Proceedings of Second International Symposium on Apatite, © Japanese Association of Apatite Science, June 1997

Comparative Studies on Apatite Artificial Root of Ankylotic and Gomphotic Type

Katsunari NISHIHARA

Department of Oral Surgery, Faculty of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113, Japan

Abstract

Comparative studies on ankylotic and gomphotic artificial roots are presented in this paper. Artificial roots made of compactly sintered hydroxyapatite with corrugated configuration are implanted in adult dogs and Japanese monkeys for the experiments. Ankylotic artificial root can be easily obtained by stress shielding of occlusion after implantation. On the contrary, gomphotic root can be obtained by physiological micromovement through mastication immediately after operation. Specimens of animal experiments are recovered and studied histopathologically. Finite element analyses of the artificial root of ankylotic and gomphotic models are also carried out. The results of animal experiments are compared with stress distribution patterns obtained from model analyses. From these studies following conclusions are obtained; Ankylotic artificial root has no remodeling system in surrounding bone. Without loading ankylosis can be obtained. However bone around the root disappear without loading. Therefore ankylotic artificial root can be recognized as antinomy system.

Key words: hydroxyapatite, artificial root, ankylosis, gomphosis, remodeling

Introduction

To study the histological difference between gomphotic and ankylotic teeth, animal experiments of functional and nonfunctional groups are carried out. For investigation of the biomechanical difference, stress analyses with model conditions approximating the animal experiments are also carried out. Thereafter, the results are compared. Fibrous tissue around roots with alveolar bone proper is observed in specimens of the functional group [1-4]. Ankylosis of the artificial roots to the surrounding bone is observed in specimens without occlusal function. Severe bone destruction is observed in cortical bone around ankylotic dental implants in the animal experiment. The pattern of bone destruction under the usual occlusal function in the experiment and the finite element analysis (FEA) pattern showed a close correlation.

The fibrous juncture system around the bioceramic has the most important role, after which the stress mitigates and disperses, and the principal stress trajectories are converted. In ankylosis, stress is distributed in cortical bone in a concentrated manner. The principal stress trajectories run continuously from the artificial root to the ankylotic peripheral bone tissue. Severe bone destruction is observed in cortical bone around a similar type dental implant in an animal experiment several years postop [2-4]. The destruction observed coincides with the stress-concentrating site of the analyzed model. Elastic moduli refer to the rate of shrinkage under loading. Therefore, different materials of a stiff bonding system i.e., ankylosis or osseointegration with different elastic moduli, disrupt under severe loading because of continuing principal stress trajectories between each other.

Materials and Methods

1. Animal experiments
The artificial roots are implanted in adult dogs. For the nonfunctional group, the roots are implanted the roots deeply at the level of the gingiva. The dogs are fed a soft diet. For the functional group, the artificial roots are implanted with the occlusal part extruded to the oral cavity through the gingiva. Then the dogs are fed a solid diet to apply physiological movement to the roots by mastication. After fixed periods undecalcified and decalcified specimens for light microscopy are prepared. For the monkey group, masticatory loading is applied after implantation for a long term, after which masticatory loading is excluded. Hydroxyapatite artificial roots are implanted in the mandible and maxilla of Japanese monkeys. Two years after implantation, the artificial roots are covered with crown splint to remove masticatory and occlusal loading. An additional two years later, the artificial roots are recovered to make specimens.

2. Finite element analyses relating to gomphotic and ankylotic apatite artificial root -Comparison of stress distribution patterns around gomphotic and ankylotic roots
The stress distribution of the gomphotic and ankylotic systems around newly tailored artificial roots of standard type, 5mm in diameter are analyzed. The analysis conditions were already reported [4].

Results

1. Animal experiments
(1) Nonfunctional group
In Japanese monkeys, ankylotic artificial roots are observed without loading by crown shielding. Artificial root and jawbone ankylosis take place only at the cortical site and almost no bone formation around the root can be seen. Bone structure around the artificial root is quite different from that of the control of a normal dental tooth (Fig. 1). Around the ankylotic artificial root with occlusal loading marked absorptive bone remodeling can be observed (Fig. 3).
(2) Functional group
Observation of an undecalcified specimen 8 weeks and 6 months after implantation revealed that the artificial roots are in direct contact with fibrous tissue, and bone formation has occurred resembling alveolar bone proper with trabeculae (Fig. 2).
Observation of a decalcified specimen 72 weeks and 4 years after implantation revealed that thin parallel fibrous tissue attaching to the root surface has turned into calcified tissue on which orthogonal fibrous tissues are anchored.

2. Finite element analyses - Comparison of stress distribution patterns around gomphotic and ankylotic roots
In the gomphotic artificial root model, stress distribution is equalized and mitigated by periodontal structures. The results are compared to histological findings of the specimens of animal experiments. The stresses are born mainly by cortical bone of the mandible through the alveolar bone proper. The orientation of principal stress trajectories in the artificial root is converted to two components, i.e. parallel and orthogonal to the root surface by periimplant fibrous tissue. On the contrary, in the ankylotic artificial root model, stress distribution is not mitigated but concentrated in the artificial root and alveolar ridge of cortical bone in the mandible.

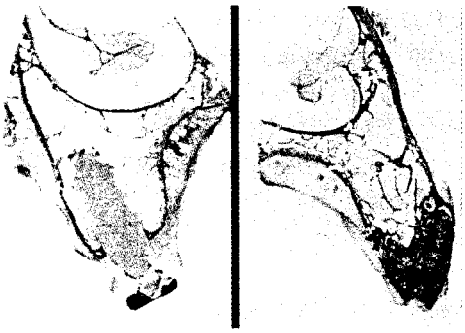

Figure 1.

Figure 2.

Figure 3.

Figure 1. Ankylotic artificial root without loading by crown shielding the control tooth.
Figure 2. Gomphotic artificial root with periodontal structures resembling natural tooth.
Figure 3. Ankylotic artificial root with occlusal load marked destructive remodeling without inflammation is observed.

Comparisons in FEA patterns with histological findings in either ankylotic or gomphotic artificial roots are found to coincide closely.

Discussion

Dental implants are conventionally invented with a concept of implantable denture, but not that of an artificial organ. The most serious problems of dentures are mobility and falling out from the jaws. Therefore, the main purpose of an implantable denture is fixation in the jawbone to prevent postop falling out. Almost all dental implant shapes are devised from the standpoint of postop fixation. On the contrary, the main function of the original tooth system is the bearing of multiple masticatory forces.

Therefore, for artificial roots the shape for bearing masticatory force is more important than fixation. The author have already reported on the shape and material effect of artificial roots on surrounding tissues[1-4]. From the research, stress distribution is definitely dependent upon the artificial root shape and jawbone morphology. Periimplant tissue formation resembling periodontal structures is almost dependent upon both shapes but very little upon the material property. From these experiments and analyses, the authors concluded that the tooth is a vehicle of multiple masticatory forces by which stresses are mitigated and equalized[1]. The stress orientations are converted by periodontal root supporting structures, after which stresses are transmitted to cortical bone of the jaw. The cortex must bear these stresses. If a stress converting system in or around the artificial root is not formed like ankylotic root, implant failure in the artificial root and/or surrounding bone can surely occur after long-term function.

Conclusion

From FEA on the functional effect of artificial roots and animal experiments, the following results are obtained:

(1) a. In a gomphotic artificial root under loading, mitigated stress is distributed evenly in alveolar bone proper and cortical bone of the jaw, and principal stress trajectories are converted to parallel and orthogonal elements in periimplant fibrous tissue.

b. In an ankylotic artificial root under loading, principal stress trajectories oriented continuously into ankylotic bone tissue, and concentrated stress is distributed in ankylotic part of the artificial root and cortical bone, where sever bone destruction occurs after long-term function.

(2) Through integrated triad research on shape, component, and functional effect, a gomphotic tooth is known to be a vehicle of multiple masticatory forces.

(3) Ankylotic tooth root system is of antinomy. Only without loading ankylosis takes place. On the contrary, under severe loading ankylosis between bone and ceramics disrupts because of differences of material constants. Therefore, ankylotic artificial root can stand up only under condition without functional loading.

This work was supported by the Grant-in-Aid for Scientific Research on Priority Area from the Ministry of Education, Science and Culture, Japan (Biomechanics, No. 06213102)

References

1. Nishihara K: Studies on peri-root tissue formation around new type artificial root made of dense hydroxyapatite. Clinical Materials 12: 159-167, 1993

2. Nishihara K: Biomechanical research on junction system of bone with biomaterials. Bio-Medical Materials and Engineering 4(3): 151-159, 1994

3. Nishihara K and Nakagiri S: Biomechanical studies on newly tailored artificial dental root. Bio-Medical Materials and Engineering 4(3): 141-149, 1994

4. Nishihara K, Nakamura M and Nakagiri S: Biomechanical studies on shape effect of hydroxyapatite artificial root upon surrounding jawbone. Clinical Materials 16:127-135, 1994