THE EFFECT OF BONE CAVITY PREPARATION METHOD ON IMPLANT FIXATION

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Introduction: Compaction of bone to create a cavity for a total joint implant is gaining recognition as a bone-saving alternative to methods of cavity preparation that involve only extraction of bone. Advantages of compaction are increased contact area at the implant-bone interface and subsequent improved initial fixation and potential for bone ingrowth. Rasping and drilling are bone extraction techniques, while bone compaction is a bone-saving method of creating a cavity. Previous published work (1) has shown that bone compaction can enhance the initial stability of intramedullary implants. This study was designed to evaluate the influence of bone cavity preparation technique on the fixation of hydroxyapatite-coated metallic implants in an animal model.

Methods: All procedures were approved by an institutional animal care and use committee. Thirty-five male New Zealand white rabbits weighing 3.6–4.5kg were divided into three groups. In all animals, a transverse cylindrical cavity was created above the lateral condyle of the right distal femur using one of three techniques: A) A series of three drills, 2.0mm, 3.6mm and 4.8mm in diameter (DRILL GROUP, n=12); B) A 2.0mm drill followed by 3.0mm and 4.8mm diameter rasps (RASP GROUP, n=11); or C) A 2.0mm drill followed by a series of smooth, rounded-tip dilators 3.0, 4.0, and 4.8mm in diameter (COMPACTION GROUP, n=12). Each implant cavity was located immediately proximal to the lateral collateral ligament and did not penetrate the medial cortex. A hydroxyapatite-coated titanium cylinder 4.8mm in diameter and 9.5mm in length, with a threaded hole in one end, was inserted into each prepared cavity until the threaded end was flush with the lateral cortex. The animals were maintained for 12 weeks before sacrifice. At sacrifice, the implanted femur from each animal was imbedded in polymethylmethacrylate cement to a point just proximal to the implant, and a threaded rod screwed into the visible end of the implant. Using the rod as a guide, the specimen was oriented so that the titanium cylinder was vertical and then clamped to the table of an Instron model 1321 servohydraulic materials testing machine. The threaded rod was clamped to the machine’s actuator and the implant extracted at a rate of 1mm/min while recording force and displacement. The peak pull-out forces were subjected to ANOVA and Newman-Keuls tests to determine differences between groups.

Results: The table below reports the mean pull-out forces for each method of cavity preparation.

<table>
<thead>
<tr>
<th>Cavity Preparation Method</th>
<th>Mean Pull-Out Force</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>Drill (n=12)</td>
<td>444.7 N</td>
<td>167.5 N</td>
</tr>
<tr>
<td>Rasp (n=11)</td>
<td>498.1 N</td>
<td>118.3 N</td>
</tr>
<tr>
<td>Compaction (n=12)</td>
<td>347.0 N</td>
<td>118.4 N</td>
</tr>
</tbody>
</table>

Analysis of variance indicated no significant difference in the pull-out forces resulting from the three cavity preparation methods. Comparing between groups, subsequent Newman-Keuls tests revealed p-values of 0.355 for drilling vs. rasping, 0.186 for drilling vs. compaction, and 0.397 for rasping vs. compaction.

During implant extraction, failure occurred through shear between the HA coating and the surrounding bone over approximately 50% of the implant’s area. The remaining 50% of the surface showed shearing of the HA layer from the surface of the titanium substrate.

Discussion: The long term fixation of orthopaedic implants is largely dependent upon obtaining stable initial fixation by matching the shape of the implant cavity with the shape of the implant. This study demonstrated that bone compaction is not significantly different than other tested techniques for implantation of a hydroxyapatite-coated test cylinder in the distal femur of a rabbit. Traditional methods of cavity preparation for the implantation of total hip femoral components and total knee tibial components rely on extraction of bone material by milling/drilling, broaching, or rasping. A method that preserves bone stock, rather than removing it, and which provides a greater degree of contact between the implant and the surrounding cancellous bone, would be desirable for a number of reasons. First, we and others have shown previously that bone compaction enhances the initial stability of an intramedullary implant (1,2). Additionally, bone compaction may allow an implant of smaller size to be placed since the increased stability could partially obviate the need to achieve cortical contact for stability. A smaller implant preserves bone stock.

The significance of this study is that it investigates the in vivo attachment strength of bone to implant when using the compaction technique. One concern about bone compaction is that the densification of bone around the implant created by compaction is the result of microfracture and condensation of trabecular bone. The effect of this bone condensation or “internal grafting” on the attachment strength of bone to implant was previously unknown. This study confirms that the compaction of bone around a hydroxyapatite-coated implant did not compromise the attachment of bone to the surface of the implant when compared to other commonly used bone preparation techniques. Further histologic study of the implant-bone interface is ongoing.

While earlier studies have confirmed the advantage of bone compaction in the initial mechanical stability of implants, the results of this study do not provide evidence of the superiority of bone compaction in fixation of a metallic implant after a period of bone remodeling when compared to drilling or rasping in the hydroxyapatite-coated cylinder model. In drawing conclusions from this work, two qualifications must be considered. The cylindrical implants used had a smooth surface texture. It is possible that, although ongrowth of bone to such a surface is not significantly enhanced by the compaction method, an implant with a porous coating might benefit measurably due to more rapid or more thorough ingrowth into the interstices. Also, this study employed an unloaded implant, and results may differ if an implant were employed that was subjected to load-induced micromotion during weight bearing.