Influence of the Axial Surface of Keeper Coping on the Circumferential Tissue Using Three-Dimensional Finite Element

N. Shibuya[1], D. Yamanaka[1], T. Uchida[1], T. Ohyama[1,2], S. Nakabayashi[1,2], S. Tadokoro[1], H. Toyoma[1,2], K. Ohtani[1,2], T. Fujimoto[1], M. Ishijima[1] and T. Ishigami[1,2]

[1]Department of Partial Denture Prosthodontics, Nihon University School of Dentistry
[2]Division of Clinical Research, Dental Research Center, Nihon University School of Dentistry

Introduction

When the keeper coping is applied to the abutment tooth for an overdenture, the shape of the axial surface of the keeper coping may affect the stress distribution to the abutment tooth and the circumferential tissue. The aim of this study was to evaluate the influence of the axial surface shape of the keeper coping on the circumferential tissue, and to analyze the biomechanical behavior of the cortical bone under the denture base during three different loading conditions using three-dimentional finite element method.

Materials and Methods

A complete overdenture model with keeper coping delivered on mandibular right canine was evaluated. The outline of the abutment tooth and mandible were modeled on the basis of three-dimentions data from a multi-detector CT (Asteion Super4 Edition, Toshiba, Japan). The periodontal ligament, cortical bone, cancellous bone, and alveolar mucosa shapes were modeled with reference to anatomical measurements. The analysis models constructed were tooth, cortical bone, cancellous bone, denture base, keeper coping, periodontal ligament and alveolar mucosa. For this study, Rhinoceros (Version 1.0, Robert McNeil & Associates, U.S.A) and ANSYS (Version 12.1, Ansys Inc., U.S.A.) were used. Table 1 shows the Young modulus and Poisson's ratio.

Material	Young's modulus (MPa)	Poisson's ratio
Dentin	11721.1	0.30
Cortical bone	10414.7	0.30
Cancellous bone	88.3	0.30
Denture base	1960	0.30
Au-Ag-Pd alloy	110800	0.30
Periodontal ligament (First load)	0.049	0.49
Periodontal ligament (Second load)	0.7	0.49
Alveolar mucosa	0.045	0.49

Table 1: Material Properties

Fig.1 shows the design of keeper coping and analysis models.
The height of the keeper coping was 2.5mm from the lingual alveolar crest.
The abutment tooth was set to incline 15 degrees for the occlusal plane, and the top surface of the keeper coping was set perpendicularly to the tooth axis.
Model A was set the inclination angle on axial surface is 0 degree.
Model B was set the inclination angle on axial surface is 30 degrees.
Model C was set the form of axial surface was curved.

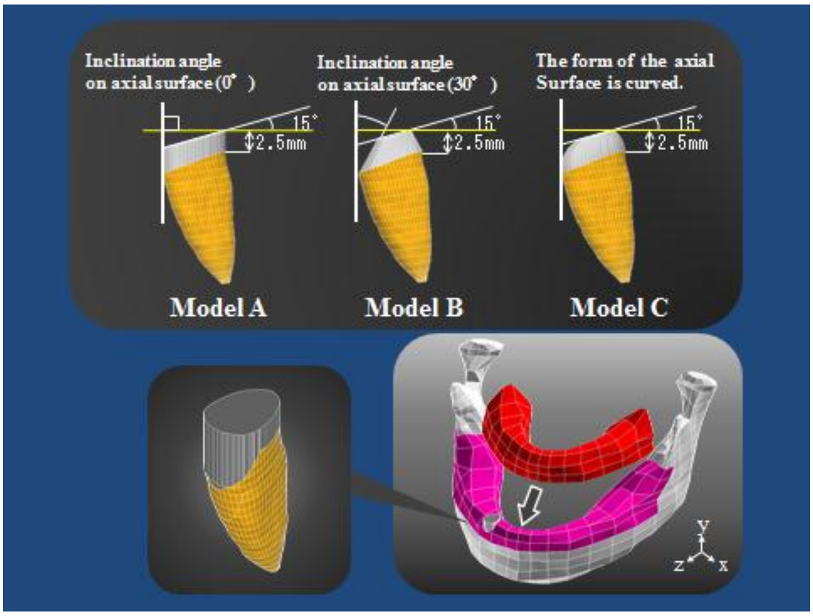

Fig.1: The Design of Keeper Coping and Analysis Model

The three different loading simulations (clenching in bilateral occlusion, left lateral occlusion and right lateral occlusion) was set up with the vector of masficatory muscles.
Table2 shows the loading conditions.

	Node number	Load				
		Bilateral Occlusion	Left Lateral Occlusion		Right Lateral Occlusion	
			R	L	R	L
Superficial Masseter	14	190.4	114.2	137.1	137.1	114.2
Deep Masseter	5	81.6	49.0	58.8	58.8	49.0
Medial Pterygoid	11	132.8	104.9	146.8	146.8	104.9
Anterior Temporalis	9	154.8	91.6	115.3	115.3	91.6
Middle Temporalis	12	91.8	64.1	63.1	63.1	64.1
Posterior Temporalis	9	72.6	29.5	44.6	44.6	29.5
Inferior Lateral Pterygoid	3	18.1	0	0	0	0
Superior Lateral Pterygoid	3	16.9	0	0	0	0
Anterior Digastric	1	11.2	0	0	0	0

Table. 2: The Loading Conditions

The paths of each mandibular condyle ware constrained. Guidance by the articular eminence was simulated with a planar constraint. It permitted rotations and translations in the specified plane.
The constraining plane was angled 30 degree forward and downward relative to the occlusal plane, and it was canted 5 degrees medially. The inclination angle of buccal cusp of artificial teeth was set 30 degrees and the lingual cusp of the artificial tooth was 20 degrees.
The balanced occlusion was simulated by ten occlusal stops on complete overdenture (Fig.2).

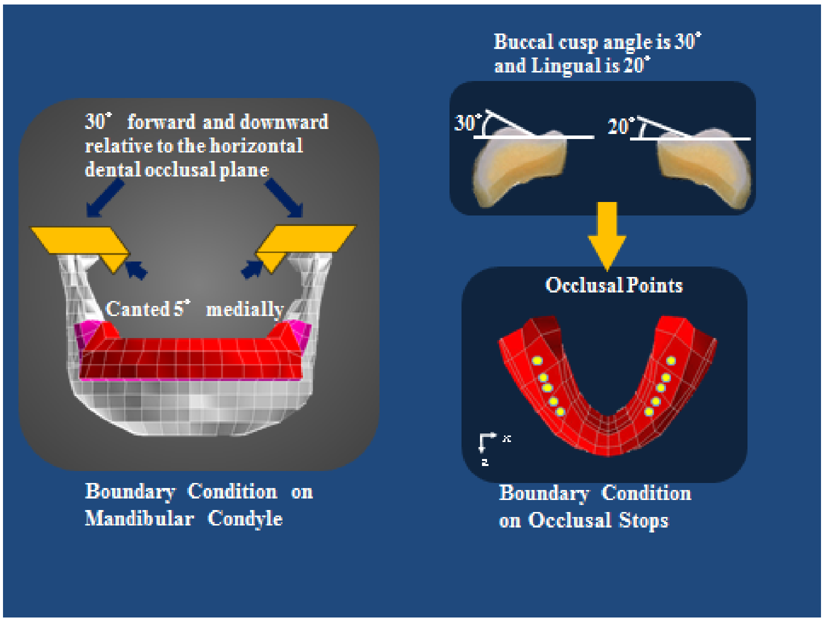

Fig.2: Constraint Conditions

Results

Figure 3-5 shows the stress distribution of the abutment tooth clenching in bilateral occlusion, left lateral occlusion and right lateral occlusion. There were no differences in the stress distribution of the abutment tooth among three kinds of analysis models in three different loading conditions.

The stress concentration was detected on the labial and lingual side of the abutment tooth and the center of the mandible.

Figure 6-8 shows the stress distribution graph of the top surface of cortical bone clenching in three different loading conditions. The thirteen analysis points were set on the top surface of cortical bone (analysis points:a-m). There were no significant differences with all models in bilateral occlusion and right lateral occlusion. It was showed the difference of stress distribution around the abutment tooth in left lateral occlusion. The stress concentration around the abutment tooth (mesial side and distal side) was decreased in model C.

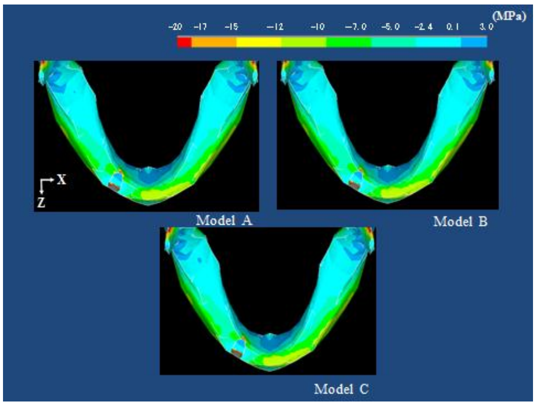

Fig.3:Bilateral occlusion

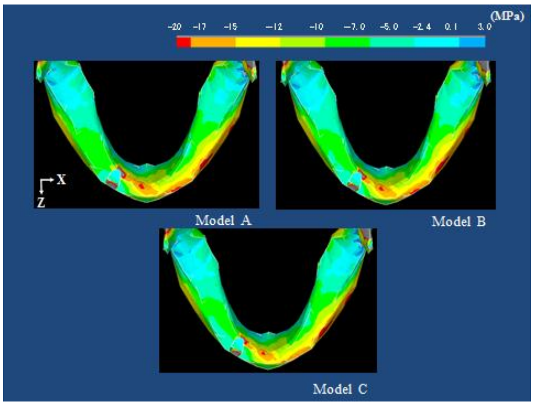

Fig.4:Left lateral occlusion

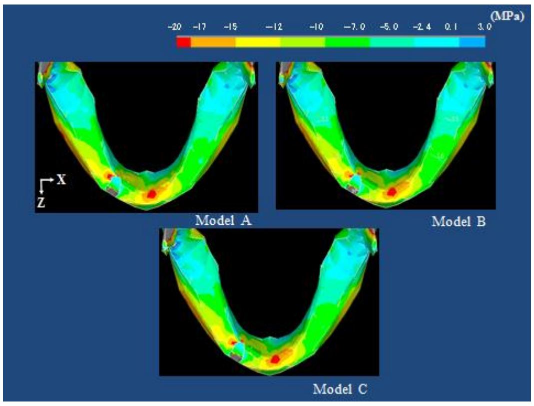

Fig.5:Right lateral occlusion

The Stress Distribution
(Minimum Principal Stress)

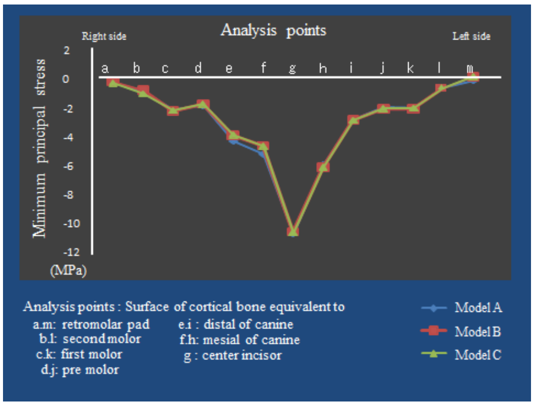

Fig.6:Bilateral occlusion

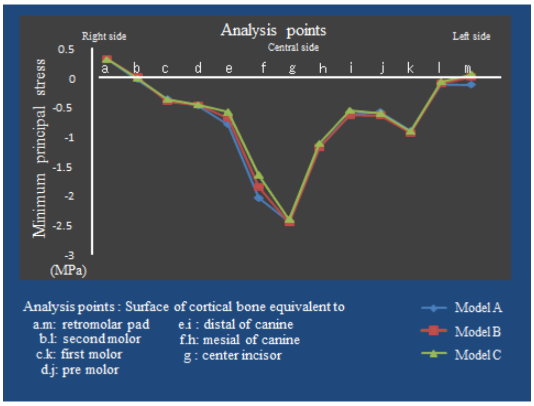

Fig.7:Left lateral occlusion

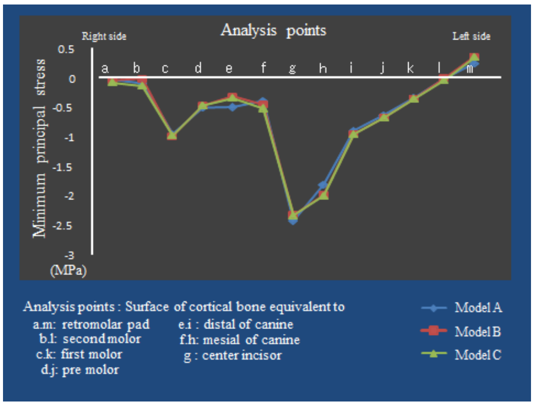

Fig.8:Right lateral occlusion

The Stress Distribution Graph
of The Top Surface of Cortical Bone

Discussions

In model A during left lateral occlusion, the lowest stress concentration was found around the abutment tooth. It could be thought that the axial surface of keeper coping curved was available to reduce the force loading on the abutment tooth.

Conclusions

Within the limitations of this study- it was thought the curved form of the axial surface reduced the biomechanical risks of the circumferential tissue around the abutment tooth in overdenture.

References

1. Korioth TW, Hannam AG, Deformation of the Human Mandible During Simulated Tooth Clenching, J Dent Res 73:56-66, 1994.
2. G.E.J. Langenbach, A.G. Hannam, The Role of Passive Muscle Tensions in A Three-dimensional Dynamic Model of the Human Jaw, Arch Oral Biol 44:557-573, 1999