Mechanical consideration of implant support in removable partial denture design applied by a magnetic attachment using three-dimensional finite element analysis

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Abstract
The purpose of this study was to examine the mechanical effects of implant support in removable partial denture design using three-dimensional finite element analysis. The analysis model was a partial edentulous mandibular where #35, 36, 45, 46 and 47 were missing. For design of the basic model, the RPI clasps were designed on #34 and #44 as retainer, and a magnetic attachment was applied on #37 as overdenture abutment. The implant support models were created in which two types of implants with different lengths (6.5 mm and 10.0 mm) were placed in cantilever missing on the right side of the mandible of the basic model. Stress analysis of these analysis models was conducted. In the implant support models, there was no significant difference in the analysis results depending on the length of the implant. Additional support by the implant demonstrated the stress reducing of the abutment teeth even by the short implant. These results suggest implant supported removable partial denture would expand its indication on designing removable partial denture.

Introduction

In the design of removable partial dentures in which tooth support and tissue support with different amount of tissue displacements are complicated, it is very difficult to set appropriate mechanical distribution especially for cantilever missing.

In such a situation, the application of the magnetic attachment to the posterior molar can change the missing form from the cantilever missing to an intermediary missing by providing the tissue support at the posterior position. In addition, it is clinically very useful to acquire the retentive force of the denture by the attractive force of the magnetic attachment.

In recent years, as a method of prosthetic treatment from the crown bridge to the removable denture, although implant treatment has been established, as another method, as well as the magnetic attachment applied to the posterior molar, There is also report on the use of implant support in the at the posterior position to stabilize removable partial denture.

However, there are still many questions about the mechanical effects of implant support in the design of removable partial denture.

Objective

The purpose of this study was to examine the mechanical effect of implant support in the design of removable partial denture applied by a magnetic attachment using three-dimensional finite element analysis.

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 Angeles, 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. [1]

Fig.1 : The mandibular model used in this study

Fig.2 : Mandibular plaster model and a skull model

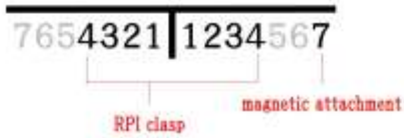

Fig.3 : The design of the removable partial denture

The design of the removable partial denture is shown in Fig.3. The magnetic attachment was applied on #37 as overdenture abutment and the RPI clasp was applied on #34 and #44 as the direct retainer. The magnetic attachment applied in this research was GIGAUSS D1000 and accurately reproduced its high diameter and width for model construction.
The analysis model created by the above method was used as the basic model in this study.

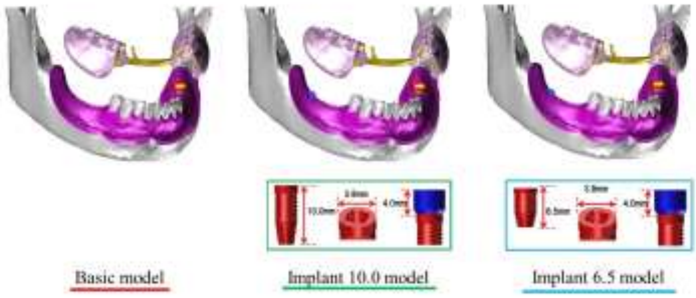

Fig.4 : Analysis items

2. Analysis Items

Analysis items are shown in Fig.4. The implant support models were created in which two types of implants with different lengths (6.5 mm and 10.0 mm) were placed in cantilever missing on the right side of the mandible of the basic model. The implant of the implant support model was equipped with a healing abutment (height 4.0 mm) and set as a support area under the denture base.

Table1 : 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

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）.

Table2 : 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.5. The loading site was a total of 4 places on the denture occlusal surface and the loading direction was perpendicular to the occlusal plane. Based on the literature value, the load amount was set to 200 N in total[2]. The inferior border of the mandible was defined as a constraint condition in the x, y, and z directions. In the contact

Fig.5 : Load conditions

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. [3]

The evaluation of the analysis results was based on the Von Mises stress and the displacement of the denture.

Analysis Results

1. Stress distribution in the alveolar bone

Fig. 6 shows a stress distribution in the alveolar bone in each abutment tooth. In the #37 of the alveolar cavity which applied a magnetic attachment, stress relaxation was confirmed in the implant 10.0 model, the implant 6.5 model as compared with a basic model. Next, in the #34 of the alveolar cavity, no significant difference was confirmed in the alveolar cavity in any of the models. However, in the distal alveolar cavity, stress relaxation was confirmed in the implant 10.0 model and the implant 6.5 model compared with the basic model.

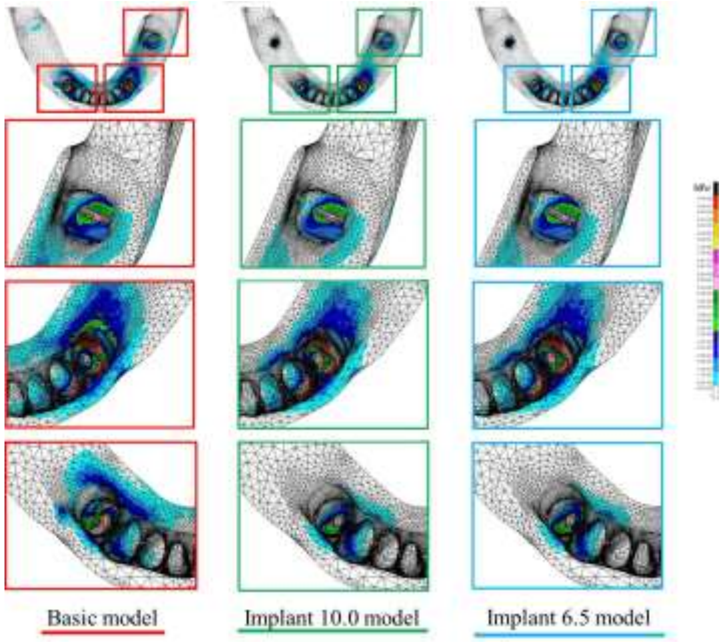

Fig.6 : Stress distribution in the alveolar bone

2. Stress distribution in the residual mucous membrane

Fig. 7 shows the stress distribution in the residual mucous membrane. In the residual mucous membrane of the right side, significant stress relaxation was observed in the implant 10.0 model and the implant 6.5 model compared with the basic model, confirming that the mucosa supporting area of denture was decreased. Next, comparing the implant 10.0 model with the implant 6.5 model, no significant difference was observed in stress distribution in the residual mucous membrane.

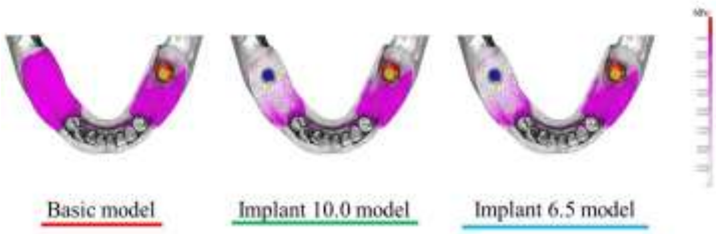

Fig.7 : Stress distribution in the residual mucous membrane

3. Displacement of denture base

Fig. 8 shows the amount of displacement of the denture base. In the part corresponding to the # 45, 46 and 47, a decrease in the amount of displacement was observed in the implant 10.0 model and implant 6.5 model compared with the basic

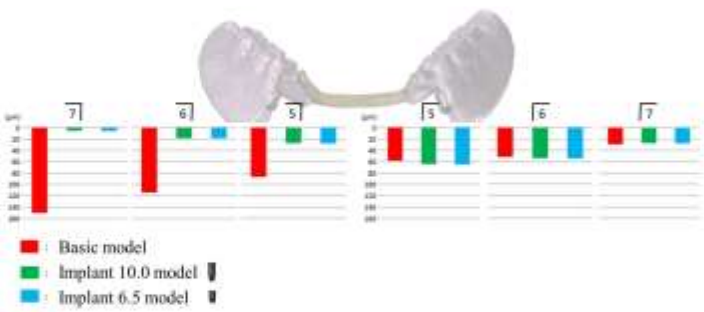

Fig.8 : A mount of displacement of the denture base

model. The basic model showed a tendency for the displacement amount to increase toward the distal side, and the implant 10.0 model and the implant 6.5 model showed a tendency for the displacement amount to increase toward the mesial side. In the part corresponding to the # 35, 36 and 37, the difference in the amount of displacement was not observed in all models, and the amount of displacement tended to increase toward the mesial side.

Discussion and Conclusion

From the results of this study, as a mechanical effect of implant support in the design of removable partial denture,

1: Stress relaxation was observed in the tissue around the abutment tooth, including the magnetic attachment.

2: In the burden style of denture, it was confirmed that the tissue borne area was reduced and the displacement of the denture base was suppressed.

3: In the implant 10.0 model and the implant 6.5 models, significant differences were not observed in both stress distribution and denture displacement in the alveolar bone.

Therefore, these results suggest implant supported removable partial denture would expand its indication on designing removable partial denture.

References

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