Short Communication

Effects of a Removable Partial Denture and Its Rest Location on the Forces Exerted on an Abutment Tooth In Vivo

Tetsuo Kawata[a]/Takeshi Kawaguchi[a]/Nobuhiro Yoda[a]/Toru Ogawa[a]/Tsunemoto Kuriyagawa[b]/Keiichi Sasaki[a]

The 3-dimensional forces exerted on an abutment tooth of a removable partial denture (RPD) were measured in vivo during clenching using a force-measuring device with a piezoelectric transducer. The device was mounted on the mandibular right second premolar of a subject with an edentulous maxilla. The magnitude of the forces was higher and the direction was more posterior without the RPD in place. The direction was most posterior with an RPD with a distal rest only and most anterior with an RPD with a mesial rest only. The 3-dimensional forces exerted on an abutment tooth thus depend on both the presence of a denture and the rest location. *Int J Prosthodont 2008;21:50–52.*

The forces exerted on the abutment teeth of a removable partial denture (RPD) play a critical role in determining the prognosis of the teeth; therefore, many studies regarding the relationship between RPD design and the resultant forces have been carried out. However, few studies have measured these forces in vivo.[1] Similarly, although theories have been proposed for RPD designs that protect the abutment teeth and supporting tissues,[2,3] in vivo measurements of the 3-dimensional (3D) forces exerted on the teeth have not been reported. This may be a result of the problematic size and sensitivity of the devices conventionally used to measure these forces.

A recently developed 3D force-measuring device with a piezoelectric transducer enables in vivo time-series measurement of the forces exerted on a tooth.[4] The aim of this study was to measure in vivo the forces exerted during clenching on an abutment tooth of an RPD and to investigate the effects of an RPD and its design (ie, the placement of its rests) using the 3D force-measuring device.

[a]Division of Advanced Prosthetic Dentistry, Tohoku University Graduate School of Dentistry, Sendai, Japan.
[b]Tohoku University Graduate School of Engineering, Sendai, Japan.

Correspondence to: Tetsuo Kawata, Division of Advanced Prosthetic Dentistry, Tohoku University Graduate School of Dentistry, 4-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan. Fax: +81 22 717 8371. E-mail: tkawata-tohoku@umin.ac.jp

Materials and Methods

The force-measuring device comprises *(1)* an inner part forming a metal core, *(2)* a force transducer, and *(3)* an outer part forming a metal tooth crown (Fig 1). These 3 parts are joined together with a stainless steel screw. The transducer contains 3 crystals in a stainless steel housing to measure the forces triaxially and bidirectionally along each orthogonal axis, both simultaneously and independently in 3D. A custom-made component is used to affix the transducer to a tooth root.

The subject was a 63-year-old healthy woman with a partially edentulous mandible (Fig 2). The research ethics committee of the Tohoku University Graduate School of Dentistry approved this study, and the subject provided informed consent. The altered cast technique was used to take an impression of the subject's edentulous arch, and this impression was then used to create an experimental RPD. Slight adjustments were made to the denture surface by hand. The remount technique was used to obtain balanced occlusion, which was precisely tuned immediately before the experiment. The experimental RPD had removable mesial and distal rests (Fig 3). The force-measuring device was mounted on the mandibular right second premolar and held in place using temporary cement.

The magnitudes and directions of the forces exerted on the tooth were measured during maximum voluntary clenching for 4 conditions: without the RPD and with the RPD supported by the mesial and distal rests, only the mesial rest, and only the distal rest. Five trials were conducted for each condition, and the condition for each trial was randomly set. To minimize the effect

Table 1 Direction (deg) and Magnitude (N) of Forces Measured for 4 Conditions

Condition	Anteroposterior*	Mediolateral	Magnitude**
Without RPD	21.9 ± 0.9	9.9 ± 0.9	112.19 ± 8.1
RPD with mesial and distal rests	16.8 ± 0.9	11.2 ± 1.4	93.5 ± 15.3
RPD with mesial rest only	12.8 ± 1.6	10.2 ± 0.8	87.6 ± 13.8
RPD with distal rest only	19. 5 ± 0.3	9.0 ± 1.0	76.3 ± 3.9

*$P < .01$ between without RPD and RPD with mesial rest only and between RPD with mesial rest only and RPD with distal rest only;
**$P < .05$ between without RPD and RPD with distal rest only (Dunn test).

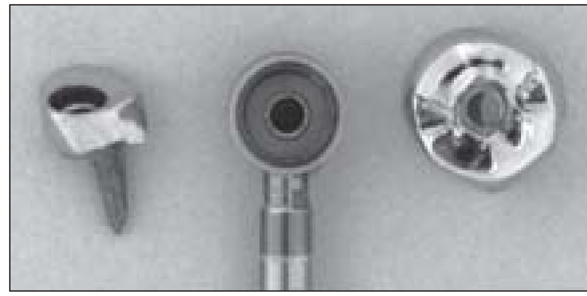
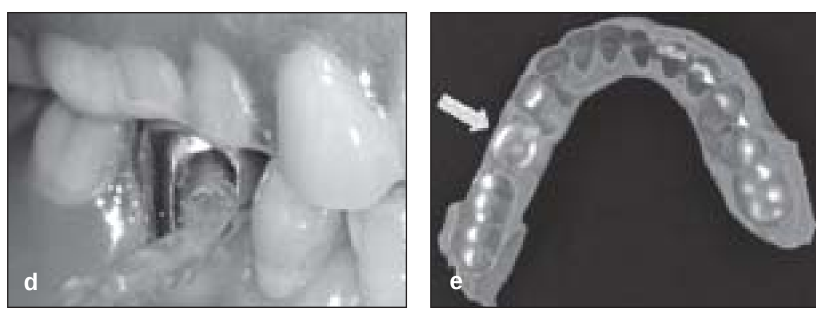
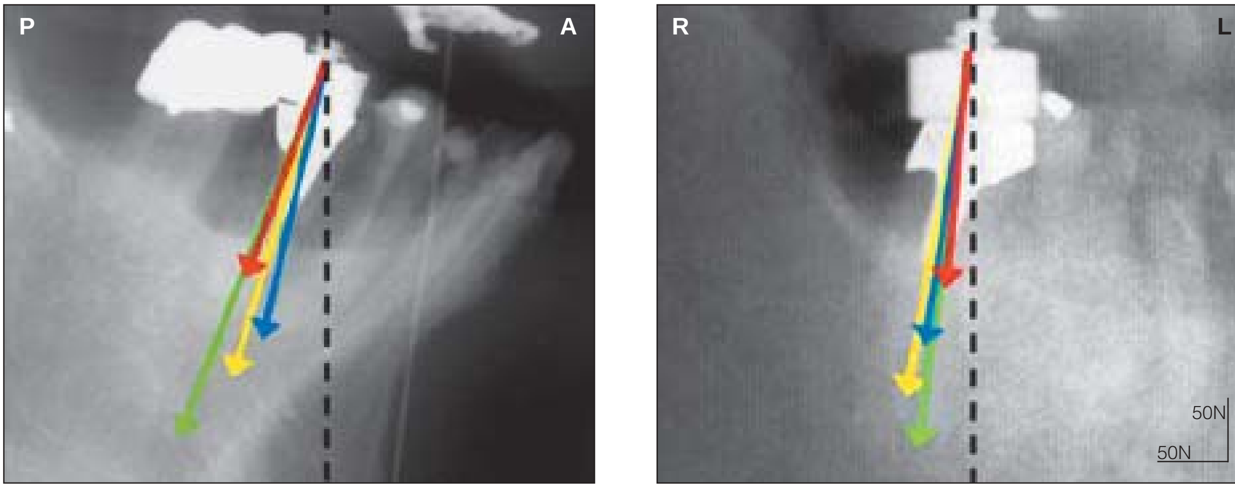


Fig 1 Device for measuring 3D forces: *(left)* inner part (similar to metal core), *(middle)* force transducer, and *(right)* outer part (similar to metal crown). The 3 parts were joined together with a stainless steel screw.



Figs 2a to 2e **(a)** Occlusal view of the maxilla with a complete denture. **(b)** Occlusal view of the mandible. **(c and d)** Placement of the device on the tooth (the *arrow* indicates the steel screw). **(e)** Occlusal contact (visualized using silicone) when the mouth was closed, as viewed from the mandibular side with transmitted light. The area of occlusal contact and interocclusal distance for the test tooth *(arrow)* were equivalent to those of other natural and artificial teeth. The denture base was evenly fitted to the residual ridge as closely as possible.

Figs 3a to 3d Experimental RPD **(a)** with removable mesial and distal rests, and close-up views of the abutment tooth for 3 rest locations: **(b)** mesial and distal, **(c)** mesial only, and **(d)** distal only.



Figs 4a and 4b Vector directions at maximum magnitude during maximum voluntary clenching: *(left)* sagittal plane view (anteroposterior direction) and *(right)* coronal plane view (mediolateral direction). Three-dimensional forces were converted into two 2-dimensional forces (coronal and sagittal planes). The top of each graph represents the FH plane, and *black dashed lines* run perpendicular to the FH plane. *Green arrows* indicate forces without the RPD in place; *yellow arrows* indicate forces for RPDs with mesial and distal rests; *red arrows* indicate forces for RPDs with a distal rest only; and *blue arrows* indicate forces for RPDs with a mesial rest only. R = right; L = left; P = posterior; A = anterior.

of patient fatigue and possible pain from the RPD under load, the clenching time was kept to only 2 seconds, and the trials were separated by rest periods of at least 2 minutes.

The 3D forces calculated from the outputs of the transducer were expressed as a vector of the coordinates based on the Frankfort horizontal plane (FH plane) and sagittal plane. The force directions were indicated as an angle to the perpendicular line of the FH plane in the coronal and sagittal planes. Statistical comparisons were performed using the Kruskal-Wallis test and Dunn test.

Results

The force direction without the denture was more posterior than with the denture (Fig 4a and Table 1). Among the 3 rest locations, the force direction with the distal rest was the most posterior, while the force direction with the mesial rest was the most anterior. For the mediolateral direction, the force direction with the mesial and distal rests was most lateral, while the force direction with the mesial rest was the most medial (Fig 4b and Table 1). There were no significant differences in the direction among the 4 conditions. The magnitude of the forces was the highest without the denture and the lowest with the distal rest.

Discussion

The finding that the magnitude of the forces was the highest without the denture indicates that wearing an RPD reduces the forces exerted on a tooth. This suggests the possibility that an RPD does not create an overload on the tooth in front of the distal extension but rather contributes to a decrease in the forces acting on the tooth.

Conclusion

The 3D forces exerted during clenching on an abutment tooth of an RPD were recorded. The direction and magnitude of the forces depended on both the presence of the RPD and on the rest location. This measurement method should greatly assist in establishing RPD designs based on biomechanics.

Acknowledgments

This study was supported in part by Grants-in-Aid for Scientific Research from the Japan Ministry of Education, Science, Sports and Culture (Project 11771212).

References

1. Maxfield JB, Nicholls JI, Smith DE. The measurement of forces transmitted to abutment teeth of removable partial dentures. J Prosthet Dent 1979;41:134–142.
2. Boucher LJ, Renner RP. Treatment of Partially Edentulous Patients, ed 1. St Louis: Mosby, 1982.
3. McGivney GP, Castleberry DJ. McCracken's Removable Partial Prosthodontics, ed 9. St Louis: Mosby, 1995.
4. Kawaguchi T, Kawata T, Kuriyagawa T, Sasaki K. In vivo 3-dimensional measurement of the force exerted on a tooth during clenching. J Biomech 2007;40:244–251.