Mechanical analysis of implant support in removable partial denture design applied a magnetic attachment

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Abstract

The purpose of this study was to investigate the effect of implant support on the tissue around the abutment tooth and the behavior of the removable partial denture using three-dimensional finite element method in the design of the removable partial denture applied a magnetic attachment.

The analysis model was constructed using a mandibular plaster model and a skull model. The missing teeth were right lower second premolar, first and second molar, left lower second premolar, and first molar. The basic model used a retainer with RPI clasp on both first premolar and the magnetic attachment on left second molar. The analysis items were two types of the basic model and the implant support model in which implants were embedded in right free end missing of the basic model. The analysis conditions were set for these models, and three-dimensional finite element analysis was performed.

The results of this analysis, the mechanical effect of the implant support in the design of removable partial denture decreased the displacement of the denture, and showed the relaxation of the stress of the tissue around the abutment tooth on the implant side.

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 free end missing.

In such a situation, the application of the magnetic attachment to the posterior molar can change the missing form from the free end 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 defect prosthesis 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, for the intervention of the implant support in the design of removable partial denture, at present, still there are many questions about mechanical effects.

Objective

The purpose of this study was to analyze by using the three-dimensional finite element method, and to examine what kind of mechanical effect of using implant support in the design of removable partial denture with magnetic attachment.

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 11.0, 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. [1]

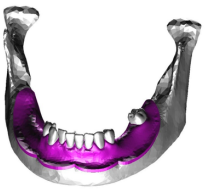

Fig.1 : The mandibular model used in this study

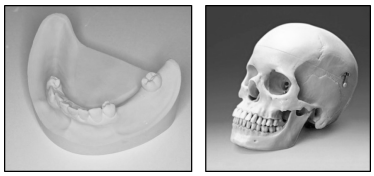

Fig.2 : a mandibular plaster model and a skull model

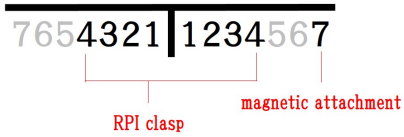

Fig.3 : The design of the removable partial denture

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 retainer.The magnetic attachment applied in this research was GIGAUSS D1000 and accurately reproduced its high diameter and width for model construction.

2. Analysis Items

Analysis items are shown in Fig.4.

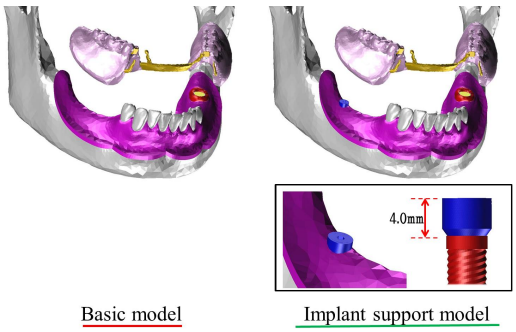

Fig.4 : the analysis items

The analysis items were two types of the basic model and the implant support model with implant (lemgth 10.0mm φ3.8mm) embedded in the second molar equivalent of 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.

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.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 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 μ = 0.090 for this study. [3]

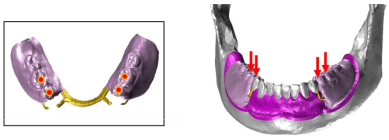

Fig.5 : the load conditions

Analysis Results

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

1. Alveolar cavity of the mandibular left second molar

Fig. 6 shows the stress distribution of the alveolar cavity of the mandibular left second molar. Compared to the basic model, stress relaxation was confirmed in the implant support model.

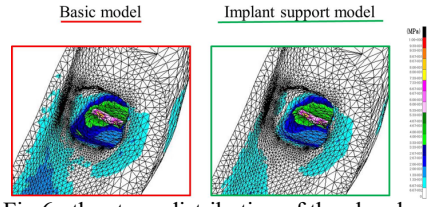

Fig.6 : the stress distribution of the alveolar cavity of the mandibular left second molar

2. Alveolar cavity of the mandibular left first premolar

Fig. 7 shows the stress distribution of the alveolar cavity of the mandibular right first premolar. Compared with the implant support model, stress spread was observed at the distal portion of the alveolar cavity in the basic model, but no significant difference was observed around the alveolar cavity.

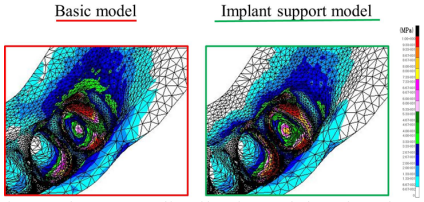

Fig.7 : the stress distribution of the alveolar cavity of the mandibular left first premolar

3. Alveolar cavity of the mandibular right first premolar

Fig. 8 shows the stress distribution of the alveolar cavity of the mandibular right first premolar. At the distal portion of the alveolar cavity and around the alveolar cavity, Compared to the basic model, stress relaxation was confirmed in the implant support model.

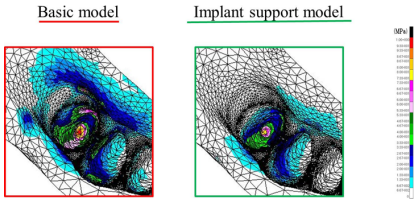

Fig.8 : the stress distribution of the alveolar cavity of the mandibular right first premolar

4. Displacement of denture base

Fig. 9 shows the amount of displacement of the denture base. The displacement of the equivalent to mandibular right second molar, first molar, and second premolar was reduced in the implant support model compared to the basic model. As for the amount of displacement, the basic model tended to increase as the distance toward the distal, and the implant support model tended to increase as the distance toward the mesial. There was no significant difference between the two models in the displacements of equivalent to mandibular left second molar, the first molar, and the second premolar. As for the amount of displacement, both models tended to the increase as the distance toward the mesial.

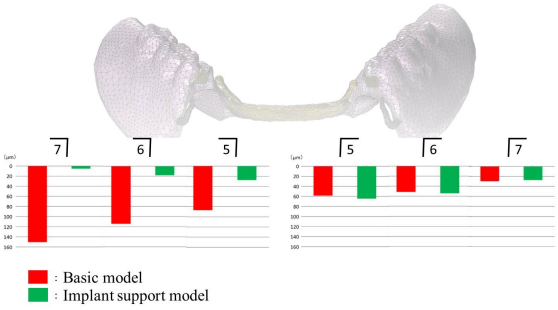

Fig.9 : The amount of displacement of the denture base

Discussion and Conclusion

The results of this study confirm that the mechanical effects of implant support in the design of removable partial denture using magnetic attachment include stress relaxation of the tissue around the abutment tooth using the magnetic attachment and the tissue around the abutment tooth on the implant support side. It was also confirmed that the use of implant support for the free end missing reduced mucosal burden zone of the denture and suppressed the amount of the displacement of the denture base. From the above, in the design of removable partial denture in the free end missing, taking advantage of the implant support the rearmost missing form an intermediate missing reduction, possibly attained stability of partial denture was suggested.

References

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