Broach Handle Offset and Impact Acceleration During Femoral Preparation for Total Hip Arthroplasty

Stephen Kayiaros MD, Lee Eric Rubin MD*, Alison Biercevicz PhD*,
Richard Limbird MD*, David Paller PhD**

Investigation was performed at the Rhode Island Hospital Orthopedic Foundation Laboratory, Providence, Rhode Island. At the time of the investigation, all authors were members of the Department of Orthopaedic Surgery within the Warren Alpert Medical School of Brown University.

Introduction

The direct anterior approach for minimally invasive total hip arthroplasty has become increasingly popular. [1] Preparation of the femoral canal using this approach can be technically challenging. Instrumentation of the femur involves a posteromedial capsular release, extension and external rotation of the operative leg and elevation of the femur anteriorly. Curved offset femoral broaches have been specifically designed to safely prepare the femoral canal through this single incision. [2,3] The objective of this study was to evaluate the amount of impact force generated and thus transferred to the proximal femur using a variety of curved single-offset broach handles compared to a traditional straight handled broach handle. The amount of acceleration transmitted through the femur could then be correlated to the number of impacts on the broach handle and thus operative time as well as trauma to the surrounding tissue.

Methods

A total of four Corail (DePuy, Raynham, MA) broach handles were tested for impact acceleration magnitude; solid straight handle (SS), medium curved single-offset with cannulated handle (MC), extended curved single-offset with solid handle (ES)

Figure 1: Schematic of four broach handles used during impact testing: A: SS, B: MC, C: EC and D: ES

and extended curved single-offset with cannulated handle (EC) (Figure 1). Broach insertions were simulated with the aid of a custom hinged impact assembly. For each trial a 1.1 kg mallet impacted the head

* Department of Orthopaedic Surgery
Warren Alpert Medical School
Brown University

of the broach handle from a height of 75mm. The impact assembly allowed investigators to strike the broach handle at a constant velocity for each trial. A Sawbones (Pacific Research Lab, Vashon, WA) proximal femur was embedded in a Shore A 10 hardness Silicon Rubber (Smooth On Easton, PA). The silicon rubber simulated the soft tissue surrounding the femur. A PCB tri-axial accelerometer was rigidly mounted on the base of the Sawbones femur to record impact acceleration (g). Data was collected digitally using custom LabView software at an acquisition rate of 20 kilohertz.

A total of two conditions were tested for each broach handle; partially and fully seated. For the partially seated condition, a size 13 broach was initially inserted into the proximal femur to simulate preparation of the femoral canal. A total of 40 impacts were recorded for each broach handle. The impact order was randomized into four trials of ten impacts for each broach handle. Following the completion of the initial tests, a size 14 broach was inserted to simulate a fully seated trial implant. Similar to the first test condition a total of 40 impacts were recorded for each handle in random order. Impact force was calculated using Newton's second law: $F = m \cdot a$. In this case, acceleration was the maximum recorded value from the accelerometer and the mass was the total mass of the impact hammer and broach handle.

A one-way ANOVA with the Tukey method for post-hoc analysis was used to determine if the mean impact force was significantly different between different broach handles. Additionally, a two way ANOVA was performed to determine if significant differences existed between impact force and condition (partially seated versus fully) seated. A P-value of 0.05 was defined a priori and adjusted for multiple comparisons.

Results

For the experiments with the fully seated broach, the mean impact force in the SS was 231.4 ± 10.4 N. The mean impact force in the MC, ES and EC was 206.3 ± 12.8 N, 206.2 ± 13.4 N and 207.2 ± 16.5 N

Figure 2: Summary of impact test results.

respectively. The mean acceleration of the SS was significantly higher than the ES ($p < 0.001$), EC ($p < 0.001$) and MC ($p < 0.001$). Figure 2 shows a summary of test results.

For the partially seated experiments, the mean impact force in the SS was 162.4 ± 12.6 N. The mean impact force in the MC, ES, and EC was 135.6 ± 13.4 N, 134.3 ± 16.5 N and 136.6 ± 18.4 N respectively. Results from the partially seated testing failed an equal variance test. Therefore, a Kruskal-Wallis one way ANOVA on ranks was performed. The mean impact force of the SS was significantly higher than the ES ($p < 0.05$), EC ($p < 0.05$) and MC ($p < 0.05$). Within all broaches, the impacted force in the seated condition was significantly higher compared to the impact force of the partially seated broaches, 212.8 ± 17.1 N versus 140.5 ± 19.8 N ($p < 0.001$).

Discussion

Clinical experience with the direct anterior approach for total hip arthroplasty suggests the curved offset broach handle may not allow the surgeon to properly seat the final femoral trial. This is most likely due to the large moment arm created by the bend in the offset handle. It can sometimes be necessary to switch to the straight handle to fully broach the femur, or utilize a straight impactor to seat the final prosthesis.

For all tests performed, the mean impact acceleration was highest using the traditional straight handle broach. Mean impact accelerations for all single-offset broach handles (including the MC, ES, and

EC) were significantly lower than the solid straight handle (SS). As expected, the mean impact acceleration for the MC was significantly higher than both extended curved offset broaches. It may be concluded that while curved offset broach handles may help to facilitate femoral preparation while utilizing a small direct anterior incision, the surgeon must be critical to assess that final implant position is correct and should employ a straight handle broach or seating impactor when appropriate.

There were several limitations to this study. A Sawbones model was used to approximate bone and soft tissue properties. The setup for generating impact strikes with the mallet on the broaches did not

exactly replicate intraoperative conditions of proximal femoral preparation. However the results did provide data for each broach that was directly comparable and statistically significant. Further studies using a cadaveric model and an impact load cell would provide more information.

References:

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