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COMPARATIVE STUDIES ON PERIODONTAL TISSUES AROUND NEW TYPE ARTIFICIAL ROOTS MADE OF ZIRCONIUM OXIDE, TITANIUM, AND HYDROXYAPATITE

K. NISHIHARA and T. AKAGAWA
Department of Oral Surgery, Faculty of Medicine, University of Tokyo, 7-3-1, Hongo, Bunkyo-ku, Tokyo, 113, Japan

Abstract We devised a new type of artificial root featuring fibrous tissue attachment. We prepared artificial roots made of hydroxyapatite, zirconium oxide, and titanium. To observe the material effect, we performed animal experiments on eight adult mongrel dogs. Tissue reactions around artificial roots of the same shape but different materials were investigated by light and scanning electron microscopy (SEM). Mirror-polished specimens of the implanted artificial roots also were surveyed with a microanalyzer. In this experiment, fibrous tissue attachment and osteogenesis similar to lamina dura were observed in all artificial roots regardless of the materials used. From these results, shape is believed to be the most important factor for mechanical supportive organ systems such as teeth and bone. Among the materials observed, hydroxyapatite was unique in that calcified material very similar to cementum in pattern attached to the artificial root. We consider hydroxyapatite to be the most suitable material for use as an artificial root. Tissue reactions to implants have been considered to depend exclusively upon the material component. Actually, however, a biological reaction occurs in close relation to three factors: material component (material effect), morphology (shape effect), and functional stress (functional effect) applied to the implant.

INTRODUCTION

From the standpoint of comparative anatomy and phylogenesis, the tooth is classified as a unique entity in the mechanical supportive organ system, showing close correlation between its morphology, function, and constitutional component with the microstructure. Considering these characteristic correlations in the tooth, we devised a new type of artificial root with a bonding system of fibrous tissue attachment to the alveolar bone, resembling the periodontal ligament [1]. To investigate the mechanical supportive artificial organ, we have to clarify the shape effect [2], component effect [3,4,5], and functional effect of the concerned organ [6,7]. Therefore, we conducted studies on the shape effect of hydroxyapatite artificial roots of the

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fibrous tissue attachment type concerning various configurations with the aid of the finite element method (FEM) and reported the results at the 1st Congress of Biomechanics (San Diego,1990) [2]. From this study, it was concluded that the artificial root shape is quite an important element to disperse the stress mitigated equally in the jawbone [2].

In this paper, we describe the component effect of the artificial root on the surrounding tissue. We investigated tissue reactions around artificial roots of the same shape but different materials and compared them by light microscopy and microanalyzer.

MATERIALS AND METHOD

Eight adult mongrel dogs, one to two years of age and weighing 9-12 kg, were used in these experiments. Artificial roots of sintered hydroxyapatite, zirconium oxide, and titanium, 4mm in diameter, were prepared and implanted in premolar sites of the dogs. The artificial roots were fabricated by Asahi Optical Company, Tokyo. The artificial roots were implanted at the time of extraction of the upper or lower premolars. Each artificial root was implanted in isolation to attain physiological movement of the recipient roots by encouraging mastication. The animals were placed on a soft diet for two weeks postop and were thereafter maintained on a solid diet.

Processing of the specimens proceeded as follows:

After a fixed period (1 to 17 months), the dogs were sacrificed at different intervals, and undecalcified and decalcified specimens were prepared. Undecalcified specimens with mirror-polished surfaces were also prepared for the microanalyzer. The specimens were observed by microscopy and analyzed with a microanalyzer Kevex 8000.

RESULTS

Of the 30 implanted artificial roots, 3 were fractured and 3 were exfoliated. Macroscopic observation revealed that the state of implantation of the remaining 24 artificial roots was satisfactory with no mobility and no evidence of infection. Satisfactory epithelial and submucosal fibrous tissue attachments resembling those of natural teeth were observed in the undecalcified sections of the artificial roots (AR) of hydroxyapatite (HA) (FIGURE 1), zirconium oxide (ZrO_2) (FIGURE 2), and titanium (Ti) (FIGURE 3) regardless of the different materials at the periodontal region. The modality of epithelial attachment was almost the same in all materials.

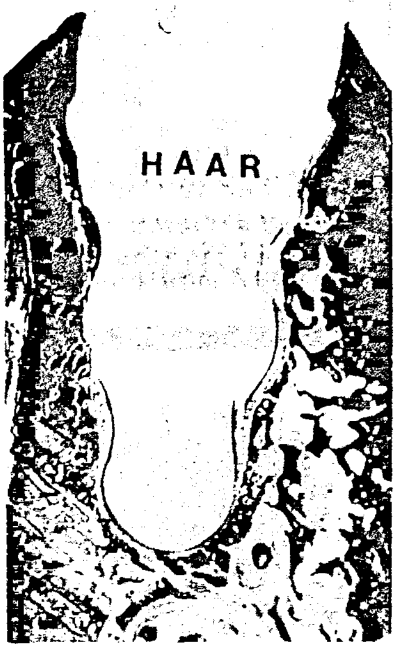

FIGURE 1
Decalcified section of
HA AR 6 weeks postop

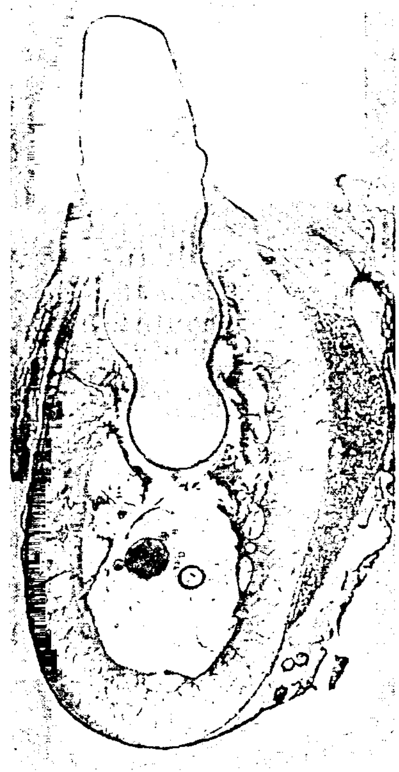

FIGURE 2
Undecalcified section
of ZrO2 AR
2 months postop

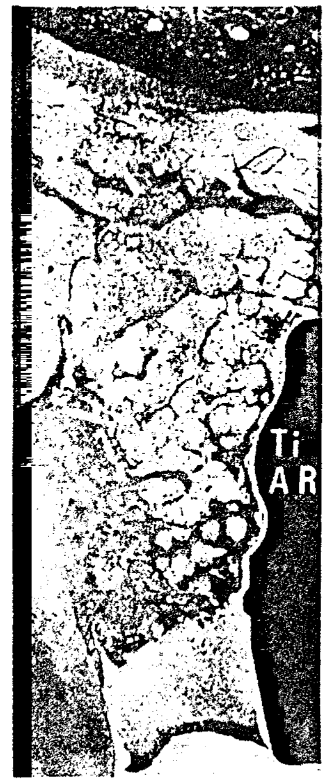

FIGURE 3
Undecalcified
section of Ti AR,
7 months postop

A layer of connective tissue rich in blood vessels was present in constant width around the artificial roots of hydroxyapatite, zirconium oxide, and titanium (FIGURES 1-4,8-11), and bone tissue similar to the alveolar bone proper formed around this layer (FIGURES 1-3,8,9,11). At the concave site of the artificial root, the root surface was fixed to the alveolar bone by means of fibrous connective tissues that ran at right or acute angles (FIGURES 4,6,8,9). In most cases, the bone was indirectly fixed with angled fibrous tissue to the artificial root surface. The layer of fibrous tissue was attached to the root surface with parallel orientation (FIGURES 4-6,9,10). At the convex site, fibrous connective tissues ran parallel with the artificial root surface. Observation by light microscope and SEM with Kevex 8000 of the mirror-polished surfaces of dog specimens revealed that in all artificial roots of the

FIGURE 4
Decalcified HA AR specimen
6 weeks postop

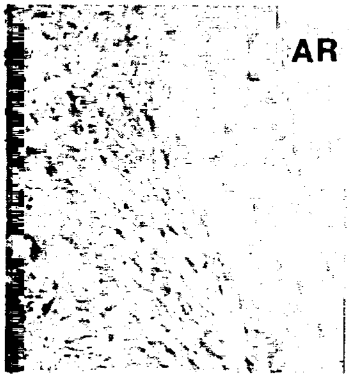

FIGURE 5
Decalcified HA AR specimen
2 months postop

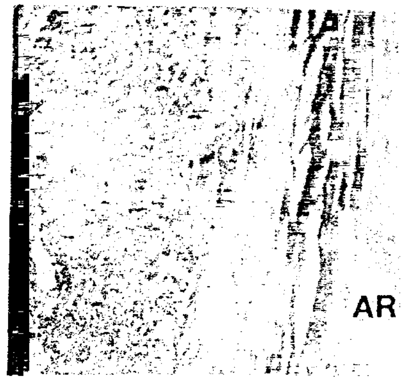

FIGURE 6
Decalcified HA AR specimen
17 months postop

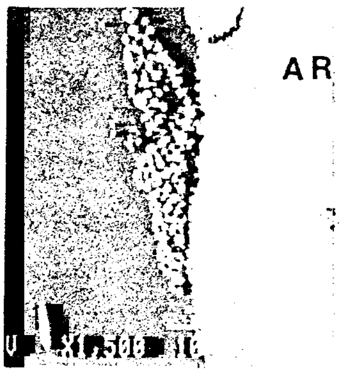

FIGURE 7
Mirror-polished HA AR specimen observed

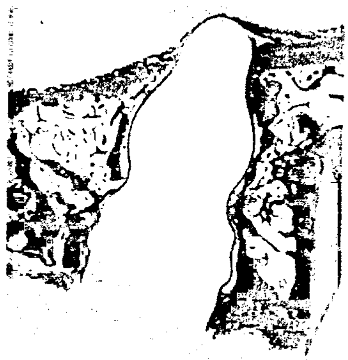

FIGURE 8
Decalcified ZrO2 AR specimen
4 months postop

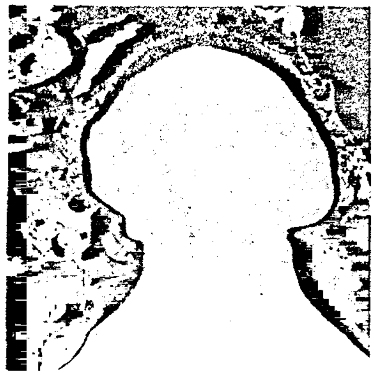

FIGURE 9
Undecalcified ZrO2 AR specimen
4 months postop

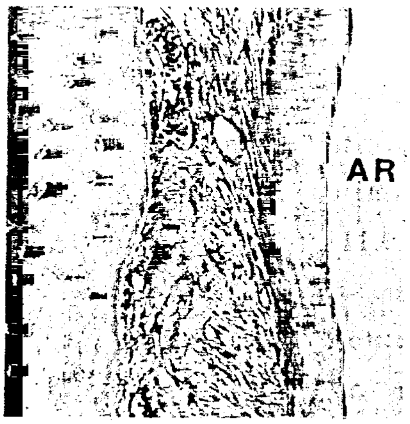

FIGURE 10
Decalcified Ti AR specimen,
4 months postop

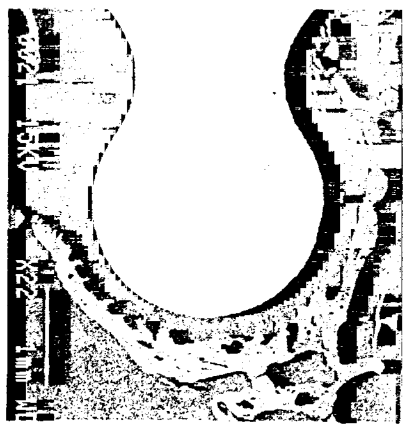

FIGURE 11
Mirror-polished ZrO2 AR specimen observed by SEM,
9 months postop

three different materials, alveolar bone proper (lamina dura) with trabeculae was observed, which was assumed to coincide with the principal stress trajectories as seen here in specimens (FIGURE 1-3,11). However, calcified material similar to cementum or bone attached to the hydroxyapatite artificial root surface exclusively (FIGURES 6,7). This finding is substance-specific for hydroxyapatite. The surface of the sintered hydroxyapatite appeared porous and seemed to remineralize (FIGURE 7). By SEM, calcified substance was observed attaching to the hydroxyapatite artificial root surface [5]. Calcium and phosphate contents similar to cementum or bone were detected by the Kevex 8000 microanalyzer system [5] (FIGURE 7). The surfaces of the titanium and zirconium oxide artificial roots showed no change and lacked calcium substance when studied by Kevex 8000 (FIGURE 11).

DISCUSSION

These days, dental implants of titanium/ceramics are being developed and applied clinically. At the same time, infection, alveolar bone resorption, and fracture of the implants have become serious issues.

The concept of an artificial root is quite different from that of a dental implant which is along the line of a removable denture. It works as an anchor instead of clasped teeth. The concept of a dental implant is far from that of an artificial organ. On the contrary, the artificial root is a kind of artificial organ which has systematic tooth-supportive tissues. Recently, ankylosis or osseointegration has been commonly accepted as an ideal bonding system of artificial root to the jawbone. However, ankylotic teeth are found in animals of a lower order without systematic mastication as in mammals. These teeth are isodontic and polyphyodontic with only prehensile functions. On the other hand, mammalian teeth bond to the jawbone by means of gomphosis and have ligamentous articulation, by which oral digestion, i.e., mastication, can be performed effectively.

Mechanical supportive organ systems such as teeth or bones have a close correlation between their morphology and functions. From this point of view, we believe that proper configuration and adequate masticatory function of the tooth can induce periartificial root tissues resembling periodontal supportive system. For the substitution of a tooth, an appropriate shape with periodontal ligament-like tissue is essential to carry out the mastication function. Multiple force of occlusion is dispersed by form and component of the root, and the dispersed stress is transmitted to the periodontal ligament, which induces osteogenesis or osteoclasia according to the principal stress trajectories. It is to say the tooth is a vehicle [4,7-8] of masticatory force, which bears multiple force in it, then disperses and translates to the force of the osteogenetic remodeling of bone in accordance with Wolff's Law. The tooth is one effective vehicle of force which disperses the occlusal stress equally in the jaws and invites osteogenesis, osteoclasia, and remodeling according to Wolff's law of trajectorial architecture in osseous tissue. As the vehicle of force, proper morphology of the root and periodontal ligament is essential to carry out the mastication function.

In our experiment, fibrous tissue attachment and osteogenesis similar to lamina dura were observed in all artificial roots regardless of the materials used. From these results, shape is believed to be the most important factor for mechanical supportive organ systems such as teeth. Among the materials observed, hydroxyapatite was unique in that calcified material very similar to cementum in pattern attached to the artificial root surface. Therefore, we consider hydroxyapatite to be the most suitable material for use as an artificial root.

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