Simulation of an Occlusal Interference of an Implant Crown

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Abstract

A periodontal ligament is a tissue that forms between a tooth and a supporting bone. It absorbs and distributes the occlusal force to the supporting bone. In addition, it contains mechanoreceptors which sense the mechanical load. In dental implantation, bone forms around the implant without the periodontal ligament. Therefore, the sensitivity to the mechanical load decreases. Occlusal interference of an implant crown is an interference of a mandible movement by an initial contact between an implant crown and its antagonist teeth. There is potential of overloading of an implant if the occlusal interference occurs. In this study, an occlusal interference of an implant crown was simulated to quantify the magnitude of the resulting occlusal force. A finite element model of a mandible with an implant anchored in the first molar position was created. A rigid plate was used to collectively represent the maxillary first molar, which is the antagonist tooth, the periodontal ligament and the maxilla. Finite element contact analysis was performed to simulate the occlusal interference. The occlusal interference height was calculated from the combined displacements of the implant crown from the finite element analysis and the maxillary first molar from the existing experimental results. From the obtained results, the occlusal interference height of 100 micrometers can result in an increase of the magnitude of occlusal force of 84.82 N.

***Keywords**:* Occlusal interference, Finite element method, Dental implant

1. Introduction

A periodontal ligament (PDL) is a tissue that forms between a tooth and a supporting bone. It absorbs and distributes the occlusal force to the supporting bone. In addition, it contains mechanoreceptors which sense the mechanical load. In contrast to natural teeth, bone forms around the implant without the PDL. Therefore, the sensitivity to the mechanical load decreases. Occlusal interference of an implant crown is an interference of a mandible movement by an initial contact between an implant crown and its antagonist teeth. Occlusal interference can cause an excessive loading on the surrounding bone since it inhibits the load sharing among the implant crown and teeth. In addition, since the bone-implant interface lacks the PDL which contains mechanoreceptors, the risk of excessive loading on the bone increases. Therefore, a quantitative study on the influence of occlusal interference height on the magnitude of an occlusal force is useful for dentists and engineers who are working with the implant. In general, to simulate the occlusal interference of an implant crown by finite element (FE) analysis, an FE model of the implant anchored in its supporting bone, the implant crown and the antagonist teeth with their PDL and their supporting bone must be created. The difficulty arises when the FE model includes the PDL because it is difficult to numerically model the PDL. Various types of numerical model of the PDL were proposed such as linear [1,2], bilinear [3,4], hyperelastic [5] and viscoelastic [6] models which provided different values for the stiffness of the PDL. In addition, creating an FE model of teeth, their PDL and their supporting bone is a time consuming process.

This study aimed to simulate the occlusal interference caused by an implant crown using the FE contact analysis. To overcome the difficulties mentioned earlier, the load-displacement relationship of a tooth averaged from the literature was used in this study. The influence of an occlusal interference height on the occlusal force was analyzed in this study.

2. Materials and Methods

In this study, an FE model of a mandible with an implant anchored in the first molar position was created as shown in Fig. 1. The FE model of the mandible was created from CT

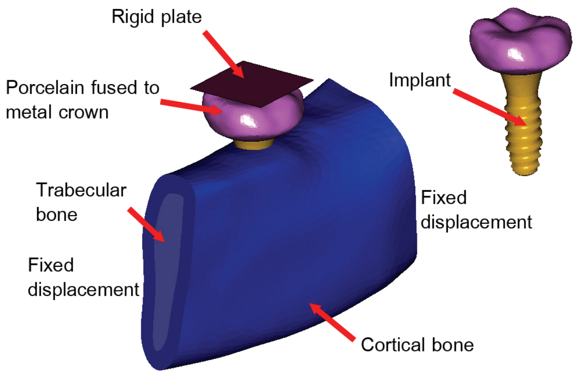

Fig. 1 FE model of a mandible with an implant anchored in the first molar position

images. The implant crown was made of a porcelain fused to metal crown. The implant had a diameter of 4.1 mm and was 10 mm long. The shape of the implant was screw-shaped. This study simulated an occlusal interference from the initial contact of the implant crown with its antagonist teeth, both of them displaced until the teeth adjacent to the implant crown just started to be in contact with their antagonist teeth. Therefore, there were no contact forces between the adjacent teeth and their antagonist teeth. Furthermore, this study considered the worse-case scenario where the occlusal force could not be transferred from the implant crown to its adjacent teeth. As a result, the teeth adjacent to the implant crown were not modeled. A rigid plate was used to collectively represent the maxillary first molar, which was the antagonist tooth [7], the periodontal ligament and the maxilla. Four-noded tetrahedral elements were used to construct the mesh. The FE model consisted of 47,269 nodes and 249,853 elements. A convergence test was performed. The material properties used in the model were obtained from the literature and shown in Table. 1 except for the cortical bone. The Young's modulus

Table. 1 Material properties used in the analysis

Material	Young's modulus (MPa)	Poisson's ratio
Trabecular bone [8,9]	1,370	0.30
Titanium [10,11]	110,000	0.30
Gold alloy [8]	91,000	0.33
Porcelain [8]	67,200	0.30

and Poisson's ratio of the cortical bone were 14.5 GPa and 0.323, respectively, which were averaged from Ashman and Van Buskirk [12]. All materials were assumed to be linear elastic isotropic. The FE analysis was performed in the Marc Mentat program to simulate the occlusal interference. For the boundary conditions, the displacements of nodes on both ends of the mandible were fixed. The implant was assumed to be osseointegrated. In general, the straightforward way to vary the occlusal interference height is to change the height of implant crown. This is a time consuming process because it requires remeshing. In this study, the occlusal interference height was varied by the combined displacement of the implant crown from the FE analysis and the displacement of the maxillary first molar from the load-displacement relationship that was averaged from the biting experiments carried out by Picton [13] shown in Fig. 2. The displacement of maxillary first molar could be obtained as follows. The rigid plate moved down to compress the implant crown in the displacement-controlled manner (Fig. 3). The contact force was achieved from FE contact analysis. This contact force represented the occlusal force between the implant

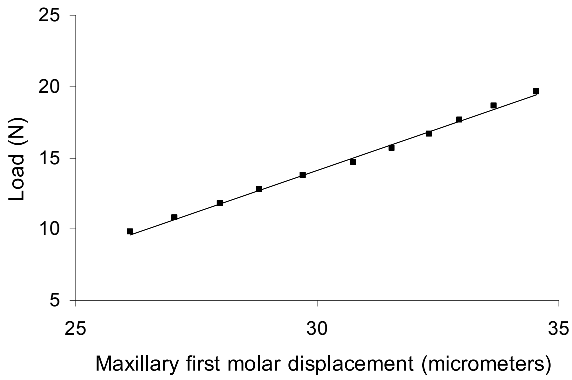

Fig. 2 Load-displacement relationship averaged from experiment of Picton [13]

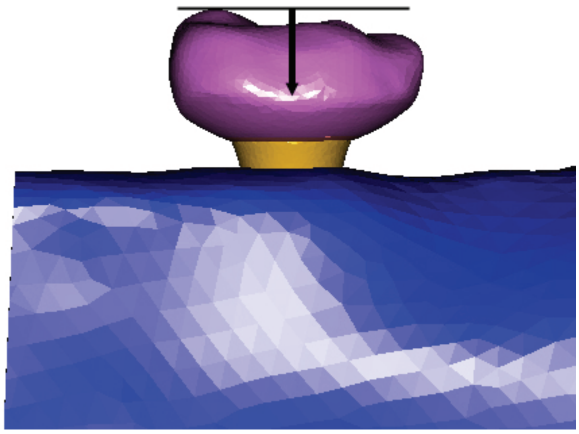

Fig. 3 The movement of the rigid plate

crown and the maxillary first molar. This contact force was then used to find the displacement of the maxillary first molar from the load-displacement relationship shown in Fig. 2. Therefore, the occlusal interference height was varied without remeshing. This is also the advantage of using the rigid plate to represent the maxillary first molar, PDL, and maxilla. In this study, the rigid plate displacements from 5 to 25 micrometers were analyzed. The control case was the case with no occlusal interference where no rigid plate displacement occurred.

3. Results and Discussion

The contact forces obtained from FE contact analysis are shown in Table. 2. These contact forces were used to calculate the displacement of the maxillary first molar by linearly extrapolating from Fig. 2. After that, the occlusal interference heights were calculated as shown in Table. 3. The obtained relationship between the occlusal interference height and the occlusal contact force is shown in Fig. 4. Ikeda et al [14] studied an influence of occlusal interference height on tooth pain threshold in humans. They discovered that occlusal interference heights less than 100 micrometers did not generate any occlusal pain or cold water triggered pain. Therefore occlusal interference height of 100 micrometers can be considered as tooth pain threshold. From Fig. 4, it can be seen that the occlusal interference of 100 micrometers causes the increment of force equal to 84.82 N. For the case with an implant, the pain threshold should be higher than 100 micrometers due to lack of PDL. Ferrario et al [15] measured the maximum bite forces of men and women. The average value of the maximum bite force of the first molar was 284.04 N. The additional contact force from the occlusal interference height of 100 micrometers is about 29.86 % of this maximum bite force. This result indicates that the effect of the occlusal interference is significant. In the occlusal adjustment, the occlusal interference should be avoided as much as possible.

4. Conclusion

In this study, a new method to analyze the occlusal interference caused by the implant crown malpositioning was proposed. The rigid plate was used to collectively represent the antagonist teeth, the PDL and maxilla. The occlusal interference was simulated by the

Table. 2 Displacement of the maxillary first molar

Rigid plate displacement (micrometers)	Contact force (N)	Displacement of the maxillary first molar (micrometers)
5	45.20	56.68
10	90.40	95.47
15	137.53	135.92
20	186.40	177.88
25	235.27	219.83

Table. 3 Occlusal interference heights obtained from the simulation

Contact force (N)	Occlusal interference height (micrometers)
45.20	61.68
90.40	105.47
137.53	150.92
186.40	197.88
235.27	244.83

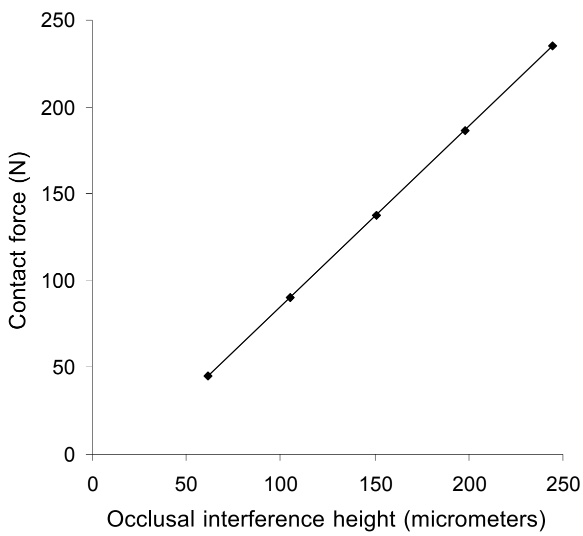

Fig. 4 The relationship between occlusal force and occlusal interference height

combined displacement of the rigid plate and the displacement of the antagonist teeth which was approximated from the literature. This approach can reduce the time for creating the mesh. In addition the occlusal interference height can be varied without remeshing. The results showed that the magnitude of force caused by occlusal interference is considerable. This finding highlights the risk of the occlusal interference.

5. References

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