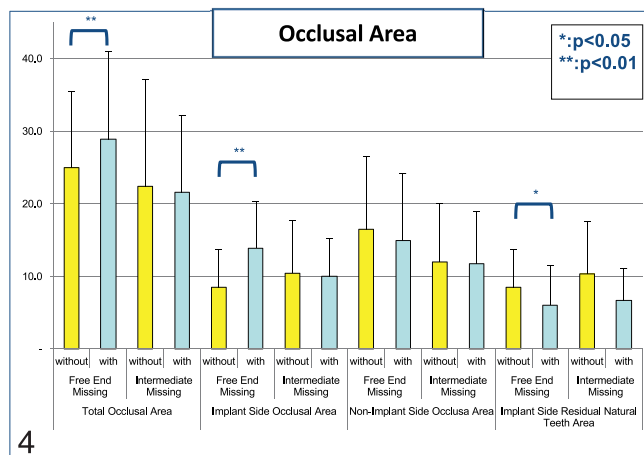
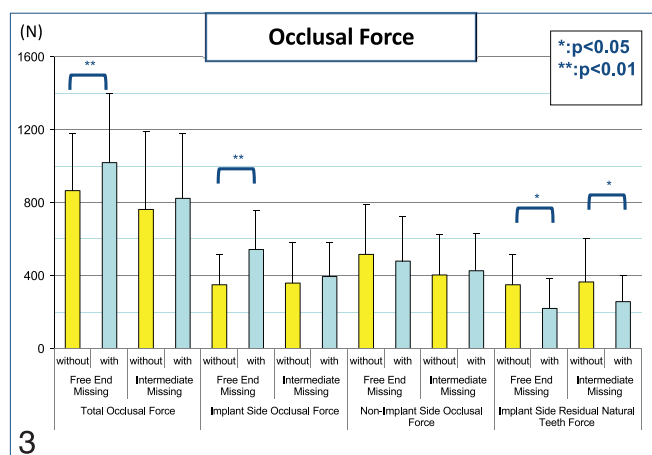
In the free-end missing cases, the proportions of the implant-side occlusal area, non-implant-side occlusal area, and implant-side occlusal area of the residual natural teeth relative to the total occlusal area were significantly different with and without the prosthesis 6 months after placement (*P* = .018, .018, and .018, respectively). In cases with intermediate missing teeth, the proportion of the implant-side occlusal area of the residual natural teeth relative to the total occlusal area was significantly different 6 months after implant prosthesis placement (*P* = .018; Figure 6).

DISCUSSION

Masticatory function was associated with the procedure for occlusal fitting of the implant-supported crowns to obtain near contact with opposing teeth and restorations. It has been reported that fitting to near contact also results in an occlusal load during a maximum bite of only 40–60% of the load on the corresponding natural teeth,¹⁴ which was standard and desirable since osseointegrated implants do not permit the same mobility during chewing and loading as teeth with periodontal ligaments.¹⁵ We used this style of prosthetic occlusal contact, and even under this loose loading condition, the implant prosthesis demonstrated favorable results.

In our study, the total occlusal force and implant-side occlusal force showed statistically significant differences associated with the implant prosthesis in the free-end cases, but no significant difference was observed in the intermediate cases. However, in both cases, the non-implant-side occlusal force showed no statistically significant difference with and without a prosthesis. Conversely, the implant-side occlusal force showed statistically significant differences associated with the implant prosthesis. These results suggest that the use of implant prostheses in free-end cases may be effective for restoring the occlusal force and decreasing the occlusal load on the implant-side of residual natural teeth in free-end and intermediate cases. The total occlusal area, implant-side occlusal area, and implant-side residual natural teeth area showed statistically significant differences associated with the implant prosthesis in free-end cases, but no significant difference was observed in intermediate cases. Therefore, in free-end cases, the use of an implant prosthesis may have a favorable effect on the total occlusal area, implant-side occlusal area, and implant-side occlusal area of the residual natural teeth.

The occlusal force and area achieved with the implant prosthesis in our study were consistent with those obtained in subjects with complete dentition.^{16–19} Goshima et al reported that implant prostheses provide significant increas-



FIGURES 3–6. **FIGURE 3.** Occlusal force determined for each region by using Dental Prescale film. The bar chart shows the mean occlusal force. Error bars indicate the standard deviation. **FIGURE 4.** Occlusal area determined for each region by using Dental Prescale film. The bar chart shows the mean total occlusal area. Error bars indicate the standard deviation. **FIGURE 5.** Ratio between the occlusal force and implant or non-implant-side occlusal force. The bar chart shows the mean ratio between the occlusal force and the implant or non-implant-side occlusal force. Error bars indicate the standard deviation. **FIGURE 6.** Ratio between the occlusal area and implant or non-implant-side occlusal area. The bar chart shows the mean ratio between the occlusal area and implant or non-implant-side occlusal area. Error bars indicate the standard deviation.

es in the maximum occlusal force, contact area, and masticatory ability and performance, although the masticatory efficiency did not change significantly.¹⁴ They suggested that the interindividual variation with respect to the location and number of replaced teeth or the functional efficiency was already high before implant prosthesis placement. However, associations between implant prostheses and the development of a higher occlusal force and area, and functional improvement remain unknown.

The occlusal force and occlusal area on the implant side in free-end cases differed significantly depending on whether an implant prosthesis was used. Additionally, the non-implant-side occlusal force and area were reduced using a dental implant prosthesis in free-end cases. Therefore, dental implant prostheses may have a favorable effect on the distribution of implant-side occlusal force and occlusal area, and this approach can restore the proper balance of occlusal force and area on the nonimplant side. However, in intermediate cases, the presence of a dental implant prosthesis did not significantly affect these

parameters. Therefore, the total balance of the occlusal force and occlusal area had already been achieved by the natural dentition in the intermediate cases. Implant prosthesis in intermediate cases may have a limited effect on the implant side. In both free-end and intermediate cases, the proportion of the implant-side occlusal force and area relative to the residual natural teeth was significantly different between those with and without a dental prosthesis. This result suggests that the use of an implant prosthesis may decrease the same-side occlusal load on the natural teeth.

CONCLUSIONS

In free-end missing cases, implant prostheses significantly increased the occlusal force and area, which resulted in the proper occlusal distribution. In intermediate missing cases, an implant prosthesis may only improve the same-side occlusal loading of the natural teeth.

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