Soft Tissue Biological Response to Zirconia and Metal Implant Abutments Compared With Natural Tooth: Microcirculation Monitoring as a Novel Bioindicator

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Introduction: *Zirconia is often used for implant abutments for esthetics. The aim of this clinical study was to compare the effects of zirconia and metal abutments on periimplant soft tissue.*

Materials and Methods: *Ten maxillary anterior implant patients, 5 with metal abutments and 5 with zirconia abutments, were enrolled in this trial. The soft tissue around the implant abutments was evaluated by 2-dimensional laser speckle imaging and thermography. The blood flow in soft tissue around natural teeth was also measured to correct for differences among the subjects.*

Results: *Significantly greater blood flow was detected in the zirconia abutment group (95.64 ± 5.17%) relative to the metal abutment group (82.25 ± 8.92%) in free gingiva (P = 0.0317). Reduced blood flow (by almost 18%) was detected in the tissue surrounding metal abutments compared with the tissue surrounding natural teeth. The surface temperature showed no significant difference for all measurements.*

Conclusions: *These results suggest that blood flow in tissue surrounding zirconia abutments is similar to that in soft tissue around natural teeth. Moreover, zirconia abutments could be advantageous for the maintenance of immune function by improving blood circulation. (Implant Dent 2015;24:37–41)*

Key Words: blood flow, laser speckle imaging, thermograph, zirconia abutment

Due to the recent development of computer-assisted designing/computer-assisted manufacturing, ceramic materials such as glass ceramics, poly-crystalline alumina, and zirconia-based ceramics have begun to be used as dental materials.[1] In particular, zirconia is widely applied clinically as a substriate for conventional metals, and it is used in crowns and copings for natural teeth and in the framework of fixed partial dentures.[2] Given its excellent strength and resistance to fracture, zirconia has begun to be used widely in dentistry[3–5]; furthermore, in dental implant treatment, as the price of zirconia is more stable than that of noble metals, it is used in abutments and implant-supported all-ceramic zirconia frameworks.[6] Moreover, because zirconia offers sufficient strength and esthetic properties without the risk of releasing metal ions, it is an implant fixture material expected to replace conventional titanium implants for patients with metal allergies.[7] Reports indicate significantly reduced bone loss around zirconia implants compared with titanium implants[8] and that zirconia accumulates less bacterial plaque than titanium,[9,10] suggest the high biocompatibility of the material. Given its excellent mechanical properties and biocompatibility, zirconia has gained wide acceptance as a dental material.[11]

High-strength ceramics such as alumina and zirconia have also been developed as implant abutment materials.[12,13] The advantages of ceramic abutments include less mucosal discoloration compared with metal abutments,[14] less

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bacterial adhesion compared with titanium abutments, and, in animal studies, more favorable soft tissue integration compared with titanium abutments.[15] Although high-strength ceramics such as alumina and zirconia generally have high fracture resistance, zirconia, in particular, has sufficient fracture resistance for use as an abutment material. Zirconia abutments supporting anterior and premolar single crowns have shown high survival rates in some studies,[16–18] and a high 5-year survival rate was reported in a randomized-controlled clinical trial of zirconia and titanium abutments in posterior regions.[19]

For the long-term stability of favorable outcomes following implant treatment, the health of the soft tissue around implants must be maintained (ie, plaque control and blood flow preservation are indispensable). In bone-level implants, because implant abutments come into contact with the soft tissue around the implants, selection of the implant abutment material is considered very important for the health of periimplant soft tissue. However, the effects of the implant abutment material on the periimplant mucosa, particularly on its blood flow, have not been clarified. In this study, therefore, we selected zirconia, which is used widely as an implant abutment material because of its excellent esthetic properties and biocompatibility, and compared the effects of zirconia and metal abutments on periimplant soft tissue by evaluating the microcirculatory dynamics and surface temperature.

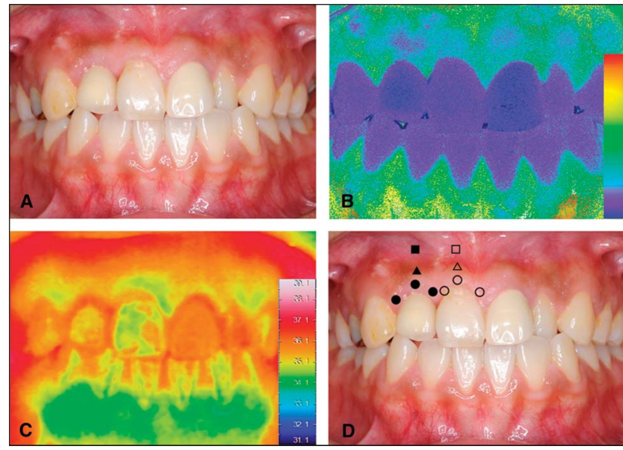

Fig. 1. Examples of acquired images. **A**, Oral photograph (#11 is a natural tooth, #12 is an implant-supported prosthesis). **B**, Blood flow image: The color scale shows the blood flow from 0 (dark blue) to 64 mL·min^{-1}·100 g^{-1} tissue (red). **C**, Thermograph: The color scale shows the surface temperature from 32 (dark blue) to 37.5°C (red). **D**, Regions of interest: ○, free gingiva; ●, free gingiva (implant); △, attached gingiva; ▲, attached gingiva (implant); □, alveolar mucosa; and ■, alveolar mucosa (implant).

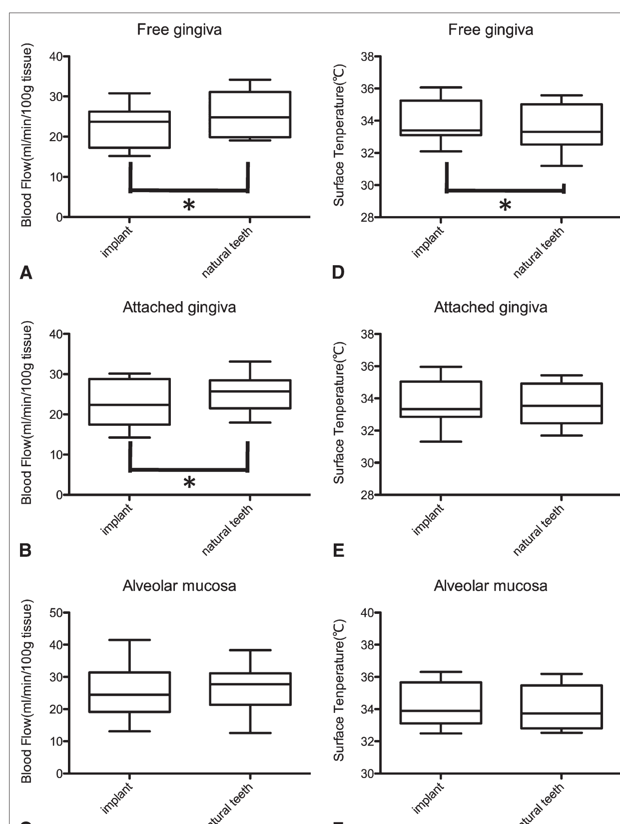

Fig. 2. Blood flow and surface temperature around implants versus natural teeth. Blood flow from LSI (left panels) and surface temperature from thermograph (right panels) in free gingiva (**A** and **D**), attached gingiva (**B** and **E**), and alveolar mucosa (**C** and **F**) was compared between implants and natural teeth. *$P < 0.05$ with paired *t* test. Significantly greater blood flow was detected in natural teeth relative to implants in free gingiva and attached gingiva (free gingiva, $P = 0.0055$; attached gingiva, $P = 0.0052$). The surface temperature was significantly higher in the implant in free gingiva ($P = 0.0079$).

Materials and Methods

Subjects

This study was performed with the approval of the Ethics Committee of Kyushu Dental College (Fukuoka, Japan; nos. 10–25). Subjects were chosen from those who had undergone implant placement in the anterior maxilla at Kyushu Dental College Hospital (Fukuoka, Japan), and showed a favorable prognosis, no signs of surrounding bone resorption on a follow-up dental x-ray, and no signs of soft tissue inflammation. The patients received a detailed explanation of the study, and then signed a consent form. Those who had a systemic disease such as diabetes or blood-blood vessel disease were excluded. A total of 10 subjects were included in the study (mean age, 51 years; range, 21–78 years; 5 men and 5 women).

Blood Flow and Surface Temperature Imaging

Blood flow was monitored with a 2-dimensional blood flow analysis machine using infrared laser speckle imaging (LSI; 780 nm) (OZ-1; Omegawave, Tokyo, Japan); its effective measuring depth was within 1 mm of the surface. A CCD camera was set at a right angle to the buccal surface at a 25-cm distance, and 10 images were obtained from each subject. Subjects were asked to wear goggles (YL331; Yamamoto Kogaku Co., Ltd., Higashiosaka, Japan) to avoid possible eye discomfort. The surface temperature was then monitored by thermography (Thermo GEAR; NEC Avio, Tokyo, Japan) at a 10-cm distance to obtain 4.3 cm high and 5.7 cm wide images. Additionally, a spot thermometer (Thermo-Hunter PT-7LD; Optics Co., Ltd., Otsu, Japan) was used to verify the temperature from the thermograph. Subjects were asked to remain quiet on a dental chair for at least 10 minutes before each measurement. Blood flow imaging and temperature measurements were then performed.

Data Analysis

Ten-pixel regions of interest (ROIs) were set on the buccal free gingiva, attached gingiva, interdental papilla, implant-dental papilla, and alveolar mucosa for blood flow imaging, as shown in Figure 1.

Temperature data were also obtained from the thermograph in reference to the ROI on blood flow images. For the comparison of blood flow between zirconia and metal abutments, our values were corrected by the value on the gingiva surrounding adjacent natural teeth. A paired t test was used to compare the subjects' natural teeth and implants. The Mann-Whitney test was used for comparisons between abutments. In all cases, $P < 0.05$ was considered to indicate a significant difference.

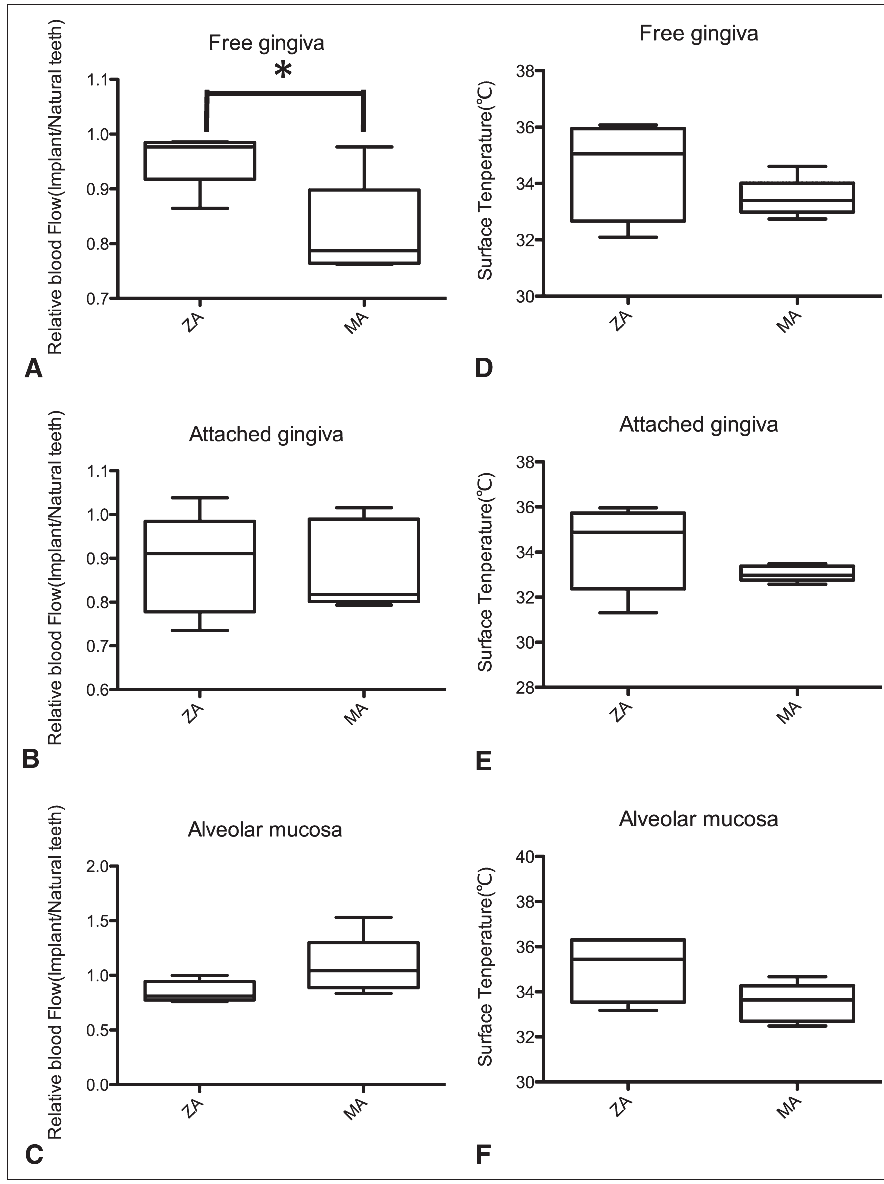

Fig. 3. Blood flow and the surface temperature around zirconia abutments (ZA) versus metal abutments (MA). Relative blood flow from LSI (left panels) and surface temperature from thermograph (right panels) in free gingiva (**A** and **D**), attached gingiva (**B** and **E**), and alveolar mucosa (**C** and **F**) was compared between zirconia and metal abutments. Relative blood flow values were corrected by the value on the gingiva surrounding adjacent natural teeth. *$P < 0.05$ with Mann-Whitney test. Significantly greater blood flow was detected with a zirconia abutment (95.64 ± 5.17%) relative to a metal abutment (82.25 ± 8.93%) in free gingiva (*$P = 0.0317$).

Results

Laser Speckle Imaging

Implants versus natural teeth (Figure 2). Significantly greater blood flow was detected in natural teeth (25.808 ± 5.370 $mL \cdot min^{-1} \cdot 100\ g^{-1}$ tissue) than in implants (22.628 ± 5.182 $mL \cdot min^{-1} \cdot 100\ g^{-1}$ tissue) in the free gingiva ($P = 0.0055$) and attached gingiva (tooth: 25.362 ± 4.685; implant: 22.682 ± 6.084 $mL \cdot min^{-1} \cdot 100\ g^{-1}$ tissue; $P = 0.0052$); however, there was no significant difference in the alveolar mucosa (tooth: 25.703 ± 8.985; implant: 25.362 ± 4.685 $mL \cdot min^{-1} \cdot 100\ g^{-1}$ tissue; $P = 0.19$).

Zirconia versus metal abutments (Figure 3). As a result of correction in the value of natural teeth, the blood flow was significantly higher in zirconia abutments (95.64 ± 5.17%) than in metal abutments (82.25 ± 8.93%) in the free gingiva ($P = 0.0317$); however, there was no significant difference in the attached gingiva (zirconia: 88.70 ± 11.51; metal: 88.01 ± 10.22%) or alveolar mucosa (zirconia: 84.92 ± 9.59; metal: 108.34 ± 26.59%).

Temperature Measurement Using Thermography

Implants versus natural teeth. The surface temperature was significantly higher in implants (33.97 ± 1.34; tooth: 33.61°C ± 1.45°C) than in natural teeth (33.61°C ± 1.45°C) in the free gingiva ($P = 0.0079$); however, there was no significant difference in the attached gingiva (implant: 33.63 ± 1.42; tooth: 33.58°C ± 1.22°C) or alveolar mucosa (implant: 34.27 ± 1.36; tooth: 34.16°C ± 1.34°C).

Zirconia versus metal abutments. The surface temperatures were not significantly different among the free gingiva (zirconia: 34.46 ± 1.72; metal: 33.48°C ± 0.68°C), attached gingiva (zirconia: 34.21 ± 1.89; metal: 33.05°C ± 0.35°C), and alveolar mucosa (zirconia: 35.02 ± 1.42; metal: 35.51°C ± 0.85°C).

Discussion

Recently, blood flow has attracted attention as a method of assessing oral soft tissue, and noncontrast and noninvasive laser Doppler flowmetry (LDF) was developed to evaluate blood flow in marginal tissue.[20,21] The use of an infrared laser to irradiate red blood cells in microvessels causes reflection and scattering, and the Doppler shift causes a frequency change between the incidence and reflection that is proportionate to the blood flow. In dentistry, much research has been conducted using this method, including analyses of the relationship between periodontal disease and gingival blood flow,[22] changes in gingival blood flow after periodontal surgery,[23,24] and the relationship between smoking and blood flow.[25,26]

However, although LDF is advantageous for the real-time measurement of local microcirculatory dynamics, as it is a technique for point measurement with a narrow measuring range of 1 mm^2, comparing the blood flow dynamics among different regions is difficult, and the technique has not been applied clinically. To solve this problem, LSI was recently developed.[27,28] These measurement methods are basically the same, but in LSI a laser is applied to the object of measurement, and granular changes called speckles are rapidly scanned with a CCD camera and measured as an index of the blood flow dynamics. By LSI, noncontact, noninvasive measurement is possible, and the blood flow dynamics are extracted as 2-dimensional images and captured as visual information, permitting blood flow measurement over a wide area as well as conventional point measurement. Also, as multiple ROIs can be displayed on the same image, quantitative analyses (eg, comparison of the blood flow dynamics among sites at the same time point) have become possible. Given these advantages, LSI has been clinically applied to cerebrovascular surgery,[29–31] skin diseases,[29–31] and blood recovery from burn injury.[32]

Moreover, we found that 2-dimensional temperature measurement by thermography could be used to clarify the assessment of and diagnostic criteria for soft tissues. Thermography provides 2-dimensional images of temperature distribution, similar to LSI, and is used in many fields for a variety of purposes.

Using these methods, we evaluated differences in the blood flow and surface temperature between tissues around implants and natural teeth. We also evaluated the effects of the abutment material on periimplant soft tissue. We found that the blood flow was significantly lower in periimplant soft tissue than in soft tissue around natural teeth in free and attached gingiva. These results are in agreement with those we reported previously.[33] In addition, when comparisons were made among abutment types, the blood flow was ~4% lower in the zirconia group and ~18% lower in the metal group than in the free gingiva around natural teeth, indicating that a richer blood flow can be secured in periimplant soft tissue around zirconia than around metal abutments ($P = 0.0317$). Because the pocket depth of the periimplant mucosa was <2 mm in all patients, and no bleeding was noted on probing, the effect of local inflammation could be excluded.

In contrast, the proportion of leukocytes in the epithelium has been reported to be lower around zirconia than titanium abutments or other cast-to-abutments,[34] suggesting the superiority of the mucosal seal of zirconia. Also, *in vitro* and *in vivo* data indicate that bacterial colonization on the abutment surface differs by abutment type, that the amount of plaque attachment is significantly smaller on zirconia than on titanium, and that zirconia may be involved in the formation of the periimplant mucosa. These characteristics of zirconia may have affected the blood flow in this study. The results of this study suggest that zirconia abutments promote microcirculatory dynamics in periimplant mucosa that are closer to those around natural teeth. Moreover, securing a rich blood flow in soft tissues around implants is considered to be advantageous for the maintenance of immune function.

It is important to consider not only the resistance and esthetic properties of abutment materials, but also their effects on soft tissues for long-term preservation of the health of periimplant soft tissues. However, as various factors are involved in a complex manner in the selection of abutments for implant treatment, it is necessary to select an appropriate abutment design and material based on the state of plaque control, esthetic effect, and prosthetic design in each patient.

Conclusions

Blood flow in soft tissue around zirconia abutments is similar to that around natural teeth, and significantly greater blood flow was maintained around zirconia abutments compared with metal abutments. Moreover, zirconia abutments could be advantageous for the maintenance of immune function by improving blood circulation.

Disclosure

The authors claim to have no financial interest, either directly or

indirectly, in the products or information listed in the article.

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