FIXATION OF REVISION IMPLANTS WITH ALLOGRAFT IS IMPROVED BY CRACKING THE SCLEROTIC BONE RIM

+Midwest Orthopaedic and Minneapolis Medical Research Foundations, 914 South Eighth St.Minneapolis Minnesota, 55409 USA
*Department of Orthopaedic Surgery, University of Aarhus, Aarhus Denmark
#Biomechanics Laboratory, CHU Purpan, Toulouse, France

INTRODUCTION
Revision joint replacement implants have shorter longevity, poorer functional outcome, higher costs, and longer rehabilitation times than primary implants. In a previous study, we showed that fixation of revision implants was significantly improved with a low energy surgical technique that locally disrupts (cracks) the sclerotic bone rim that typically forms during the process of aseptic loosening (Fig. 1; Ref. 1).

Since it is known that allograft improves fixation of revision implants, we wished to experimentally investigate whether allografting would similarly improve revision implant fixation when the sclerotic bone rim is locally cracked. We hypothesized that the revision procedure to locally crack the sclerotic bone rim followed by allografting, will increase implant fixation (interfacial strength, stiffness and energy), compared with the standard revision procedure followed by allografting.

MATERIALS AND METHODS
Following approval by our institution’s Animal Care and Use Committee, we implemented our previously established controlled revision protocol (2). This protocol engenders a periarticular tissue reaction characteristic for a revision setting, consisting of a sclerotic bone rim, dense layers of fibrous tissue with synovial-like lining cells, macrophages with ingested particulate polyethylene (PE), and elevated inflammatory cytokines. Specifically, for eight weeks in each knee of 8 dogs, 6.0 mm loaded polymethylmethacrylate (PMMA) implants axially pinstioned 0.5mm concentrically in a hole, surrounded by a 0.75mm gap. The implants were in the presence of PE (0.5 – 50 mg/implant). At a second operation at eight weeks, one of two surgical techniques was used to insert revision Ti plasma sprayed implants (Fig. 2) into the revision cavity. Both were followed by insertion of tightly packed bone allograft.

Crack revision procedure (right): Following the same procedure to remove the fibrous membrane and lavage the sclerotic endosteal surface, an 8.2 mm (outer diameter) tool with 12 evenly spaced 0.2 mm pointed splines is axially advanced (with hammer blows) over a guidewire into the revision cavity, thereby producing controlled cracking and local perforation of the sclerotic endosteal rim. Following this procedure, an identical stable plasma sprayed titanium implant is inserted, and allograft is tightly packed into the gap.

Mechanical testing: Specimens were obtained at 4 weeks and stored frozen until testing. Mechanical push-out tests (5.0 mm/min) were performed on 3.0 mm transverse sections of the implants using an Instron materials test machine (Model 4302, Instron, UK). Ultimate shear strength (MPa), apparent shear stiffness (MPa/mm) and energy absorption (J/mm) were calculated from force-displacement curves.

RESULTS
No infections were seen (intraarticular swabs at euthanasia).

Statistics: The Wilcoxon Signed Ranked Test was applied, as differences between the paired values were not normally distributed. Results are given as median and interquartile range. Significance for two-tailed test is p<0.05 (*).

<table>
<thead>
<tr>
<th>REVISION TECHNIQUE</th>
<th>Shear Strength (MPa)</th>
<th>Energy abs. (J/mm²)</th>
<th>Stiffness (MPa/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crack of sclerotic rim + graft (n=8)</td>
<td>2.69 (0.55 - 3.36)</td>
<td>414 (109-655)</td>
<td>10.7 (1.9 - 12.0)</td>
</tr>
<tr>
<td>Standard revision + graft; control (n=8)</td>
<td>0.07 (0.01 - 0.1)</td>
<td>6 (1-20)</td>
<td>0.3 (0.1 - 0.4)</td>
</tr>
<tr>
<td>Improvement w/ crack vs. control</td>
<td>38 times</td>
<td>69 times</td>
<td>36 times</td>
</tr>
</tbody>
</table>

* p = 0.02

Revision implant fixation (shear strength, stiffness and energy absorption) was significantly improved by cracking the sclerotic bone rim followed by allograft, when compared with the control’s standard revision technique also followed by allograft. All of the implants with rim cracking were able to support and resist pushout load, while two of the eight implants with the standard revision technique had no measurable resistance to pushout (ultimate strength = 0).

DISCUSSION AND CONCLUSIONS
This current study demonstrates that cracking the sclerotic bone rim markedly improves revision implant fixation when used in combination with allograft. Energy absorption increased 69-fold, strength 36-fold, and stiffness 36-fold. We have previously shown (1) that cracking the sclerotic bone rim without allograft improved energy 7-fold, strength 5 fold and stiffness 8 fold. The more pronounced effect when allograft is present suggests that there is a synergistic effect between the sclerotic rim cracking technique and allograft. Biologically, it is known that a benefit of allograft is that it serves as an osteoconductive material for the laying down of new bone as the graft is being resorbed (creeping substitution). This biological process may be enhanced by the improved access of autologous growth factors and blood supply to the revision cavity when the sclerotic bone rim is locally cracked or perforated. Mechanically, we have shown that the sclerotic bone rim is associated with inferior fixation (3). Disrupting the rim may additionally improve fixation by aiding the process of allograft integration between the implant and the surrounding bone. The results of this study should be interpreted with the constraints of this particular loaded gap implant model and revision protocol. Further study is needed to investigate if bone allograft in combination with HA or other implant coatings can provide even further improvement to the rim cracking technique.

REFERENCES:

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