2000

Interface Between Titanium Miniplate/Screw and Human Calvaria

Kun Hwang

John M. Schmitt

George Fox University, jschmitt@georgefox.edu

Jeffrey O. Hollinger

Follow this and additional works at: http://digitalcommons.georgefox.edu/bio_fac

Part of the [Biology Commons](#)

Recommended Citation

Hwang, Kun; Schmitt, John M.; and Hollinger, Jeffrey O., "Interface Between Titanium Miniplate/Screw and Human Calvaria" (2000). *Faculty Publications - Department of Biology and Chemistry*. Paper 60.
http://digitalcommons.georgefox.edu/bio_fac/60

This Article is brought to you for free and open access by the Department of Biology and Chemistry at Digital Commons @ George Fox University. It has been accepted for inclusion in Faculty Publications - Department of Biology and Chemistry by an authorized administrator of Digital Commons @ George Fox University. For more information, please contact arolfe@georgefox.edu.

Interface Between Titanium Miniplate/Screw and Human Calvaria

Kun Hwang, MD, PhD*

John M. Schmitt, BS[†]

Jeffrey O. Hollinger, DDS, PhD[†]

Inchon, Korea
Portland,
Oregon

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 10×5mm (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

From the *Department of Plastic Surgery, Inha University Hospital, Inchon, Korea; and the [†]Northwest Wound Healing Center, Division of Plastic and Reconstructive Surgery, Oregon Health Science University, Portland, Oregon.

Address correspondence and reprint requests to Dr Kun Hwang, Department of Plastic Surgery, Inha University Hospital, 7-206 Shinheung-dong, Choong-gu, Inchon, 400-103, Korea. E-mail: jokerhg@inha.ac.kr

Direct, rigid fixation plays an important role in the management of facial trauma and in orthognatic and reconstructive surgery.¹ Monocortical miniplate osteosynthesis has been used successfully for the management of facial fractures. Michelet et al developed the concept of miniplate osteosynthesis in 1973.² Stainless steel miniplates with monocortical, self-tapping screws are widely used, but recently titanium systems have been introduced.³ 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 osseointegration.⁴

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.⁵ Cheung measured the amount of direct bone contact with titanium screw in mandible and maxilla of four fibrous dysplasia patients.⁶ Miller compared tissue response of stainless steel and titanium screws in calvaria of beagle dogs.⁴ 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-

Fig 1 (A) Right calvarial bone including titanium miniplate/screw. (B) Radiography of right calvarial bone (50KV, 3mA, 30sec).

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 50 seconds (Fig 1B), fixed with 4% formaldehyde, dehydrated with grading alcohol, and embedded in methylmetacrylate. Fifteen μ 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 μ 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 Axiophot, 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 μ m. Therefore, one unit in $\times 100$ magnification was 9.7 μ 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) ($BCSR = CS \times 100 / SSP$). 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 (KeveX, KeveX 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 $\times 39$). (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 $\times 375$).

Fig 3 (A) Appearance of titanium screws in grafted calvaria (van Gieson stain, original magnification $\times 22.5$). (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 $\times 225$).

Table 1. Graft and Control Screw Interface Data

Screw Location	Number of Screws	Mean Screw Surface Perimeter	Mean Contact Surface	Bone/Screw Contact Surface Ratio
Graft	4	14,943 $\mu\text{m} \pm 3759$	9101 $\mu\text{m} \pm 2930$	60.4%
Normal	2	18,765 $\mu\text{m} \pm 1062$	12,988 $\mu\text{m} \pm 328$	69.3%
Total	6	16,216 $\mu\text{m} \pm 3549$	10,397 $\mu\text{m} \pm 3033$	69.3%

SSP = screw surface perimeter; CS = contrast surface.

Table 2. Trabecular Bone Area and Percentage Around the Screws

Screw Location	Trabecular Bone Area (mm ²) per 50mm ² of Diploe Measured	Percent Trabecular Bone
Graft	40.82	81.6%
Normal	45.25	90.5%
Total	43.02	86.1%

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 10×5mm (50mm²) rectangular area of diploe surrounding the screws was 43.02mm²; 45.25mm² in normal calvaria; and 41.82mm² 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.⁵ 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 2.0mm 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-

Fig 4 Contact microradiography of 15μm thickness specimen (23KV, 3mA, 30sec).

cant difference in bone contact percent between non-vascularized calvarial bone graft and normal calvaria ($P \geq 0.05$). In craniofacial surgeries, including reduction of facial bone fractures, the miniplate and screws are usually used in nonvascularized bone fragments. In this aspect, our results can serve as an index for bone-titanium miniplate/screw interface.

Cheung measured the amount of direct bone contact with titanium screw in mandible and maxilla of four fibrous dysplasia patients.⁶ Bone contact percentage in normal bone was 44%, while 25% in fibrous dysplasia patients. In comparison to this data,

Table 3. Ca/P EDX Ratio

Screw Location	Calcium/Phosphate (9mm radius around implant)
Graft	1.51 ± 0.07
Normal	1.37 ± 0.03
Total	1.47 ± 0.09

EDX = energy dispersive x-ray.

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.⁷ 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% vanadium, 0.1% carbon, and 0.25% iron) instead of pure titanium.

Gottlander placed titanium-coated intramobile cylinder (IMZ) dental implants (Interpore International, Irvine, CA) into distal femurs of rabbits.⁸ Six months after placement, 59.9% bony contact was observed in the titanium-coated implants. Comparing the present data (64.1% contact) to the above two studies (44.0% and 59.9% contact), it is thought that the bone contact percentage of miniplate is not much different from that of a titanium dental implant which is wider and longer (3.3–4mm diameter, 10–11mm length).

Albreksson and Hansson, using light and electron microscopy to see the metal/bone interface of unthreaded stainless steel and titanium implants, found direct integration of bone with a titanium implant, but the stainless steel implants had a connective tissue layer of one or two cells surrounding them.⁹ In the titanium implant there was no cell in the interface which consisted of a proteoglycan layer about 200–400Å width instead. Bundles of collagen appeared at a minimum distance of 1000–2000Å from the metal surface.

The current definition of osseointegration is "a direct structural and function connection between ordered, living bone, and surface of load-carrying implants."^{10,11} According to this definition, Cheung⁶ pointed out that the direct bone contact with the titanium screw, observed in light microscopy, should not be considered as osseointegration because miniplate and screw do not carry any functional loading

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, phalanges, 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.

The authors thank Dr. Xi Gong, MD, for her efforts in making the histology slides, Dave Buck, MS, for his efforts in performing EDXA, and Robert S. Chung, MD, FACS, for reviewing this manuscript.

This work was supported, in part, by a grant from Inha University, Seoul, Korea, and in part by a grant from Northwest Wound Healing Center, Oregon Health Science University, Portland, Oregon, USA.

REFERENCES

1. Baker S, Dalrymple D, Betts N. Concepts and techniques of rigid fixation. In: Fonseca RJ, Walker RV (eds). *Oral and Maxillofacial Trauma*. Philadelphia: WB Saunders, 1997:1275–1328
2. Michelet FX, Deymes J, Dessus B. Osteosynthesis with miniaturized screwed plates in maxillofacial surgery. *J Maxillofac Surg* 1973;1:79–84
3. Tucker MR, Oshs MW. Basic concepts of rigid internal fixation; mechanical considerations and instrumental overview. In: Tucker MR, Terry BC, White RP, Van Sickels JE (eds). *Rigid Fixation for Maxillofacial Surgery*. Philadelphia: Lippincott, 1991:30–50
4. Miller BG, Frame JW, Browne RM. A histological study of stainless steel and titanium screws in bone. *Br J Oral Maxillofac Surg* 1990;28:92–95
5. Schon R, Schmelzeisen R, Shirota T, Ohno K, Michi K. Tissue reaction around miniplates used for fixation of vascularized iliac crest bone grafts. *Oral Surg Oral Med Oral Path* 1997;83:433–440
6. Cheung LK, Samman N, Pang M, Tideman H. Titanium miniplate fixation for osteotomies in facial fibrous dysplasia—a histologic study of the screw/bone interface. *Int J Oral Maxillofac Surg* 1995;24:401–405
7. Gerner BT, Barth E, Albreksson T, Ronningen H, Solheim LF, Wie H. Comparison of bone reactions to coated tricalcium phosphate and pure titanium dental implants in the canine iliac crest. *Scand J Dent Res* 1988;96:143–148
8. Gottlander M, Albreksson T, Carlsson LV. A histomorphometric study of unthreaded hydroxyapatite-coated and titanium-coated implants in rabbit bone. *Int J Oral Maxillofac Implants* 1992;7:485–490
9. Albreksson T, Hansson HA. An ultrastructural characterization of the interface between bone and sputtered titanium or stainless steel surfaces. *Biomaterials* 1986;7:201–205
10. Branemark PI. Introduction to osseointegration. In: Branemark PI, Zarb GA, Albreksson T (eds). *Tissue-Integrated Prosthesis: Osseointegration in Clinical Dentistry*. Chicago, IL: Quintessence, 1985:11–76
11. Branemark PI. Osseointegration and its experimental background. *J Prosthet Dent* 1983;50:399–410