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Original research

Hemispherical and minimally invasive total hip reamers: a biomechanical analysis of use and design

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A B S T R A C T

Background: The purpose of this study was to determine the accuracy of used and new reamer systems for both hemispherical and minimally invasive (MIS) acetabular reamers.

Methods: New and used hemispherical and MIS acetabular reamers were tested on a computer numerical control machine to ream holes in special machinable wax blocks. Each reamer was tested 3 times in sizes 48 mm through 55 mm.

Results: The used reamers significantly underreamed by an average of 1.33 vs 0.28 mm compared to new reamers. Hemispherical reamers underreamed significantly more than MIS reamers, with a mean difference of 0.99 vs 0.63 mm, respectively. Used hemispherical reamers showed an average ream undersize of 1.61 vs 0.37 mm, compared to new hemispherical reamers. Used MIS reamers showed an average ream undersize of 1.06 vs 0.20 mm for the new MIS reamers.

Conclusions: For a manufacturer-specified reamer size, both hemispherical and MIS reamers underream. Newer reamers cut truer to expected values than used ones. MIS reamers performed more accurately than hemispherical reamers. Used acetabular reamer systems may negatively affect the sizing of prepared acetabular beds; therefore, awareness of this potential inaccuracy should be considered when performing total hip arthroplasty.

Introduction

Total hip arthroplasty is one of the most commonly performed orthopaedic procedures worldwide. Modern cementless implantation techniques rely on the accurate press fit of components to obtain initial stability and to allow for bony ingrowth. Cementless acetabular components are typically implanted with 1-3 mm of press fit [1,2]. The diametrical mismatch between the reamed acetabulum and a relatively oversized prosthetic component allow for the tight, initial screw-less fixation known as a "press fit." Any unexpected alteration in the size of reamed acetabulum can compromise the surgeon's intended press fit and lead to poor results [3,4]. Underreaming can lead to loosening, as the implant fails to seat properly or in extreme circumstances may create an acetabular fracture [3,4]. Overreaming can lead to acetabular loosening via excessive micromotion and failure to obtain bony ingrowth.

Accurate press fit requires the manufacturer's stated reamer size to correlate closely with the actual size of the hole reamed [5], thereby allowing the surgeon to make the correct intraoperative decisions regarding implant size to obtain the desired press fit. Manufacturing tolerances of the reamers, the quality and wear of instruments, acetabular bone stock, and surgical technique all impact the degree of press fit obtainable at surgery. Previous studies have attempted to address these factors using cadaver pelves, but variability of bone quality using these specimens adds inconsistency to accurate measurements of acetabular reamers. In addition, the use of factory new reamers in many of these studies fails to reproduce the intraoperative experience that surgeons can expect. Various methods of measurements

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have included sophisticated 3-dimensional digitizing systems, computed tomography scans, mold and cast methods with no clear standardized measurement tool [6-9]. Thus, many variables may affect press fit, and no single study has yet been conducted to elucidate the role of the reamer itself in a standardized fashion.

Acetabular reamer systems typically consist of a modular hemispherical cutting shell and a compatible extension handle that can be attached to a power drill. Recently, reamers with smaller volume hemispherical shells have been developed to enable reaming through a smaller hole, so called minimally invasive (MIS) reamers. The purpose of this study was to answer 3 questions:

1. Is there a difference between the hemispherical and MIS reamers in terms of accuracy and the quality of the reamed surface?
2. What is the difference between new and used reamers in terms of accuracy and quality of the reamed surface?
3. Does the reamed cavity match the manufacturer's stated size and sphericity?

We hypothesized that multiple uses of used, off-the-shelf reamers would cause them to ream a hole smaller than the expected size compared to new reamers. We did not expect a difference in ream accuracy due to head design between the standard fully hemispherical and cutout MIS reamers.

Material and methods

Used acetabular reamers were studied and compared to their brand new counterparts. We compared 2 separate reamer head designs: partially hemispherical MIS surgery sets, and fully hemispherical "conventional" (standard) sets (Fig. 1). The MIS sets were manufactured by Precimed (MPS Precimed, Switzerland). The conventional sets were manufactured by Symmetry Medical (acquired by Tecomet, Warsaw, IN). Both reamer sets were distributed by Zimmer (Warsaw, IN). We compared the accuracy of all used and new reamers to both each other and to the manufacturer's specified size. All used sets tested were taken from our current hospital inventory. The surgeries in which these reamers were used were reviewed. The used hemispherical and MIS reamers had been in service for differing amounts of time. Based on our hospital records, hemispherical reamers were in service for approximately 2 years and were processed about 48 times. The MIS reamers had been in service for about 1 year and were processed about 40 times.

We tested reamers sized from 48 mm through 55 mm in 1-mm increments, as these were the most commonly used sizes at our institution. The reamer test consisted of using an industrial-grade Cincinnati Milacron computer numerical control machine (Cincinnati Machines, Cincinnati, OH) to drill a hemispherical hole into a machinable wax block (Freeman Manufacturing and Supply Company, Avon, OH). Machinable wax blocks were selected, as they allowed for a reproducible test substrate. The blocks are a constant size and density, quick to machine, require no coolant to use, are easy on tooling, and are recyclable. The material allows for excellent detail and resolution.

The machinable wax blocks were sequentially placed into a machinist vice. The computer numerical control machine was programmed to perform the trial ream at a preselected rotational rate of 350 rpm and a Z-axis advancement rate of 7 inches per minute. The terminal depth was selected to ensure the ream depth exceeded the proximal lip of the reamer. The trial was performed 3 times for each reamer (Fig. 2).

After all the blocks were reamed, they were inspected and measured. All reamed holes were assessed for edge quality and surface finish. The researcher was blinded to actual reamer size during all measurements. All reamer cavities were blindly measured using a Brown & Sharpe MicroVal PFx (Hexagon Manufacturing Intelligence, North Kingstown, RI) coordinate measuring machine with an accuracy exceeding ± 0.005 mm. The measurement depth was fixed at 0.5 mm below the surface of the block. A minimum of 8 data points were collected for each reamed hole by manually touching the data probe in sequential locations around the perimeter (Fig. 3). The coordinate measuring machine has a pressure-sensitive stylus that electronically triggers the machine to record the data point in 3-dimensional space when the probe contacts the wax block. The built-in computerized software was used to calculate the "best-fit" circle diameter. The diameter and sphericity of each reamed hole were recorded.

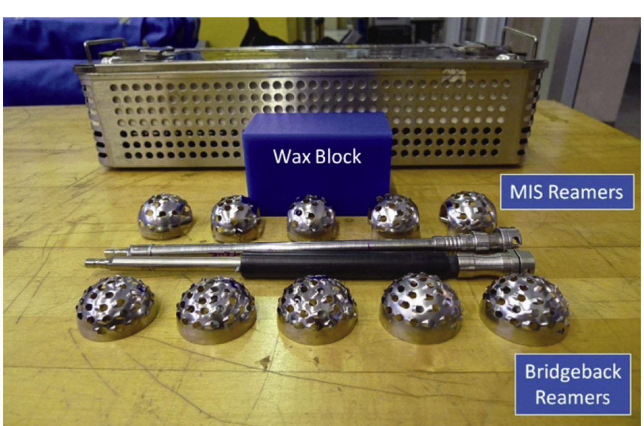

Figure 1. MIS and conventional hemispherical Bridgeback acetabular reamers. The conventional reamers in the foreground have a hemispherical shell. The minimally invasive (MIS) reamers in the background are not full hemispheres.

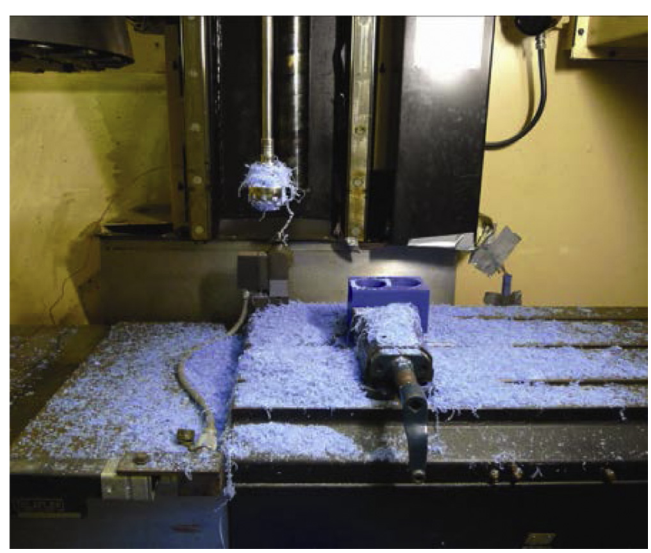

Figure 2. Cincinnati Milacron computer numerical control machine testing setup. The computer numerical control machine holds the handle which is attached to the tested reamer. The reamed cavity in the wax block is shown as well. All trials are performed in this automated manner.

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