Stress analysis of the tissue around the abutment tooth by the difference in the keeper angles of the most posterior molar in magnetic attachment dentures

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Abstract

Application of the magnetic attachment to the most posterior molar is effective as the most posterior support region of the denture. However, a good clinical prognosis is rarely provided for the abutment tooth is located under the denture base with poor self-cleaning property. In this study, we investigated the mechanical influence of angular difference of the keeper attractive surface applied to the most posterior molar to the abutment teeth and surrounding tissues using three dimensional finite element method.

The analysis model was constructed using a mandibular cast model manufactured by Nissin Co., Ltd. In the prosthetic design, the overlay prosthesis was made by applying a magnetic attachment to the mandibular left second molar. Analysis items were modeled by setting the keeper attractive surface parallel to the occlusal plane and a model in which the keeper attractive surface was set perpendicular to the tooth axis of the abutment.

From the analysis results, relaxation of the stress distribution in the mandibular left second molar was observed in the model that the keeper attractive surface was set perpendicular to the tooth axis of the abutment. In addition, decrease of the periodontal ligament burden area and increase of mucous burden area could be confirmed.

Introduction

Application of the magnetic attachment to the most posterior molar is effective as the most posterior support region of the denture and furthermore the retention force of the denture can be obtained by the attractive force of the magnetic attachment. The change in attractive force with the change in angle of the keeper attractive surface angle of the magnetic attachment exerts the maximum attractive force in the direction perpendicular to the keeper attractive surface.[1] For this reason, it is recommended that the keeper attractive surface of the root cap is basically set parallel to the occlusal plane so that the maximum attractive force can be exerted. However, by setting it parallel to the occlusal plane in order to acquire the maximum attractive force, the occlusal force is received in a direction different from the tooth axis and clinical symptoms may be confirmed in the tissue around the abutment tooth.

Objective

The purpose of this study was to investigate the mechanical influence of the difference in angle of the keeper attractive surface applied to the most posterior molar to the surrounding tissue of the abutment for the mandibular removable partial denture by using the three dimensional finite element method.

Material and Methods

1. Analysis model

The mandibular model used in this study is shown in Fig.1. For model construction, a mandibular plaster model and a skull model (P10 - SB.1) manufactured by Nissin Co., Ltd. were used (Fig. 2).

Initially, this mandibular plaster model was scanned using a model and impression scanner (7

series, Dental Wings, Montreal, Canada) to make model shape data in STL format. Next, a skull model was CT photographed and the obtained CT data was prepared in STL format with mandibular bone data and tooth root shape data using three-dimensional construction soft (Mimics version l1.0, Materialise, Leuven, Belgium). We imported these data into computer aided engineering（CAE）pre／post processing software (Patran 2013 windows 64bit, MSC software, Los Angels, USA) and constructed a model. The thickness of the residual ridge mucosa and periodontal ligament were set with reference to the literature values and the morphology of the mandible was simple form. [2]

Fig.1 : The mandibular model used in this study

Fig.2 : a mandibular plaster model and a skull model

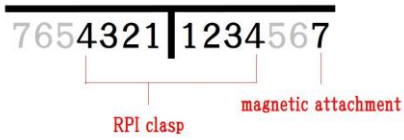

Fig.3 : The design of the removable partial denture

The design of the removable partial denture is shown in Fig.3. The magnetic attachment was designed for the mandibular left second molar and the RPI clasp was applied on the both sides first premolar as the direct abutment device.

The constructed analysis model is shown in Fig.4. The magnetic attachment applied in this research was GIGAUSS D1000 and accurately reproduced its high diameter and width for model construction.

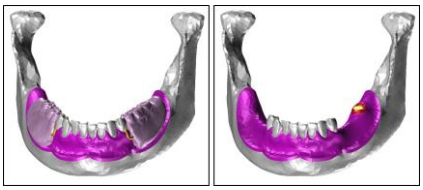

Fig.4 : the constructed analysis model

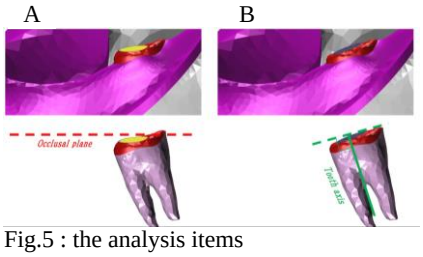

Fig.5 : the analysis items
A : occlusal plane parallel model
B : tooth axis vertical model

2. Analysis Items

Analysis items are shown in Fig.5.

The analysis items were an occlusal plane parallel model that the keeper attractive surface was set parallel to the occlusal plane and a tooth axis vertical model that the keeper attractive surface was set perpendicular to the tooth axis of the mandibular left second molar.

The mechanical property values of the analysis model are shown in Table 1. About the periodontal ligament and the residual ridge mucosa, these nonlinear viscoelastic properties were introduced by material constant conversion program（Table 2）.

Table1 : the mechanical property values

	Young Modulus (MPa)	Poisson Ratio
mandibular bone	11,760	0 . 250
enamel	41,400	0 . 350
dentin	18,600	0 . 350
metal(Co-Cr)	70,000	0 . 300
resin	2,450	0 . 300

Table2 : the material constant conversion program

	Young Modulus (MPa)	Poisson Ratio
Periodontal Ligament	0.020	0 . 200
	0.085	0 . 300
	1.500	0 . 350
	2.500	0 . 400
	4.000	0 . 490
Residual Ridge Mucosa		
	0.150	0 . 300
	0.700	0 . 350
	3.000	0 . 350
	3.900	0 . 350
	4.600	0 . 450
	11.000	0 . 470
	16.500	0 . 490

3. Analysis Conditions

The load conditions are shown in Fig.6. The loading site was a total of 6 places on the mandibular bilateral denture occlusal surface and the loading direction was perpendicular to the occlusal plane. Based on the literature value, the load amount was set to 300 N in total.[3] The inferior border of the mandible was defined as a constraint condition in the x, y, and z directions. In the contact condition, the contacting relationship with the tooth and the mucosa in contact with the denture was added by Coulomb friction and the coefficient of defined Coulomb friction was set at $\mu = 0.090$ for this study.

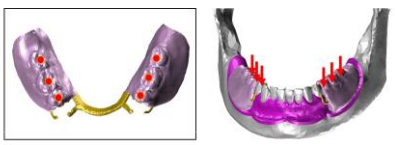

Fig.6 : the load conditions

Analysis Results

The stress in this analysis was evaluated by Von Mises stress.

1. Mandibular alveolar bone

Fig. 7 shows the stress distribution of the alveolar cavity of the mandibular left second molar. Compared to the occlusal plane parallel model, stress relaxation was confirmed in the tooth axis vertical model.

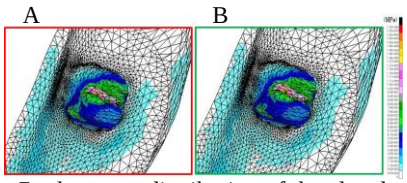

Fig.7 : the stress distribution of the alveolar cavity of the mandibular left second molar
A : occlusal plane parallel model
B : tooth axis vertical model

2. Mandibular left second molar

A stress distribution of the mandibular left second molar is shown in Fig.8. Both models showed stress spreading from the mesial root to the furcation. Especially in the mesial root, relaxation of stress was confirmed in the tooth axis vertical model compared with the occlusal plane parallel model.

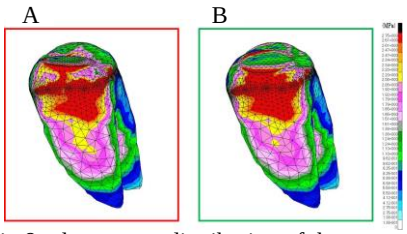

Fig.8 : the stress distribution of the mandibular left second molar
A : occlusal plane parallel model
B : tooth axis vertical model

3. Right supporting denture base mucosa

Fig. 9 shows the stress distribution of the right supporting denture base mucosa. Expansion of the stress distribution was confirmed in the tooth axis vertical model compared to the occlusal plane parallel model. An increase in mucosal burden zone was confirmed.

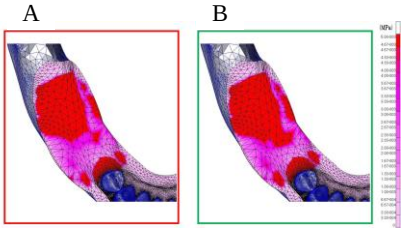

Fig.9 : the stress distribution of the right supporting denture base mucosa
A : occlusal plane parallel model
B : tooth axis vertical model

Discussion and Conclusion

In the finite element analysis studied this time, compared to the design the keeper attractive surface is set parallel to the occlusal plane, stress relaxation was confirmed in the design the keeper attractive surface is set to be perpendicular to the abutment tooth axis. It was also confirmed that in the burden form of the dental prosthesis, the region of the periodontal ligament burden decreases and the mucosal burden zone increases.

The difference in the angle of the keeper attractive surface examined this time is 15 °. According to report of Nakabayashi, the reduction rate of the attractive force is about 17%.[1]

Based on this result, when applying a magnetic attachment to the most posterior molar, it is extremely important to clarify the condition of the abutment to determine whether to give priority to the attractive force of magnetic attachment or to give priority to stress relief to the abutment tooth.

References

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