Comparison of the Coefficient of Friction of Porous Ingrowth Surfaces

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INTRODUCTION

Good primary fixation is essential in preventing excessive micromotion which can lead to fibrous fixation and potentially early loosening1. In the absence of screws and other adjunct fixation, the initial fixation will be a function of the press-fit forces (due to shape and interference fit) and the frictional resistance to motion. A high friction surface is therefore desirable in order to improve initial fixation. In order to evaluate purely the friction aspect, several contemporary and historical fixation in-growth and on-growth surfaces were evaluated in a flat on flat model against sawbones and cadaveric human tibial bone.

MATERIAL and METHODS

Test Materials

Cancellous bone specimens were harvested from the upper tibia of fresh-frozen cadavers. Cellular rigid polyurethane foam (sawbones, 12.5pcf) was obtained from Pacific Research Lab.

Coupons of porous ingrowth surfaces, Tritanium™ Primary (68-72% porosity), Duraco CrCo (2 layers of 600-800 µm beads), Scorpio CoCr (2 layers of 425-500 µm beads), CPTi Microstructured Beads (2 layers of 420-500 CPTi µm beads) and Arc-deposited CPTi. All implants were manufactured by Stryker (Mahwah, NJ, USA).

Test Method

A modified horizontal pull test (Test Method B) specified in ASTM D 4518-91 was used. A Force 5 multiaxial servohydraulic test machine was utilized. Coupon of appropriate material and surface features with test surface dimension of 0.75 x 0.75 inch (Figure 1) was mounted on the upper actuator. The upper 3 inches of the thawed tibia were dissected free of soft tissues. The cancellous bone was then exposed by sawing off the articular surface and subchondral bone. A planing tool was used to produce a flat even surface. Either the human cadaver bone or sawbones specimen (Figure 2) was then cemented into a custom holding fixture and mounted on the base of the Force 5 testing machine (Figure 3).

The coupon was translated at a constant velocity of 0.5 mm/second under a constant vertical load of 100 Newtons. The magnitude of the vertical load was determined or set based on test specimen area to generate a nominal contact stress of ~0.28MPa. A six-component load cell was used to monitor the vertical load and to measure the shear force on the interface between the coupon and bone specimen. Distilled water was used as lubricant.

A tangential displacement to the bone specimen and the tangential load was monitored. The maximum tangential force recorded at the start of displacement was used in the calculation of the coefficient of friction (µ = Tangential force/Normal force). For each specimen, the average of 3 cycles was recorded.

Statistical Analysis

A One-Way ANOVA run (InStat v. 3, Graphpad Software, Inc., San Diego, CA) was performed for pair-wise comparison among all test surfaces.

RESULTS and DISCUSSION

Table 1 lists the mean Coefficient of Friction (CoF) and Figure 4 depicts the comparative mean CoF of the different test surfaces. Statistically significant differences in mean CoF were observed between surface groups. For Tritanium™ Primary surface, there were no statistically significant differences in mean CoF between human bone specimens versus sawbones specimens. The Tritanium™ Primary surface demonstrated the highest mean CoF when tested against both human bone and sawbones specimens. Against human bone, the mean CoF of Tritanium™ Primary surface was statistically greater than for all other surfaces (p<0.01 vs. Arc-dep CPTi and p<0.001 vs. all the other surfaces). Against sawbones, the mean CoF of Tritanium™ Primary surface was statistically greater than for all other surfaces (p<0.001) except for Arc-deposited CPTi surface (p>0.05).

The Arc-deposited CPTi surface generated the next highest mean CoF, which was statistically higher than all the other groups (except the Tritanium™ Primary surface) when tested against sawbones (p<0.001); but only statistically higher than CoCr Duraco and CPTi Microstructured beaded surface when tested against human bone (p<0.001). The Arc-deposited CPTi surface generated the next highest mean coefficient of friction.

Table 1. Mean (± SD) Coefficient of Friction

<table>
<thead>
<tr>
<th>Coupon Surface</th>
<th>Human Bone Specimen</th>
<th>Sawbone Specimen</th>
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</thead>
<tbody>
<tr>
<td>Tritanium™ Primary</td>
<td>1.01 ± 0.18</td>
<td>0.98 ± 0.11</td>
</tr>
<tr>
<td>CoCr Beads-Duracon</td>
<td>0.49 ± 0.16</td>
<td>0.36 ± 0.06</td>
</tr>
<tr>
<td>CoCr Beads-Scorpio</td>
<td>0.67 ± 0.19</td>
<td>0.59 ± 0.09</td>
</tr>
<tr>
<td>CPTi Microstructured Beads</td>
<td>0.57 ± 0.13</td>
<td>0.46 ± 0.07</td>
</tr>
<tr>
<td>Arc-deposited CPTi</td>
<td>0.81 ± 0.20</td>
<td>0.95 ± 0.07</td>
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</tbody>
</table>

CONCLUSION

The Tritanium™ Primary surface exhibited the highest mean coefficient of friction against both human cadaveric bone and sawbones. Against human bone, the mean CoF of Tritanium™ Primary surface was statistically greater than for all other surfaces. Against sawbones, the mean CoF of Tritanium™ Primary surface was statistically greater than for all other surfaces except for Arc-deposited CPTi surface.

The Arc-deposited CPTi surface generated the next highest mean coefficient of friction.

REFERENCES