Evaluation of Intraoperative Impaction Energy upon Insertion of a Femoral Knee Component on a Cadaver

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INTRODUCTION

Evaluation of intraoperative impactions during insertion of the femoral knee component will help in the design of performance testing of the component as well as provide better control of surgical approach.

The purpose of this study was to evaluate impact energy applied on the femoral knee component during insertion. Calculations were performed which combined the impact force curve and speed to determine impact energy.

MATERIALS AND METHODS

Impact energy was calculated using an Impulse-Velocity (IV) method which treats the mass of the hammer as an unknown and considers it as "an instantaneous effective mass of the surgeon's arm and mallet combination immediately prior to impact."[1,2] Speed was calculated from the x, y, and z components of the hammer's velocity immediately prior to impact.

Video was collected with a high speed camera system (Del Imaging Systems, Cheshire, CT) at 500 frames per second of the surgical application and the impact speed was calculated with motion analysis software (ProAnalyst, Xcitex, Inc., Cambridge, MA). ProAnalyst plotted a speed vs. time plot, and the impact speed was determined as the speed immediately before impact.

A modified hammer with a 50kN load cell using Bioware software (Kistler Instruments, Amherst, NY) collected force data at 30,000 hertz during impact and provided a force vs. time plot. Impulse was calculated as the area under the force curve. This area was determined using the trapezoidal method.

One experienced surgeon performed insertion with a custom hammer of a non-cemented femoral knee component into a cadaveric leg with a femoral impactor.

Figure 1. Photo of high speed camera system.

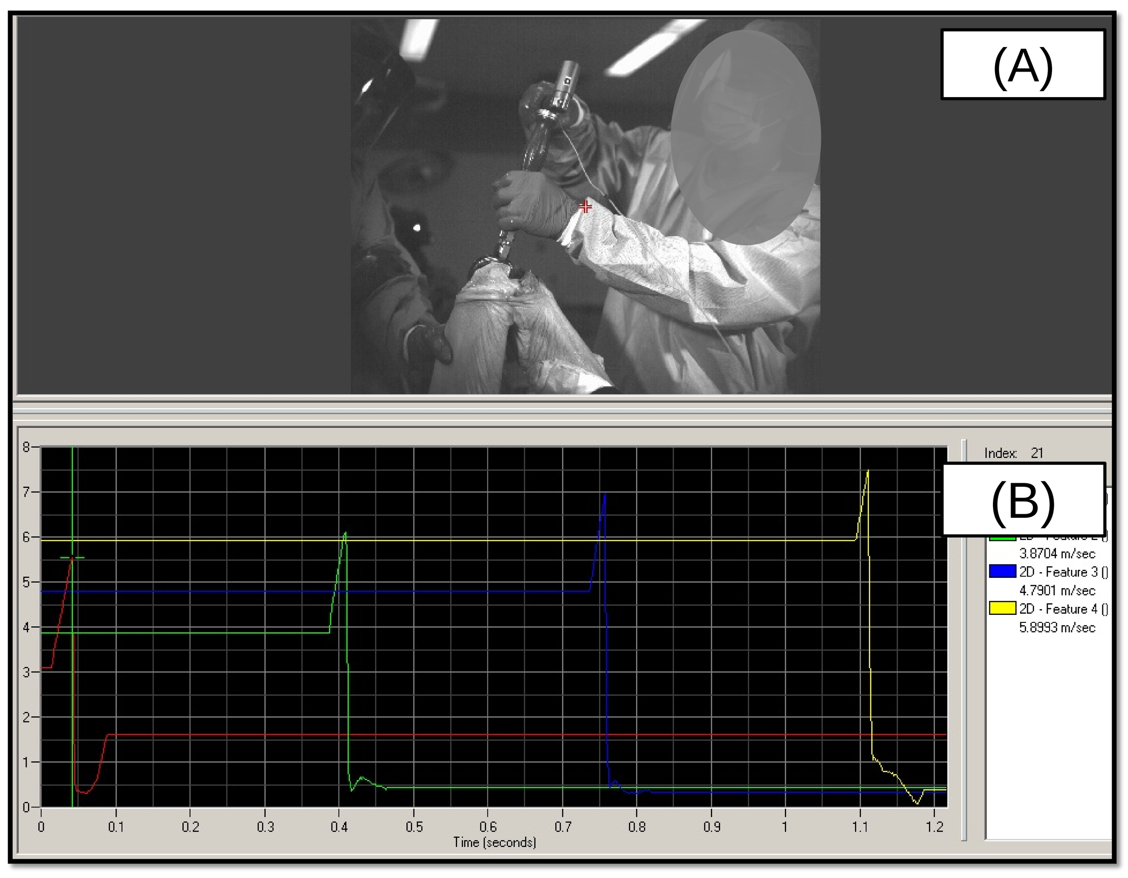

Figure 2. (A) Image of a surgeon seating the femoral component into a cadaveric knee. (B) A representative Speed vs Time graph of the hammer speed tracked with ProAnalyst software.

RESULTS

The surgeon made 26 impacts to fully seat the component onto the femur. The average impact speed recorded for the 26 impacts was 6.01m/s ± 1.20m/s. The average impact force measured was 15,781N ± 4,555N. This provided an average impact energy of 5.66J ± 2.05J.

To verify the accuracy of speed values obtained by the ProAnalyst system, the system was validated by comparing it to speed values obtained using a fiber optic sensors system with a PicoScope data acquisition software (Pico Technology, Cambridgeshire, UK) at a collection rate of 500,000 hertz. The device used fiber optic sensors at a specific distance to measure the time between triggers of each sensor. The results provided a distance per unit time value that were compared to the ProAnalyst system measurement of the same motion. The variation difference between both systems was less than 3%.

# of Impacts	26
Average Impact Speed (m/s) ± St. Dev.	6.01 ± 1.20
Average of the Maximum Impact Force (N) ± St. Dev.	15,781 ± 4,555
Average Energy (J) ± St. Dev.	5.66 ± 2.05

Table 1. Summary results of impact speed for femoral knee component onto a cadaver specimen.

DISCUSSION

The purpose of this study was to evaluate impaction of the femoral knee component during insertion. This was done by utilizing a high speed camera system, ProAnalyst, and a modified hammer. There were 26 impacts with an average speed of 6.01m/s, average of the maximum impact force of 15,781N, which provided an impact energy of 5.66J.

This method proved successful as impact speed, impact force, and impact energy was able to be captured during insertion. The variation of the impact energies between impacts can be attributed to the process of fully seating the femoral component, compliance of the cadaveric specimen, and surgical approach. It was seen that the compliance of the support material and the movement of the femoral knee component itself, had a large effect on the impact energy.

SIGNIFICANCE

Evaluation of clinically relevant impact parameters will be integral to design of orthopaedic device tests and ultimately design of these devices.

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REFERENCES

1. Internal Technical Report. RD-13-053. June, 2013.
2. Maharaj, G.R. et al. ASTM STP 1178, Philadelphia, Pa. 1193. Pp.98-108.