Reduction in Bone Volume Resection with a Newer Posterior Stabilized Total Knee Arthroplasty Design

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Received: 28 February 2013/Accepted: 27 April 2013 / Published online: 28 June 2013
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Abstract *Background:* Posterior stabilized total knee arthroplasty requires an intercondylar notch to accommodate the cam housing that articulates with the tibial post to create femoral rollback required for deep flexion. The volume of bone resected for the intercondylar notch varies with implant design, and newer designs may accommodate high flexion with less bone resection. *Questions/Purposes:* This study aims to analyze the bone volume and density resected from the intercondylar notch for three posterior stabilized implants from a single company: a Posterior Stabilized (PS) system, a Hi-Flex system (HF), and a rounded new box-reamer (RB) system and to further assess whether the newer RB with a cylindrical cutting tool would preserve more native bone. *Materials and Methods:* Using a computer model, the PS, HF, and RB femoral components were digitally implanted into CT scans of 19 cadaver femurs. Nine cadavers were fit with a size 4 implant, six with size 3, and four with a size 2. The volume of intercondylar bone resected digitally for femoral preparation was measured. Bone density was measured by CT scans in Hounsfield units (HU). A paired *t* test was used to compare the mean volume of bone resected for each implant. *Results:* For the size 4 femurs, the newer RB design removed 8% less intercondylar bone than the PS design ($7,832 \pm 501$ vs. $8,547 \pm 377$ mm³, $p < 0.001$) and 28% less bone than the HF design ($7,832 \pm 501$ vs. $10,897 \pm 444$ mm³, $p < 0.001$). The average HU for size 4 femurs for RB design was 427 ± 72 (PS = 399 ± 69 , $p < 0.001$; HF = 379 ± 66 , $p < 0.001$). For the size 3 femurs, the RB design removed 12% less intercondylar bone than the PS ($6,664 \pm 786$ vs.

$7,516 \pm 648$ mm³, $p < 0.001$) and 27% less bone than the HF ($6,664 \pm 786$ vs. $9,078 \pm 713$ mm³, $p < 0.001$). HU for size 3 femurs for the RB design was 452 ± 70 (PS = 422 ± 53 , $p < 0.1$; HF = 410 ± 59 , $p < 0.01$). For the size 2 femurs, the RB design removed 5% less intercondylar bone than the PS ($5,730 \pm 552$ vs. $6,009 \pm 472$ mm³, $p < 0.01$) and 22% less bone than the HF ($5,730 \pm 552$ vs. $7,380 \pm 532$ mm³, $p < 0.001$). HU for size 2 femurs for the RB design was 430 ± 48 (PS = 408 ± 55 , $p < 0.01$; HF = 385 ± 56 , $p < 0.01$). *Conclusions:* The newer RB design removes less bone from the intercondylar notch than the classic PS and HF designs in all sizes tested. The bone-conserving cuts incorporated into this newer implant design appear to preserve native bone without compromising design objectives.

Keywords total knee arthroplasty · bone resection · posterior stabilized

Introduction

The demand for primary and revision total knee arthroplasty is expected to increase at an exponential pace [6]. Furthermore, a growing proportion of these patients are within the younger subgroups of less than 45 and 45 to 64 years of age [5]. Younger patients can be expected to place higher demands on knee arthroplasties while desiring better range of motion [3]. As such, the drive for technological innovations in the designs of total knee replacements are at an all time high. The ideal components would maximize durability and function while minimizing bone loss to improve fixation and avoid challenging future revision procedures. Since bone stock is paramount to possible revision reconstruction as well as avoiding intra-operative femoral condyle fracture, it is incumbent on the treating surgeon to reduce unnecessary bone resection during primary total knee replacement [7].

The basic design of the femoral component, being either posterior stabilized (PS) or cruciate retaining (CR), is an

Electronic supplementary material The online version of this article (doi:10.1007/s11420-013-9340-1) contains supplementary material, which is available to authorized users.

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Fig. 1. Sizing of the distal femur using MIMICS Software (Materialise, Leuven, Belgium).

obviously modifiable aspect of the reconstruction. CR designs have been shown to resect less bone given that the intercondylar notch box cut is not needed for the post-cam articulation [8]. However, the other merits of these different design philosophies have led to considerable debate, with the trend at most centers in North America being toward the use of PS knees [1].

Different PS femoral components have been shown to require varying amounts of bone resection for the box depending on the manufacturer [4]. Within the same manufacturer, design differences such as high flexion (HF) versus standard PS as well as conventional notch guide versus reamer guide (RG) box preparation instrumentation have also been shown to result in significantly different amounts of resection [2].

The primary outcome of our study was to analyze the bone volume and density resected from the intercondylar notch for three posterior stabilized implants from a single company, the Optetrak family (Exactech, Gainesville, FL, USA): a standard PS system, a HF system, and a new rounded box-reamer (RB) system. Secondly, we set out to further assess whether the newer RB with a cylindrical cutting tool would preserve more native bone.

Materials and Methods

CT scans of the femurs of 19 cadavers were obtained for analysis. Eleven males and nine females were used with a mean age of 54.32 ± 24.74 years and a range of 15 to 92 years.

The MIMICS software (Materialise, Leuven, Belgium) was used to make 3D models of the femurs based on density

as determined by Hounsfield Units (HU). Optetrak femoral component 3D models were provided by Exactech in three sizes (2, 3, and 4) and three designs (standard PS, HF, and RG). The senior author (GW) then virtually sized and oriented the femoral components (Fig. 1).

To ensure accuracy and reliability of the component, orientation measurements were adjusted and confirmed using Pro/ENGINEER Wildfire (Parametric Technology Corporation, Needham, MA). The goals of a 5° valgus distal femoral cut, a neutral or 0° mechanical axis, and 3° of component external rotation were achieved for all sizes.

Finally, Geomagic Studio (Geomagic Inc, Morrisville, NC) was used to perform a Boolean operation simulating the bone resection needed for both peripheral and box cuts for each set of instrumentation. This allowed calculation of the volume of resection in cubic millimeters as well as the distal femoral density in HU when correlated with the original CT scan (Fig. 2). A paired *t* test was used to compare the mean volume of bone resected as well as the post-resection density for each implant.

Results

Nine cadavers were sized to a size 4 femoral component. The newer BR design removed 8% less intercondylar bone than the PS design ($7,832 \pm 501$ vs. $8,547 \pm 377$ mm³, $p < 0.001$) and 28% less bone than the HF design ($7,832 \pm 501$ vs. $10,897 \pm 444$ mm³, $p < 0.001$) (Fig. 3). The average HU for size 4 femurs for BR design was 427 ± 72 (PS = 399 ± 69 , $p < 0.001$; HF = 379 ± 66 , $p < 0.001$) (Fig. 4).

Six cadavers were sized to a size 3 femoral component. The BR design removed 12% less intercondylar bone than the PS ($6,664 \pm 786$ vs. $7,516 \pm 648$ mm³, $p < 0.001$) and 27% less bone than the HF ($6,664 \pm 786$ vs. $9,078 \pm 713$ mm³, $p < 0.001$)

Fig. 2. Bone resection calculation using HU.

Fig. 3. Bone reduction (in cubic millimeter) by component size and design.

(Fig. 3). HU for size 3 femurs for the BR design was 452 ± 70 ($PS = 422 \pm 53$, $p < 0.1$; $HF = 410 \pm 59$, $p < 0.01$) (Fig. 4).

Four cadavers were sized to a size 2 femoral component. The BR design removed 5% less intercondylar bone than the PS ($5,730 \pm 552$ vs. $6,009 \pm 472$ mm³, $p < 0.01$) and 22% less bone than the HF ($5,730 \pm 552$ vs. $7,380 \pm 532$ mm³, $p < 0.001$) (Fig. 3). HU for size 2 femurs for the BR design was 430 ± 48 ($PS = 408 \pm 55$, $p < 0.01$; $HF = 385 \pm 56$, $p < 0.01$) (Fig. 4).

Discussion

Bone resection was reduced, and therefore bone density preserved, in all sizes when the BR design was used. The difference was statistically significant from the PS design and even more marked when compared to the HF design. Whether or not this translates into clinical significance is difficult to say, but theoretically, the preservation of bone is desirable given that it improves fixation, can serve as the

foundation for later reconstructions, and is likely important for avoiding rare intra-operative femoral condyle fractures [7]. Assuming the functional outcomes are equivalent, one should favor implants and instrumentation that minimize unnecessary bone resection.

The main advantage of our study over these previous ones is that patient cadavers and therefore true patient anatomy were used when measuring bone resection. Also, three different sizes were tested to ensure that variation in size did not alter the findings. This strength does come with limitations because an imaging study and corresponding computer models are being used to gauge bone resection without any bone cuts actually being made. This is felt to be a very accurate method but is not yet validated.

These findings should also be limited to the Optetrak models, as these were the only ones tested. This manufacturer consistency allowed better comparison within our study, but caution should be used when trying to extrapolate these

Fig. 4. Bone density (HU) by component size and design.

differences to other manufacturers that utilize reamer or conventional saw cut methods of preparing the intercondylar notch. Finally, we were able to easily reach statistical significance with our 19 cadaver specimens, but this still represents a relatively small number of test subjects.

Differences in intercondylar notch bone resection between PS total knee replacement systems have been demonstrated in the past by Haas and colleagues using a fast cast wax mold technique. Using 55 anatomic saw bones, 25 small adult size and 30 large, they compared the amount of resected bone between five different contemporary PS systems in 2000. They showed that Genesis II (Smith & Nephew, Memphis, TN, USA) and Optetrak (Exactech, Gainesville, FL, USA) removed significantly less bone in small anatomic saw bones compared with the PFC Sigma (Johnson & Johnson, New Brunswick, NJ, USA), Nex-Gen Legacy (Zimmer, Warsaw, IN, USA), and Insall-Burstein II (Zimmer, Warsaw, IN, USA) designs. Genesis II also removed significantly less bone in the large bones compared with the other four PS designs [4].

Our findings corroborate those presented by Angiboud and colleagues in 2010, after they used saw bones to assess the same three Optetrak designs (Logic with BR, PS, and HF). Using 30 distal femurs, they analyzed the amount of bone resection for size 3 femoral components by weighing the bone models both before and after cuts. Similar to our findings, the BR design resulted in significantly less bone loss than the PS and HF designs [2].

The newer BR design removes less bone from the intercondylar notch than the classic PS and HF designs in all sizes tested. The bone-conserving cuts incorporated into this newer implant design appear to preserve native bone without compromising design objectives.

Disclosures

Conflict of Interest: Timothy Wright, PhD, is a board member of the Knee Society and receives royalties from Orthopaedic Research Society and Mathys ABG, stock payments from Exactech, and research support from Synthes Spine, outside the work. Geoffrey Westrich, MD, is a board member of Eastern Orthopaedic Association and receives research support from Exactech and Stryker, outside the work. Luke Pugh, MD, FRCSC, Allison Ruel, BA, and Mark Gessell, MD, have declared that they have no conflict of interest. Joseph D. Lipman, MS is a paid consultant for Ivy Sport Medicine; employee of Hospital for Special Surgery; has received payment for manuscript preparation from Stryker; has the following patents: Posterior Stabilized Knee Prosthesis, Self-aligning knee prosthesis, Dual radius glenoid prosthetic component for total shoulder arthroplasty, Pelvic Positioner, Trochlear Clamp, Patella Resection Drill and

Prosthesis Implantation Device; has pending patents for Constrained Condylar Knee Device, Prosthetic Condylar Joints With Articulating Bearing Surfaces Having A Translating Contact Point During Rotation Thereof, Elbow Replacement Apparatus And Methods, Expanding Cannula And Retractor Device And Methods Of Use and External fixation devices and methods of use; receives royalties payment from Mathys Inc. and Ortho Development Corp; has received travel support for travel to meetings from Chinese Orthopaedic Association, outside the work.

Human/Animal Rights: This article does not contain any studies with human or animal subjects performed by any of the authors.

Informed Consent: N/A

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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