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Keio University

A Thesis for the Degree of Ph.D. in Engineering

Biomechanical Study of Drilling Trabecular Bone and Lifting Maxillary Sinus Membrane in Oral Implant Surgery

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Thesis Abstract

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Thesis Title

Biomechanical Study of Drilling Trabecular Bone and Lifting Maxillary Sinus Membrane in Oral Implant Surgery

Thesis Summary

This study aims at reducing the number of serious cases occurred in the oral implant surgery through biomechanical study of mandibular trabecular bone and maxillary sinus membrane. The problem occurs when a clinician misjudges the bone quality of the trabecular bone in the lower jawbone during drilling causing perforation through the mandibular canal. Furthermore, accidents that could lead to death such as the perforation to the lingual cortical bone also might happen. In the upper jawbone the problem lies with the breakage of the maxillary sinus membrane due to perforation or dead cell caused by strain concentration that cuts the blood flow during the sinus lift up process after drilling. Therefore, to avoid the above mentioned problems, it is important to quantify the drilling force-sensing for trabecular bone and strain distribution in lifted sinus membrane.

In relation to the quantification of drilling force-sensed, a new oral implant surgery training simulator was developed so that the users can feel the real force-sense. The apparatus was tuned through experiment using fresh cadaver and expert clinician’s evaluation not only for the trabecular bone but also for cortical bone in order to simulate the accidental cases. The developed system was then evaluated by clinicians, and it was revealed that their experience was very much influential on the force-sensed by investigating the input drilling force and the output drilling speed. The developed system was then used for education of students in a problem-based learning (PBL) class at a dental college. It was quantified how correctly the students could recognize the bone quality of the trabecular bone by the drilling force-sensed. More than half of them could identify the main features of force-sensed influenced by bone quality for a bone sample. This implies that the same evaluation can be done on well experienced clinicians and they can identify them more accurately. Hence, the developed system can also help the clinician to quantify the drilling force-sensed and the bone quality after the surgery, which can be transferred to an inexperienced student.

In regards to the strain distribution in the maxillary sinus membrane, an apparatus was designed and developed in order to measure the reaction force during the lift up process using fresh cadaver. Also with the help of nonlinear finite element analysis, the material properties of sinus membrane were calibrated using a power-law constitutive equation, and finally the strain distribution was obtained. Based on the strain values, it was concluded that the RZ component of the shear strain was significant to the cutting of the blood flow in the sinus membrane, where the R component denotes the radial direction of the membrane and Z denotes its thickness direction. This fundamental study on the membrane is expected to lead to the development of sinus lift up surgery training simulator with force-sensing capability.