The Effect of Bioactive Ceramics Coating on the Osseointegration of Cancellous Screws

1Lee, JH; 1Nam, H; 2Ryu, HS; ... study on the bone-screw interface of bioactive ceramic-coated titanium screws. Biomaterials 2005;26:3249-57.

+Seoul National University, College of Medicine, SMG-SNU Boramae Medical Center, Seoul, 2Seoul National University, College of Medicine, Seoul National University Hospital, Seoul, 3Research Center, Biosalga, Sung-Nam
choonki@snu.ac.kr

Introduction:
A number of coating methods, reported to improved osseointegration in bone by coating implants with bioactive ceramics, have been introduced. The authors have previously reported that osseointegration of titanium cortical screws coated with β-calcium pyrophosphate and apatite-wollastonite glass-ceramics using the enameling method is significantly higher than the uncoated cortical screw. However, cortical screws obtain fixation from the bone cortex and are known to have higher fixation stability than cancellous screws. Also, numerous studies have been conducted on the ceramic coating of external fixator or cortical screws but cancellous screws that obtain fixation stability from cancellous bone, which is relatively fragile, have been neglected. Accordingly, the authors intend to perform four types of bioactive ceramic coating including β-calcium pyrophosphate (CPP) and CaO-SiO\(_2\)-P\(_2\)O\(_5\)-B\(_2\)O\(_3\) glass ceramic (BGS-7) on titanium cancellous screws by enameling method, and to examine the clinical applicability by comparing the osseointegration of such screws.

METHODS:
Of the possible calcium phosphate compounds, β-calcium pyrophosphate (Ca\(_3\)P\(_2\)O\(_7\), CPP) coatings were prepared, and of the bioactive glass-ceramics, apatite (Ca\(_3\)(PO\(_4\))(OH)\(_2\), CPP) and CaO-SiO\(_2\)-B\(_2\)O\(_3\) glass ceramic (BGS-7) on titanium cancellous screws by enameling method, the coated screws and the uncoated screws were inserted into the proximal tibia and distal femur metaphysis of 7 male mongrel dogs weighing about 30kg. Ten screws were implanted in the metaphysis of the proximal tibia and distal femur of each dog. The screws from each of five types were inserted into the femur and tibiae in a certain order determined by the rotation method. The initial torque values were measured at the time of insertion and the values were measured again upon the removal of screws after raising the dogs for 8 weeks. The histological analysis was carried out in the same way as the previous study using a light microscopy (Olympus U-SPT, BX51, Japan) coupled to an image analyzer (Image-Pro Plus, Media Cybernetics, USA) with a mouse enabling the observer to perform histomorphometric measurements. The aim was to study the percentage of bone-screw contact measured from photographs taken at forty times magnification of the cortical and cancellous bone. The percentage of bone contact was determined using the following equation:

\[
\% \text{ of bone contact} = \frac{\text{bone contact length/implant length}}{\text{within one pitch}} \times 100\%. \]

RESULTS SECTION:
There was no significant difference between the insertion torques measured from the uncoated screws and the insertion torques measured from the coated screws. As for the torque values measured at the removal after 8 weeks, the values of CPP group (4.9±0.7 kgf-cm) and BGS-7 group (5.0±1.2 kgf-cm) were statistically significantly higher (p=0.033 and 0.031 respectively) than the torques of uncoated group (3.9±1.4 kgf-cm), and the values of CPP group and BGS-7 group were significantly higher (p=0.043 and 0.0001 respectively) than the insertion torques.

The results of analysis on the ratio of length to direct integration with the cortical bone per each pitch of a screw showed that the CPP coated group had a significantly higher ratio, 78.3%, than the uncoated group, CSG coated group, and BGS-7 coated group (p=0.0001, 0.022, and 0.019 respectively). The W3G coated group also showed a significantly higher ratio, 83.8%, than the uncoated group, CSG coated group and BGS-7 coated group (0.0001, 0.022, and 0.0025 respectively). The groups showing significantly higher ratios compared to the uncoated group in both cortical bone and cancellous bone were the CPP coated group and the BGS-7 coated group.

DISCUSSION:
In order to evaluate the degree of osseointegration using the torques during implant removal, there must be no difference in the torques during implant insertion regardless of the coating types. There were no differences in the insertion torques from the coating types in this study that comparison between types of coating and comparison between the before and after values of each type of coating were possible. According to the results of such comparisons, the extraction torques of CPP and BGS-7 coated screws were significantly increased compared to each of their insertion torques, and were significantly higher than the extraction torques of the uncoated screw. This result signifies that the CPP and BGS-7 coated screws are capable of improving the osseointegration of the screw as well as offering stronger integration than the uncoated screws.

The histomorphometric result also supports the mechanical result. The fraction in direct contact with the cortical bone was improved significantly in all groups of coated screws compared to the uncoated screws but the fraction in direct contact with the cancellous bone was improved significantly only in the CPP and BGS-7 coated groups, which imply that osseointegration in the cancellous bone area must be improved in order to improve the osseointegration. Needless to say, it is difficult to conclude just from the histomorphometric results analyzed in this study that only the CPP and BGS-7 groups showed improvement in the osseointegration of cancellous bone, but considering that the osseointegration of W3G, which had a high osseointegration in the cortical bone area, showed insignificant difference compared to the uncoated screws in the cancellous areas, there is no doubt that the osseointegration in cancellous bone area is an important factor that increases torque.

Improving osseointegration in the cancellous bone area is very important clinically. Cancellous screw being used as the internal fixator for bone fracture is important but also osseointegration in the cancellous bone is important for the pedicle screw used in spine. Nevertheless, uncertainty remains about the longevity of ceramic coated implant even after the ceramic coating. However, since the cancellous screw used in this study or pedicle screw functions to give stability until bony union or fusion is obtained, longevity is not so important. Also, the number of patients with osteoporosis has increased with the increasing number of elderly population, and the difficulties in surgical treatment using internal fixators such as screw have been heightened, resulting in the narrowing of indication for surgery. Therefore, the screws coated with ceramics such as CPP or BGS-7 would be able to heighten fixation in the cancellous bone with poor bony quality.

REFERENCES: