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Histologic and Mechanical Evaluation of Impaction Grafting for Femoral Component Revision in a Goat Model

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abstract

A goat model of revision hip arthroplasty was used to examine the histology and mechanical performance of impaction grafting using two femoral stems varying in stem surface finish. There were no significant mechanical or qualitative histologic differences between smooth, tapered, polished stems and step-cut, grit-blasted stems. Allograft distribution, bone incorporation, and cement mantle thickness were not uniform within the femoral canal. Efforts to improve the impaction grafting technique may be more important than stem design.

The number of patients undergoing revision total hip arthroplasty (THA) continues to increase. Estimates of revision procedures run as high as 30% of all THA surgeries, with 250,000 being performed in 1991. Revision THA continues to pose a challenging problem for orthopedic surgeons. The outcome of various techniques for femoral component revision has been variable.

Recently, the use of impacted morselized cancellous allograft has been advocated to restore proximal femoral bone and provide implant stability with a cemented component. Allograft bone is packed into the femoral canal restoring lost bone and providing a cancellous bed into which a new prosthesis can be cemented. With this technique, a collarless, polished, tapered component often is used. This type of implant may subside within the cement mantle, creating compressive forces in the bone graft that are important for the incorporation and remodeling of the graft material.

While some basic science and retrieval studies have shown this does occur, only one published study has assessed the mechanical strength of the construct as it heals. Likewise, there are no published studies on impaction grafting that directly compare the mechanical and histologic effect of different femoral component surface finishes.

The authors’ clinical concerns with subsidence when using a polished stem following impaction grafting led to the concept of using an implant that would not be prone to subside within the cement mantle. This study examined the extent of biologic incorporation and mechanical stability following impaction grafting using morselized cancellous allograft in a goat model comparing two femoral stems that were identical except for surface treatment.

The study hypothesized that stem surface finish would not influence the histologic or mechanical response following impaction grafting on the femoral side and that the actual technique of impaction grafting, ie, creating a dense graft mantle, plays a greater role in the overall outcome of this type of reconstructive technique rather than the type of implant.

MATERIALS AND METHODS

Forty-six female mixed breed goats between ages 2 and 4 years were used in this study. The goat is a good model to

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simulate femoral revision because it has scant cancellous bone primarily at the proximal femur, which can be easily visualized and removed, and smooth cortical bone distally.\textsuperscript{35}

A revision hip situation was simulated in all animals by removal of all cancellous bone from the proximal femur and overreaming the femoral canal, and animals were randomly assigned to one of three groups. Animals in the control group underwent femoral component revision with a cemented polished femoral stem. The first experimental group underwent femoral component revision with impaction grafting followed by a cemented polished stem. The second experimental group also underwent impaction grafting but received a cemented grit-blasted stem into which normalizations (step-cuts located proximally on the stem) had been machined.

The stems were identical in size and geometry, and differed only in the surface treatment (Figure 1). The surface roughness, $R_a$, for the polished and grit-blasted stems were nominally 0.5 $\mu$m and 4.0 $\mu$m, respectively. Within the three groups, animals were randomly designated for sacrifice at either 8 or 16 weeks, and were further subdivided into a mechanical testing or histologic group. Five time-zero specimens for each construct type were performed on the contralateral hip after sacrifice.

**Surgical Procedure**

Hemiarthroplasty of the left hip was performed under general anesthesia using a standard procedure.\textsuperscript{36} Following hip dislocation and femoral neck osteotomy, the proximal femur and femoral canal were reamed until a smooth endosteal surface was achieved to simulate a revision situation. An intramedullary plug was then placed into the femoral canal.

Animals that were randomized to the experimental groups underwent impaction grafting using a cannulated, custom-designed instrument system. Morselized allograft was inserted and packed into the femur using cannulated tamps and broaches as described by the Exeter group.\textsuperscript{27,31} The grafting was completed when the entire endosteal surface had been coated with bone graft, and the graft had been rigidly packed into the femur so that the trial broach was rotationally stable within the graft mantle.

For all procedures, Simplex bone cement (Howmedica, Rutherford, NJ) was used. A single pack of polymer was mixed in a Stryker (Kalamazoo, Mich) vacuum cement mixer. The cement was then introduced into the femoral canal or bone graft mantle in retrograde fashion and pressurized, followed by implant insertion.

**Bone Graft**

Allograft bone was obtained from previously sacrificed goats. Bone was harvested under sterile conditions from the proximal and distal humerus, the femoral head, and the distal femoral condyles. All soft tissue was removed from the bone, and the specimens were then wrapped and stored in a freezer at $-70^\circ$ C.

Prior to use, the bone was soaked in a bacitracin saline solution at room temperature for approximately 30 minutes. Any remaining soft tissue and articular cartilage was removed, and the graft material was morselized in a bone mill (Tracer Designs, Santa Paula, Calif) using the medium-grinding cylinder. The resulting graft material had a 50th percentile particle size of approximately 1.2 mm. The bone was washed with saline and squeezed in a sponge to remove marrow and fat.

**Postoperative Care**

Following wound closure and extubation, the animals were placed in a cus-
tom-made sling designed to prevent dislocation. The sling allowed nearly full weight bearing but prevented the animal from lying down. The animals were removed from the sling on postoperative day 3 and allowed unrestricted activity until sacrifice.

Radiographs were obtained biweekly to assess gross implant position and identify any complications such as dislocation or fracture. Radiographs also were obtained at the time of sacrifice (Figure 2).

**Histology Group**

For the 12 femurs used for histologic evaluation, the soft tissues were removed and the specimens cut perpendicular to their long axis with a diamond saw. Each specimen was sectioned at approximately the same levels to facilitate comparisons.

For each femur, several representative sections 3-mm thick were decalcified, embedded in paraffin, and stained with hematoxylin-eosin. The remaining segments of the femur were fixed for an additional week in 70% ethanol, dehydrated slowly in graded series of alcohols without the use of acetone, and embedded in Spurr plastic. This method of dehydration and embedding was used to preserve bone cement and still retain cellular detail.

Additional rough cuts were then made with a diamond saw, resulting in 8 to 12 sections from each femur, each approximately 1- to 2-mm thick (Figure 3). The sections were numbered consecutively from proximal to distal, and each section was hand ground to a final thickness of approximately 50 μm and stained with Cole’s hematoxylin and 1% alcoholic eosin.

**Mechanical Testing**

Mechanical tests were conducted using a servohydraulic load frame (MTS Bionix, Model 858, Minneapolis, Minn) under load-control. Distal condyles were removed from the femoral specimens, and the specimens were potted in an aluminum cup that had a ball bearing attached to its base (Figure 4). The cup also contained a pair of removable transverse rods (axis-in-fork) allowing the transmission of torsional loads. Using this setup, three separate mechanical tests were performed.

Axial compression test. Each femur was loaded under a 0.5-Hz sinusoidal axial compression force to peak loads of 30%, 60%, 90%, 120%, and 150% of the body weight (BW) of the individual goat. During each cycle, the load returned to zero.

Three cycles of loading and unloading were performed at each level before increasing to the next load level. The loading was increased stepwise at a quasi-static loading rate to allow observation of any abrupt change in mechanical behavior indicating failure.

Relative motion between the implant and the femur was measured with a linear variable differential transformer (LVDT) (range: 1 cm, Model D2/200A, RDP Group, Heath Town, Wolverhampton, United Kingdom). A polycarbonate block was glued to the femoral head and acted as an extended target for contact with the plunger of the LVDT. Vertical displacement at two points on the polycarbonate block and medial displacement at one point on the block were measured with the LVDT. Based on these measurements, the complete two-dimensional motion (vertical and medial) of the center of the femoral prosthesis head with respect to the femoral cortex was calculated.

An additional measurement was made of the frontal plane rotation and off-plane rotation with the LVDT oriented in an anteroposterior configuration perpendicular to the polycarbonate block. Finally, the vertical change in position of the stem from the start of testing to the completion of the axial load tests was recorded. A calibration test of the LVDT measurement technique demonstrated the precision of a given LVDT measurement was ±25 μm and known axial, angular, and rotational displacements of the MTS actuator could be measured within 3% accuracy.

Axial cyclic test. Immediately following the axial compression test, the femoral head was loaded in sinusoidal compression between 20% BW and 150% BW. Five thousand cycles were performed at a frequency of 2 Hz.

Peak-valley (maximum-minimum) displacement between the prosthesis and the cortical bone was measured with the LVDT located in one of the two vertical positions described previously. The results are reported in terms of total subsidence at 500 and 5000 cycles. This is a measure of the change in vertical position of the stem beginning with the first cyclic test load cycle.

Torsion test. Following axial cyclic loading, torsional loading was applied to
the stem about the long axis of the implant while the femur was constrained against rotation. The torsional load was varied sinusoidally for three cycles at 0.5 Hz between 0.0 nm and 0.5 nm, then 1.0 nm, and finally 1.5 nm. These torques were applied with a combined axial preload equal to one times BW. Continuous axial rotation between the implant and the femur was measured with the LVDT positioned horizontally and oriented perpendicular to the polycarbonate block.

**Statistical Analysis**

Statistical tests were performed on the measurements taken for all specimens during the axial compression test in the form of axial displacement, medial displacement, and planar rotation during the final 150% BW load cycle. For the cyclic tests, the 500-cycle and 5000-cycle subsidence measurements were analyzed. The torsional test rotational measurements were analyzed for the 1.5 nm load.

For each mechanical test, single-factor analysis of variance (ANOVA) was performed to determine if there were any differences between means across both group (control, normalized, and polished) and time period (0, 8, and 16 weeks). Following any ANOVA that showed significant difference, post hoc t tests (Tukey) were performed to determine the specific groups or time periods displaying significant difference. For subsidence data with post hoc tests near statistical significance, independent sample t tests assuming unequal variance also were performed.

**RESULTS**

**Complications**

Four animals developed surgical complications and were removed from the study. Dislocation occurred in two control animals and a periprosthetic femoral shaft fracture developed in a third control animal; two of the animals were from the 8-week group and one was from the 16-week group. A fourth animal completed the postoperative period seemingly with-
Histology Results

**Normalized grit-blasted stems: 8-week group.** Most of the allograft particles were necrotic and undergoing resorption in some areas. Lymphocytes, giant cells, and poorly formed granulomas were associated with resorbing particles of dead bone (Figure 5).

The distribution of the allograft in the femoral canal was irregular. In some areas, the process of graft incorporation showed a transition from mostly necrotic bone with fibrous tissue, to areas of creeping substitution, to more mature incorporated bone graft, and finally to residual host bone.

The cement mantle in this group demonstrated areas of fibrous membrane between the implant and the cement. Fibrous membranes also were present between particles of the allograft.

The bone cement ranged from 0.3 to 1.8 mm in thickness, with an average thickness of approximately 1 mm. Areas of discontinuous cement were present mostly in the anteromedial and posterolateral regions of the proximal femur. The cement also was incomplete at all levels with prominent fibrous membranes surrounding the cement.

**Normalized grit-blasted stems: 16-week group.** Bone graft was not distributed uniformly, but appeared to have been remodeled to viable trabecular bone. A relatively thin plate of bone was present around most of the bone graft. There was minimal inflammation and very little fibrosis.

The incorporated bone graft demonstrated a neocortex around the cement. Small spicules of partially necrotic bone remodeled to larger trabeculae of more mature lamellar bone. The overall histologic appearance was suggestive of extensive incorporation of the bone graft and a stable implant.

**Polished stems: 8-week group.** Histology at 8 weeks in the polished group demonstrated necrotic bone with regions of relatively prominent bone marrow necrosis and periosteal reaction. The graft was associated with relatively prominent inflammatory reaction.

Bone graft packing was not uniform. In some areas, the bone graft appeared relatively dense, whereas in other areas, the graft mantle was sparse with fibrosis between the graft particles. Much of the bone graft was undergoing creeping substitution.

In this group, the histology appearance demonstrated the graft had not incorporated substantially. The cement mantle was relatively uniform; however, there were areas of incomplete cement proximally.

**Polished stems: 16-week group.** Most of the graft appeared to have incorporated with easily recognized creeping substitution, although there were some areas of persistent chronic inflammation associated with necrotic bone. Fibrous membranes incompletely surrounded the outer perimeter of the bone graft.

The distribution of trabecular bone was not uniform, with higher bone density near the cement and less near the endosteum. In all of the specimens, there was minimal inflammation and areas of creeping substitution suggesting graft incorporation.

Mechanical Testing Results

**Axial compression tests.** The results of the initial axial loading tests are presented in terms of displacements at the 150% BW load level. The complete two-dimensional motion of the center of the femoral head within the loading plane (neck-shaft plane) is presented as axial motion parallel to the femoral shaft axis, medial motion perpendicular to the femoral shaft axis, and varus rotation of the head with respect to the femoral shaft. Also, the initial setting of the stem into the femoral canal is presented in terms of the vertical measurement of the single LVDT location that was later used to track subsidence during the axial cyclic test.

The average axial stem displacement at 150% BW loading ranged from 0.05 mm (16-week normalized) to 0.21 mm (zero-week polished) (Table 1). Mean axial displacement was less with increased time and less in the normalized group, but these differences did not reach statistical significance by ANOVA.

The average medial displacement at 150% BW loading ranged from 0.07 mm (16-week normalized) to 0.25 mm (8-week polished). Again, there seemed to be trends for the medial displacement to be less with increased time and greater in the polished group, but there were no statistically significant differences between groups or time periods.

The average frontal plane rotational displacement at 150% BW loading ranged from 0.02º (zero-week control) to 0.25º (8-week polished). There were no statistically significant differences between groups or time periods. The large motion and variance in the 8-week polished group was due to one grossly unstable stem, which demonstrated markedly more motion than all of the other implants in that group.
Off-plane rotation during the axial test was small in all groups, <0.1°. No difference was observed among time stages or implant types.

The average initial axial stem settlement at 150% BW loading ranged from 0.01 mm (8- and 16-week normalized) to 0.23 mm (zero-week polished). There was a trend for the axial displacement to be less with increased time and in the normalized group compared to those with polished stems, but these differences did not reach statistical significance.

Axial cyclic test. The outcome measure for cyclic testing was axial subsidence. Specifically, the vertical translation on one channel (position) of the LVDT was tracked during cyclic loading at the 20% BW load level to estimate the positional change of the stem with respect to the femur over time. Because only one location of the LVDT was used to monitor cyclic behavior, there is some component of planar rotation included in the subsidence results.

Results of the cyclic loading tests at 5000 cycles are summarized in Table 2. Overall subsidence was minimal (<0.40 mm), and subsidence decreased with increasing time in situ (ie, 16 weeks <8 weeks <zero weeks).

There were no statistically significant differences between control or experimental groups at any time period. For the control and normalized groups, the subsidence dropped significantly between the zero-week and 8-week periods ($P<0.05$, post hoc Tukey). For the polished group, the significant drop occurred between 8 and 16 weeks ($P<0.05$, post hoc Tukey). More than 50% of the subsidence occurred during the first 10% (500) of the cycles.

Torsional test. The torsional test results are summarized in Table 3. All rotational displacements exhibited linear increases, with increasing torque from 0.5 nm to 1.0 nm to 1.5 nm. Therefore, all results were compared at the 1.5-nm load level.

There was a statistically significant difference between the rotational stability at zero weeks when the control group was compared to the two experimental groups ($P=0.0054$, ANOVA; $P<0.05$, post hoc Tukey). Thus, the fully cemented implant had better initial stability in torsion than the impacted bone graft technique. However, at 8 and 16 weeks, there was no statistically significant difference between any groups. The control groups showed no change over time, and the experimental groups improved.

Comparison within each group over time showed a statistically significant improvement in stability for the normalized stems from zero weeks to both 8 and 16 weeks ($P=0.0015$, ANOVA; $P<0.05$, post hoc Tukey). The ANOVA and post hoc tests could not demonstrate significant differences between time periods for the control and polished groups. However, there was a statistically significant difference between zero and 16 weeks in the polished group when those two time periods were compared directly using a $t$ test assuming unequal variance ($P<0.001$).

The reason for lack of significance in the ANOVA for the polished group is believed to arise from the large variance in the control group. If the unstable 8-week polished specimen is eliminated from the analysis, both bone-grafted groups look similar, with improving stability over time to a level at 16 weeks equivalent to the control group.

**DISCUSSION**

The short-term clinical results of femoral component revision with impaction grafting using a collarless, polished, tapered stem generally have been favorable. A concern with this type of reconstructive procedure is the degree of subsidence that may occur.

Gie et al reported 79% of 56 patients in their series had measurable subsidence, averaging 6.5 mm, with a minimum follow-up of 18 months using the Exeter stem (Howmedica International, Middlesex, England). Elting et al reported 40% of their patients had subsidence averaging 2.8 mm using the CPT stem (Zimmer, Warsaw, Ind).

In a more recent report of results of

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### TABLE 1

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Control 0 Week</th>
<th>Control 8 Week</th>
<th>Control 16 Week</th>
<th>Polished 0 Week</th>
<th>Polished 8 Week</th>
<th>Polished 16 Week</th>
<th>Satin Finish Normalized 0 Week</th>
<th>Satin Finish Normalized 8 Week</th>
<th>Satin Finish Normalized 16 Week</th>
</tr>
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<tbody>
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<td>0.132</td>
<td>0.063</td>
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</tr>
<tr>
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<td>0.010</td>
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<td>5</td>
<td>0.307</td>
<td>0.110</td>
<td>–</td>
<td>0.364</td>
<td>0.175</td>
<td>0.090</td>
<td>0.046</td>
<td>0.153</td>
<td>–</td>
</tr>
<tr>
<td>Mean</td>
<td>0.198</td>
<td>0.200</td>
<td>0.102</td>
<td>0.247</td>
<td>0.171</td>
<td>0.102</td>
<td>0.124</td>
<td>0.096</td>
<td>0.050</td>
</tr>
<tr>
<td>SD</td>
<td>0.084</td>
<td>0.118</td>
<td>0.080</td>
<td>0.083</td>
<td>0.157</td>
<td>0.084</td>
<td>0.075</td>
<td>0.063</td>
<td>0.037</td>
</tr>
</tbody>
</table>

*Differences over time are not significant for any construct.*
Impaction grafting with a CPT stem, Meding et al.\(^28\) noted subsidence averaged 5.3 mm within the cement mantle in 9% of patients. In an additional 35% of patients, the stem and cement subsided within the graft mantle. The average subsidence was 11.3 mm. They concluded the amount of subsidence with this type of reconstructive procedure was unpredictable and the overall clinical hip score may not reflect the amount of subsidence.

Subsidence of the femoral component can be a significant clinical problem leading to soft-tissue laxity, instability, and diminished overall clinical outcome. The objective of this study was to create a reconstructive model that would compare the histologic and mechanical results using impaction grafting with two different stem surface finishes. The first finish was a smooth, polished stem that would presumably subside, and the second finish was a grit-blasted stem with normalizations that was designed to decrease subsidence.

The results of the axial cyclic test demonstrated overall subsidence was minimal in each case and decreased with increasing time cycles. There were no statistically significant differences with respect to subsidence between the control and experimental groups at any time period. The results also showed more than 50% of the subsidence occurred during the first 10% of the cycles.

The normalized grit-blasted stem subsided as much as the smooth stems, although the overall subsidence was minimal in all of the animals. Because the technique measured subsidence between the implant and the femoral cortex, it could not be determined at which interface the overall subsidence occurred.

Subsidence can occur between the host-allograft bone junction, within the cancellous allograft, or between the cement and implant interface. One would expect little if any subsidence at the bone-cement interface in the control group. Because there was some subsidence in the control group, it probably occurred at the cement-prosthesis interface using the polished stem.

In contrast, one would expect little, if any, subsidence at the cement-implant interface in the normalized grit-blasted stem. Subsidence in this group, in all likelihood, occurs within the cancellous allograft mantle. The lack of any significant subsidence in this group may be attributed to the technique of impaction grafting used, which included aggressive packing of the allograft and testing rotational and axial stability with the trial tamp component prior to the insertion of the actual cemented implant.

Dense packing of the femoral canal with allograft was extremely important in this study because following surgery, the animals immediately bore full weight. Based on the minimum amount of subsidence noted in each group over the 16-week period, it is unlikely that restricting the animals’ activities through sedation or bracing would have altered the results.

With respect to histology, no qualitative differences were noted in this study based on the type of stem surface finish, either smooth polished stems, or grit-

### TABLE 2

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Total Subsidence Distance</th>
<th>Change in Subsidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Polished</td>
</tr>
<tr>
<td></td>
<td>0 Week</td>
<td>8 Week</td>
</tr>
<tr>
<td>1</td>
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<td>0.086</td>
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<td>Mean</td>
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</tr>
<tr>
<td>SD</td>
<td>0.070</td>
<td>0.010</td>
</tr>
</tbody>
</table>

* Differences were not statistically significant.
One of the most striking observations was the difference between the 8-week and 16-week groups. The allograft in the 8-week group was associated with an inflammatory response composed mainly of lymphocytes and macrophages; occasional lymphoid aggregates also were present. This inflammatory response was presumably related to the immunologic differences between the host and donor specimens and seemed to resolve in parallel with the process of bone graft incorporation.

The 8-week femora showed relatively prominent fibrosis associated with the allograft, and most of this resolved by 16 weeks. Marrow fibrosis universally accompanies bone infarcts as well as other disorders characterized by high bone turnover and probably reflects the graft resorption process. Several specimens, however, showed persistent fibrous membranes with collagen oriented around the implant, cement, and graft complex.

A striking feature noted was the overall progressive decrease in fibrous tissue between the cement and the host bone between 8 and 16 weeks. Fibrous membranes were still prominent at areas where there was a void in the graft mantle.

The lack of a uniform graft mantle or graft distribution was concerning. It is important to have a bone graft delivery system that can uniformly distribute the graft in the femoral canal.

In a multicenter review of 200 impaction grafting cases, Masterson et al examined the cement mantle on the postoperative radiographs and found a deficient or absent cement mantle in 47% of the Gruen zones. They were concerned about the deficient cement mantle and the long-term results that can be achieved with this type of reconstruction procedure.

The pattern of graft resorption and remodeling was complex. New bone formation of the surface of necrotic bone graft in some femurs created a complex geometry of mineralized tissue between the cement and the cortex. The final shape and orientation of the trabecula most closely resembled that of normal bone, but the lack of uniform density probably reflects in part the variable areas of distribution of the allograft.

In this study, the amount of graft that was retained in each femur after the 16-week period could not be quantified. It would have been helpful to have a preset constant initial volume of bone graft delivered to each femur to better quantify the amount of bone that was retained at the end of the study. The amount of graft varied in each femur based on the size of the femoral canal.

The best histologic appearance was achieved in femurs in which there was a high trabecular bone density from dense packing of the relatively small, uniform pieces of cancellous allograft and a thick preserved cement mantle. On the other hand, the worst histologic appearance was in areas that demonstrated low or absent trabecular bone, reflecting areas in which the allograft had been absent or resorbed.

The type of stem surface finish did not play a role with respect to the histologic differences. Both experimental groups demonstrated areas that were inconsistent in graft and cement mantle despite great attention to surgical technique and aggressive packing of the allograft. Because the inconsistency in the graft and cement mantle affected both groups equally, it was not believed to influence the results in this 16-week animal study. In addition, the animals were stable and ambulatory during the 16-week period.

Despite the inconsistent graft mantle, there were areas of densely packed allograft that likely supported the implant against axial and torsional loads for at least the 16-week period. However, the finding of an inconsistent graft and cement mantle in this study raises concerns about the long-term results with impaction grafting because in all likelihood, this problem also can occur clinically.

**TABLE 3**

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Control 0 Week</th>
<th>Control 8 Week</th>
<th>Control 16 Week</th>
<th>Polished 0 Week</th>
<th>Polished 8 Week</th>
<th>Polished 16 Week</th>
<th>Satin Finish Normalized 0 Week</th>
<th>Satin Finish Normalized 8 Week</th>
<th>Satin Finish Normalized 16 Week</th>
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</thead>
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<td>0.355</td>
<td>0.200</td>
</tr>
<tr>
<td>5</td>
<td>0.304</td>
<td>–</td>
<td>–</td>
<td>0.439</td>
<td>0.611</td>
<td>0.103</td>
<td>0.483</td>
<td>0.208</td>
<td>–</td>
</tr>
<tr>
<td>Mean</td>
<td>0.248</td>
<td>0.232</td>
<td>0.221</td>
<td>0.446</td>
<td>0.694</td>
<td>0.194</td>
<td>0.439</td>
<td>0.256</td>
<td>0.180</td>
</tr>
<tr>
<td>SD</td>
<td>0.039</td>
<td>0.094</td>
<td>0.031</td>
<td>0.088</td>
<td>0.670</td>
<td>0.057</td>
<td>0.117</td>
<td>0.065</td>
<td>0.019</td>
</tr>
</tbody>
</table>

*Time zero differences were significant between groups (ANOVA, P =.0054) and normalized group time differences were significant (ANOVA, P=.0015).
Torsional testing is predominantly a direct measure of the shear strength of the bone graft mantle. One therefore would expect time zero impaction grafting specimens to have greater angular displacement than the control group regardless of the stem type. If the bone graft incorporated after time in vivo, displacement to a specific applied torque should decrease. If the surface treatment of the stem affects the incorporation of the bone graft, this should be demonstrated by differences in shear stability between the two stem designs.

Our results showed significant differences between impaction grafting specimens and controls at time zero, as expected. At 16 weeks, there were no differences in torsional response between controls and impaction grafting with either component. This suggests the interface shear strength between the allograft and host bone is now equal to the cemented interface.

Because there were no differences with stem types, this suggests the grit-blasted, normalized stem did not have an adverse affect on graft incorporation compared to the smooth stem. Therefore, there were no differences between polished and grit-blasted stems with respect to graft incorporation in this model.

Duncan et al.39 addressed the role of stem design with impaction grafting. Their experience suggested stem configuration may be less important compared to obtaining an optimal graft and cement mantle.

Although the type of implant used may play a role in the final outcome of this type of reconstructive procedure, the technique of impaction grafting along with the graft properties may play an even greater role in determining overall subsidence and possibly long-term clinical results. Every effort should be made to achieve a uniform and dense graft mantle to adequately support the implant and provide immediate stability because cancellous allograft does not completely incorporate even at 16 weeks.

The optimum graft properties are yet to be determined with respect to the ideal size of the cancellous allograft along with its moisture content. Recent studies have examined the effects of washing the allograft to remove marrow and fat droplets45,46 as well as the initial stability of freeze-dried, irradiated allograft.47,48 This study complements the initial study by Schreuer et al.35 on impaction grafting in goats in which a collared implant was used. The results of this study show impaction grafting can restore proximal femoral bone loss, demonstrated by graft incorporation over the 16-week period. Immediate implant stability must be achieved with dense packing of the allograft within the femoral canal.

As suggested by Duncan et al.38 this study indicates stems surface finish may not play a significant role with respect to subsidence. The technique of impaction grafting creating a dense graft mantle void of fat and debris may play a larger role in preventing subsidence.

The lack of a uniform graft and cement mantle with impaction grafting needs to be evaluated further.

REFERENCES


