The Zirconia Implant-Bone Interface: A Preliminary Histologic Evaluation in Rabbits

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Purpose: *Zirconia ceramics, a biocompatible material with favorable mechanical properties, has been suggested for use in the manufacture of dental implants instead of the commonly used titanium. Not much data exist on the early healing response around zirconia dental implants. The aim of this study was to give a descriptive histologic assessment of the degree of early bone apposition around zirconia dental implants at 2 and 4 weeks after insertion compared to surface-modified titanium implants.* ***Materials and Methods:*** *Four zirconia and 4 titanium implants were placed in New Zealand white male rabbits. One implant was inserted in the condyle of each distal femur. Specimens were harvested at 2 and 4 weeks and processed with light microscopic analysis. The area of bone-implant contact was evaluated histomorphometrically.* ***Results:*** *A high degree of bone apposition could be observed on all implants at both time points. Differences in the percentage of implant surface covered with bone were noted between the 2 time points, with comparable results for the 2 materials.* ***Conclusion:*** *The results of this limited histologic study demonstrate a similar rate of bone apposition on zirconia and surface-modified titanium implant surfaces during early healing. To confirm these results, further studies need to be conducted, involving larger sample size at more time points.* Int J Oral Maxillofac Implants 2008;23:691–695

Key words: *early healing, implants, osseointegration, zirconia*

Dental implants used to support fixed or removable partial or complete dentures as well as single crowns have become a widely used treatment modality. The long-term success of these treatment modalities has been demonstrated.[1–5] Osseointegration, defined as direct apposition of bone to the implant surface, takes place with implants made of different materials.[6–15] A wide array of different materials has been suggested for use as dental implants, with titanium as the most commonly used. Modifications of the titanium surface by polishing, hydroxyapatite coating, sandblasting, and/or acid etching are usually performed to increase biocompatibility.[16] While this material shows a high biocompatibility and favorable mechanical properties, possible drawbacks are the unnatural grayish color, which may lead to undesirable esthetic outcomes in cases of recessed gingival tissue when the titanium surface becomes visible, and the possible accumulation of titanium particles in local lymph nodes.[17,18]

Although the use of different ceramic materials as implants has been suggested early on, these materials are rarely used today.[9,19–21]

Zirconia, a ceramic material with widespread use and good long-term results in the field of orthopedic medical implants, has been recently suggested as a material for dental implants.[22–26] Zirconia is radiopaque, extremely hard, wear resistant, and chemically inert. Its ivory color, similar to the color of a natural tooth, renders it useful in esthetically critical areas of the mouth. Also, zirconia can transmit light, which makes it an ideal candidate for use in esthetic restorations.[27,28]

The successful use of zirconia as a material for dental implants has been demonstrated in several studies. Oliva et al demonstrated a 98% overall implant success rate after 1 year of follow-up in both coated and noncoated zirconia implants.[29] Osseo-

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Fig 1 Implants used in the study. *(Left)* Zirconia implant (test). *(Right)* Surface-modified titanium implant (control).

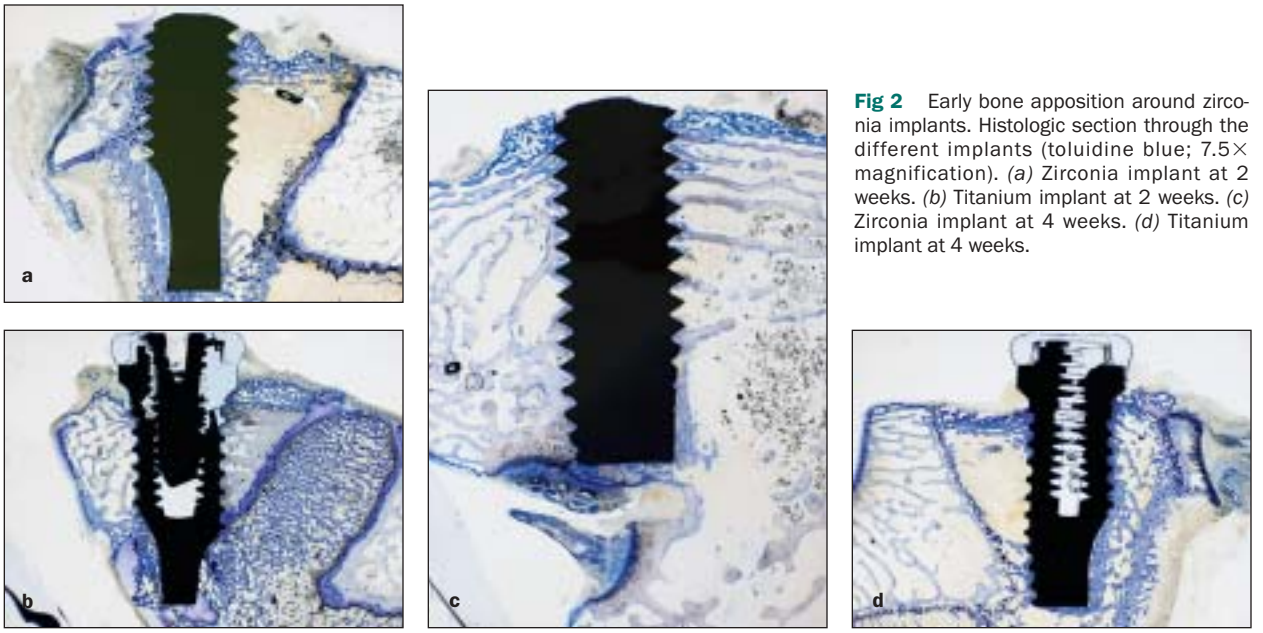

Fig 2 Early bone apposition around zirconia implants. Histologic section through the different implants (toluidine blue; 7.5× magnification). *(a)* Zirconia implant at 2 weeks. *(b)* Titanium implant at 2 weeks. *(c)* Zirconia implant at 4 weeks. *(d)* Titanium implant at 4 weeks.

integration as well as positive clinical outcomes have been demonstrated.[22–26] Furthermore, the inflammatory response and bone resorption induced by ceramic particles are much less than those induced by titanium particles, suggesting the biocompatibility of ceramics.[30,31]

There is not much data available in regard to the healing process around zirconia implants. Previous studies used comparatively long healing periods, single time points and/or no controls.[22,23,25,26] The purpose of this study is to give an initial descriptive histologic assessment of the degree of early bone apposition around zirconia dental implants at 2 and 4 weeks after insertion, compared to surface modified titanium implants.

MATERIALS AND METHODS

Experimental Design

Four male New Zealand white rabbits weighing between 2.0 and 2.5 kg were used. The study was approved by the Institutional Animal Care and Use Committee of Loma Linda University.

For this study, commercially available zirconia implants with a roughened surface (Z-Look 3 Implant, 3.25 × 10 mm, Z-systems AG, Kostanz, Germany, Fig 1) were used as test implants and commercially available titanium implants with a sandblasted, acid-etched surface (Osseotite, 3.25 × 8.5 mm, Biomet 3i, Palm Beach Gardens, FL, Fig 1) were used as controls.

One implant was placed in each distal condyle of the rear femur of each rabbit, 2 per rabbit (1 test and 1 control implant). Histologic specimens were harvested at 2 and 4 weeks after implant placement.

The animals were acclimated to the environment of the animal care facility for a period of at least 1 week before surgery to ensure their health and stability. During this time period the animals were housed in standard cages for rabbits and fed rabbit chow ad libitum. The rabbits' legs were load bearing throughout the entire study period. Sedation and induction were performed with ketamine (35mg/kg)/xylazine (2mg/kg; intramuscular) and isoflurane/O2 (masked) maintenance (1.5% to 2.5%) until completion of the surgical procedure. Local anesthesia was accomplished by infiltration with 0.5% bupivicaine with 1:200K epinephrine. Intraoperative temperature was maintained by towels and warming elements (eg, heating blanket, water bottles). Postoperative recovery temperatures were controlled by heating lamps.

Surgical Procedure

Four zirconia implants and 4 titanium implants were placed using a sterile surgical technique. All surgeries were performed by 1 surgeon (OH).

Prior to surgical draping, the animal's legs were shaved, washed, and decontaminated with iodine. Skin incision, blunt dissection of the muscles, and elevation of the periosteum were performed following anesthesia. The implant bed was prepared according to each manufacturer's guidelines using the corresponding surgical kits (Z-Systems and Biomet 3i). All implants were inserted to a depth of 8.5 mm. The abutment portion of the zirconia implants was removed with a high-speed handpiece and a fine diamond bur, and all sharp edges were thoroughly smoothed.

The surgical sites were closed in layers with the muscle, fascia, and internal dermal layers and sutured with 4.0 vicryl suture (Vicryl Plus, Ethicon, Piscataway, NJ) while the outer dermis was sutured to primary closure with 4.0 chromic gut suture (Chromic Gut, Ethicon).

The animals were rehydrated by injecting lactate ringer's solution intravenously corresponding to approximately 2% of body weight. Recovery was monitored for any possible complications, and the animals were given water and rabbit chow ad libitum during the healing period.

Two and 4 weeks after implant placement, the animals were euthanized, and the implants were surgically exposed by a sharp dissection to the bone. The implants were then removed en bloc with the surrounding bone and dehydrated in a graded series of increasing ethanol concentrations (40% ETOH for 24 hours and 70% ETOH).

Histology

Specimens were embedded in methylmethacrylate without being decalcified according to standard procedures and sectioned in the frontal plane through the middle of the cylinders. Sections of 200-µm thickness were obtained, ground, and polished to a uniform thickness of 60 to 80 µm. The specimens were surface-stained with toluidine blue.

Quantitative evaluation of bone regeneration was assessed by applying standard morphometrical techniques. Measurements were carried out directly with a light microscope at a magnification of 7.5×. To avoid any falsifications resulting from differences in implant shape or preparation of the slides, bone-implant contact was determined at the longest continuous area of implant threads at each implant. All the lengths of direct bone-implant contact in the chosen area were measured, and their sum was divided by the total length of the implant perimeter in the area. The results were expressed as percentage of bone-implant contact.

Statistical Analysis

The Student *t* test was implemented using a commercially available software package (SSPE 15.0, Chicago, IL).

RESULTS

Surgical procedures and healing were uneventful with the exception of 1 animal that died for unknown reasons three days after the second surgery. The specimens of this animal were not collected, and the procedures for these time points were repeated with a different animal. None of the implants showed clinical signs of mobility or inflammation.

Histologic evaluation of the specimens revealed bone apposition on all implants at each time point. In areas of bone apposition, bone was in direct contact with the implant surface, and no gaps or connective tissue were observed at the interface (Fig 2).

Significant differences ($P < .015$) in the percentage of implant surface covered with bone were noted between the 2- and 4-week time points. The rate of bone apposition at the 2 time points showed slight differences between the individual implants but was comparable for the 2 materials. At the 2-week time point, the 2 zirconia implants showed bone apposition of 55.40% and 54.80%. The controls demonstrated bone apposition of 42.80% and 52.50%, respectively. At the 4-week time point, the zirconia implants showed 62.20% and 80.70% bone apposition and the titanium implants 68.00% and 91.70% (Fig 3).

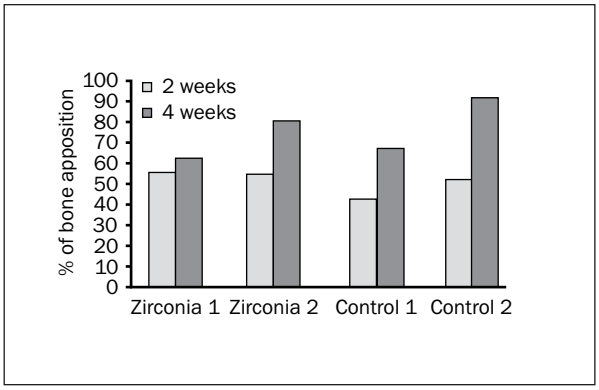

Fig 3 Bone apposition around zirconia implants and titanium controls at 2 and 4 weeks.

DISCUSSION

A wide array of different materials has been suggested for the use as dental implants. While the most commonly used material today is surface-modified titanium, the use of zirconia has been suggested and seems to include a wide range of properties that may make it a more advantageous choice for this use.[22–26] This material shows favorable mechanical characteristics and tooth-like color together with the ability to transmit light, which are of benefit in esthetically sensitive areas.[27,28]

The high degree of biocompatibility of this material has been demonstrated previously. Zirconia disks inserted into the subcutaneous tissue were encapsulated by a thin layer of connective tissue, and only minor inflammatory cell infiltrate was found.[30] Histologic analysis of disks implanted into rabbit muscles revealed no carcinogenic, toxic, or immunologic effects of this material.[32] Previous in vitro testing confirmed that zirconia does not have any oncogenic effects.[33]

Of major importance for the long-term success of the implant is a sufficient degree of osseointegration of the material. The time necessary for this to take place is of significance since, it may be an indicator for the time point at which the implant can be loaded. Since bone healing in rabbits is 2 to 3 times faster than in humans, time intervals of 2 and 4 weeks were chosen in this study.[34,35] These approximately resemble healing times of 4 to 12 weeks in humans, covering the time span usually suggested for early and regular loading of dental implants. Little data exists so far comparing the histologic healing of zirconia to titanium implants after shorter healing times. Our study, although limited by the number of samples, represents an attempt to give an initial overview of the rate of early healing around zirconia implants.

With the exception of 1 titanium implant, all implants retrieved 2 weeks after insertion showed bone apposition exceeding 50%, indicating that a significant degree of osseointegration can be observed even at this early time point. A further increase of bone apposition on both implant surfaces could be observed at the 4-week time point.

The zirconia implants demonstrated a slightly higher degree of bone apposition compared to the titanium controls at the 2-week time point. However, bone apposition was marginally higher in the controls when compared to the test implants at 4 weeks. Although this could be due to individual differences, it may also indicate better healing due to the superior biocompatibility of the ceramic surface, resulting in accelerated osseointegration of the zirconia implants at an earlier point of time, while the osseointegration of the titanium implants has its onset at a later time point but then with a slightly higher rate of bone apposition. It should be noted that the surface of the titanium implants used shows a high degree of surface roughness and reportedly performed better than other titanium surfaces in use for dental implants in regard to the rate of bone apposition at a time point similar to the 4-week one in this study.[36,37] The fact that the percentage of bone apposition on the zirconia implants in this study was better at 2 weeks and only slightly lower at 4 weeks in spite of the lower roughness compared to the titanium implants indicates a good biocompatibility of this material. The use of zirconia implants with a roughened surface may be a promising treatment approach.

The percentage of bone apposition observed at the 4-week time point did not substantially differ from the amount reported in other studies with significantly longer healing periods.[23,25,26] This could imply that extending the healing time may not necessarily always be of further benefit.

This limited histologic evaluation indicates a substantial rate of bone apposition around zirconia dental implants during the early healing time period. These findings are drawn from a relatively small sample size and as a result are preliminary in nature. Therefore, further studies need to be conducted involving a larger sample size at more time points to confirm the results of the present study.

DISCLAIMER OF CONFLICT OF INTERESTS

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