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Interface Between Titanium Miniplate/Screw and Human Calvaria

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This study demonstrates interfacial changes of titanium miniplate/screw with normal calvaria and nonvascularized calvarial bone graft ensued from craniectomy in a 53-year-old female. In 18 months after operation, a right parietal bone containing an L-shaped miniplate with screws, 5mm long and 2mm in external diameter, was harvested, fixed, and embedded in methylmetacrylate. Fifteen micrometer thick sections were made by an EXAKT cutting-grinding system (Exakt Company, Hamburg, Germany), and reviewed under the bright field light microscope. The mean of the bone-contacting surface ratio (BCSR) in six screwed bone was 64.1%; 69.3% in normal bone, and 60.4% in grafted bone. The trabecular bone areas in 10x5mm (50mm²) rectangular area of diploe surrounding the screws was 43.02mm²; 45.25mm² in normal calvaria; and 41.82mm² in grafted bone. The mean Ca/P peak-height ratio of the plated and screwed calvaria was 1.47 in a 9mm wide zone around each screw; 1.37 in normal calvaria; and 1.51 in grafted calvaria. We concede that the effect of direct contact of titanium with screws onto the bone is as much as an osseous integration (osseointegration).

Key Words: Interface, titanium miniplate/screw, bone contact, osseointegration

Direct, rigid fixation plays an important role in the management of facial trauma and in orthognatic and reconstructive surgery. Monocortical miniplate osteosynthesis has been used successfully for the management of facial fractures. Michelet et al developed the concept of miniplate osteosynthesis in 1973. Stainless steel miniplates with monocortical, self-tapping screws are widely used, but recently titanium systems have been introduced. Although Vitallium and modern stainless steel is well-tolerated, titanium (Würzburg Miniplate Set, Würzburg, Germany) is virtually inert, becoming integrated with bone under certain conditions, so called osseeointegration.

In spite of their wide usefulness, there are a few studies that show the interface between titanium miniplate/screw and bone. Schon measured the direct bone/screw contact in vascularized iliac crest bone graft in pig model. Cheung measured the amount of direct bone contact with titanium screw in mandible and maxilla of four fibrous dysplasia patients. Miller compared tissue response of stainless steel and titanium screws in calvaria of beagle dogs. There is yet, however, no study showing the interface between titanium miniplate/screw and human calvaria.

In this study, interface between titanium screw and calvaria and nonvascularized calvarial bone in situ bone graft is shown, following craniectomy in a 53-year-old female.

Materials and Methods

Case History

A 53-year-old female underwent the craniectomy for removal of a solitary lesion on her right parietal lobe. After removal of the tumor, the craniectomy site was covered with an in situ cranial bone graft and secured with titanium-alloy miniplate and screws. Two L-shaped miniplates and eight screws were used. Screw length was 5mm and external di-
ameter was 2mm. Eighteen months later, she expired of a metastatic adenocarcinoma of the lung.

**Histological Procedures**

Right parietal bone, including the miniplate and screws, were removed (Fig 1A) and radiography was taken at 50KV and 3mA for 30 seconds (Fig 1B), fixed with 4% formaldehyde, dehydrated with grading alcohol, and embedded in methylmetacrylate. Fifteen \( \mu \)m thickness sections were prepared by EXAKT cutting-grinding system (Exakt Company, Hamburg, Germany) and stained with von Gieson stain. Blocks were trimmed and cut in the longitudinal plane of six screws and horizontal plane of two screws. Two slides containing each screw were examined.

**Contact Microradiography**

Contact microradiography (CMR) of the specimen at of 15\( \mu \)m was performed at 23KV and 3mA for 30 seconds (AXR Minishot, East Haven, CT, USA).

**Histomorphometric Measurement**

The specimens were examined under a bright field light microscope (Zeiss Axiohot, Oberkochen, Germany). To qualify the percentage of direct bone contact to the surface of titanium screws, a optical lens with a scale (Carl Zeiss, Oberkochen, Germany) was used. The 100 units of optical lens in \( \times 100 \) magnification was 9.7\( \mu \)m. Therefore, one unit in \( \times 100 \) magnification was 9.7\( \mu \)m. The mean screw surface perimeter (SSP) within the bony margins (with and without bony contact), and the length of the contact surface (CS) of the bone to the screw surface were measured and used to calculate the bone-contacting surface ratio (BCSR) (BCSR=CS\times100/SSP). Statistical comparison of the BCSR between the screws in cranium and grafted bone was performed with the paired Student's t-test.

The trabecular bone densities in normal and grafted calvaria were also measured with the National Institute of Health’s (NIH) image analyzing system. Statistical comparison of the trabecular bone areas in cranium and grafted bone was performed with the paired Student’s t-test.

**Energy Dispersive X-Ray Analysis**

Energy dispersive x-ray analysis (EDXA) of the titanium screw surfaces was performed using scanning microscope (10KV, 150J) connected with an energy dispersive x-ray analyzer (Kevek, Kevek X-Ray Inc., Scotts Valley, CA). The calcium (Ca) and phosphorus (P) K2 peak heights were measured and the Ca/P height ratios were computed. In each bone specimen, a 0.9-mm-wide zone of bone around each titanium screw was analyzed and compared with the Ca/P peak height ratio according to the sites (normal calvaria versus graft).

**RESULTS**

**Histologic Observation and Histomorphometric Measurement**

The direct contact of titanium screws and bone could be seen. There was no fibrous capsular formation between them. At the bone area adjacent to the titanium screw, osteon development is obvious (Figs 2 and 3).
Fig 2  (A) Appearance of titanium screw in normal calvaria (van Gieson stain, original magnification ×39). (B) Close-up view of interface of titanium screw and bone. At the bone area adjacent to titanium screw, osteon development is obvious (original magnification ×375).

Fig 3  (A) Appearance of titanium screws in grafted calvaria (van Gieson stain, original magnification ×22.5). (B) Close-up view of interface of titanium screw and bone. At the bone area adjacent to titanium screw, osteon development is obvious (original magnification ×225).

Table 1. Graft and Control Screw Interface Data

<table>
<thead>
<tr>
<th>Screw Location</th>
<th>Number of Screws</th>
<th>Mean Screw Surface Perimeter</th>
<th>Mean Contact Surface</th>
<th>Bone/Screw Contact Surface Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graft</td>
<td>4</td>
<td>14,943µm ± 3759</td>
<td>9101µm ± 2930</td>
<td>60.4%</td>
</tr>
<tr>
<td>Normal</td>
<td>2</td>
<td>18,765µm ± 1062</td>
<td>12,988µm ± 328</td>
<td>69.3%</td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>16,216µm ± 3549</td>
<td>10,397µm ± 3033</td>
<td>69.3%</td>
</tr>
</tbody>
</table>

SSP = screw surface perimeter; CS = contrast surface.
The mean of the BCSR in six screwed bone was 64.1%; 69.3% in normal bone (two screws); and 60.4% in grafted bone (four screws). There was, however, no significant difference between BCSR in normal bone and grafted bone ($P \geq 0.05$) (Table 1). The trabecular bone areas in $10 \times 5$ mm ($50 \text{mm}^2$) rectangular area of diploe surrounding the screws was $43.02 \text{mm}^2$; $45.25 \text{mm}^2$ in normal calvaria; and $41.82 \text{mm}^2$ in grafted bone. There was no significant difference between trabecular bone areas in normal bone and in grafted bone ($P \geq 0.05$) (Table 2).

**Contact Microradiography**

Radiographically, there was close contact of the screws onto the bone in both normal calvaria and grafted bone (Fig 4).

**Energy Dispersive X-Ray Analysis**

The mean Ca/P peak-height ratio of bone in a 9-mm-wide zone around each screw was 1.47; 1.37 in normal calvaria; and 1.51 in grafted bone (Table 3).

**DISCUSSION**

There are a few studies that show the interface between titanium miniplate/screw and bone. Schon et al measured the direct bone/screw contact in vascularized iliac crest bone graft, which was adapted to the defect in the mandible of six miniature pigs. Two weeks postoperatively, 24% of the total screw surface was in direct contact with the grafted bone and 55% with the mandibular bone. At 4 weeks, 56% of the total screw surface was in direct contact with the grafted bone and 64% with the mandibular bone. At 8 weeks, 75% of the total screw surface was in direct contact with the grafted bone and 77% with the mandibular bone. They used the titanium miniplate system of 2.0 mm external diameter as did the authors. In this report, the bone contact percentage was 60.4% in nonvascularized bone graft and 69.3% in normal calvaria at 18 months postoperatively. It is noticeable that there was no signifi-
44% bone contact from the normal portion of mandible and maxilla of fibrous dysplasia showed lower than 63.4% in calvaria. It is believed that the reason for higher bone contact percentage in calvaria than mandible or maxilla is thicker bone thickness and more abundant blood supply in calvaria than mid and lower facial bones.

There are several studies that measured the bone contact percentage of titanium dental implant. Gerner reported that the direct bone contact percentage in three titanium implants which were inserted into canine iliac crest was 44.0% mean value (26.9%, 60.9%, and 44.3%) at 14 weeks after insertion. In his study, he also measured the Ca/P ratio by EDXA, which showed 1.6±0.2 in bones in a 9-mm-wide zone around implants. In this study, the mean Ca/P peak-height ratios of bone in a 9-mm-wide zone around each titanium screws was 1.47; 1.37 in normal calvaria; and 1.51 in grafted bone (Table 3). It is believed that the reason of relatively low Ca/P ratio in this study is because the screw used in this report is made of titanium alloy (Ti-6Al-4O; 88.3–90.8% titanium, 5.5–6.5% aluminum, 3.5–4.5% venadium, 0.1% carbon, and 0.25% iron) instead of pure titanium.

Gottlander der placed titanium-coated intramobile cylinder (IMZ) dental implants (Interpore International, Irvine, CA) into distal femurs of rabbits. Six months after placement, 59.9% bony contact was found direct integration of bone with a titanium im­

in the long term. Another reason in their report is that the titanium implant showed less bone contact percentage (22% in dysplastic bone and 44% in normal bone).

In the opinion of the authors, miniplate and screws inserted in certain areas (e.g., mandible angle, zygomatic arch, palhanges, and metacarpals) are carrying functional loadings. Furthermore, the bone contact percentage in our report showed 63.4%; the similar range of titanium dental implants (44.0–59.9%). It is believed, therefore, that the direct bone contact with titanium screws can be interpreted as osseointegration.

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REFERENCES