Validation of a Novel Technique to Measure Surgical Strike Speed Using a High Speed Camera System

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INTRODUCTION

Orthopaedic manufacturers use impaction tests to develop and test surgical instruments. These impaction tests are meant to simulate surgical use; however impaction technique varies between surgeons. In addition, there are limited publications that quantify the speed at which an instrument gets impacted by the surgeon, which, in turn, can lead to improper or inconsistent testing of products.

This work demonstrates a method utilizing a high speed camera system to measure the speed of a hammer strike on orthopaedic products. Analysis shows validation of the system by verifying accuracy of the data collection and analysis method. The use of this tool for data collection will ultimately help in the calculation of energy for product impaction tests. [2].

MATERIALS AND METHODS

A 3D high-speed camera system (Del Imaging Systems, Cheshire, CT) was utilized to collect the video stream from a validation test with a gravity driven mechanism (n-25 each). The video was high definition at 1280x1024 resolution and 500 frames per second. The camera video was analyzed in 2D and 3D with ProAnalyst 3-D Professional Edition software (Xcitex, Cambridge, MA) to convert the travel of a gravity driven weight into a speed based on discrete differentiation analysis. The validation entailed measuring the motion of the objects path based on image pixels and a calibration device was used to define this pixel per distance value. Expected displacements were input into the Newtonian equation $V_{final} = V_{initial} + 2*acceleration*displacement$ to find the expected velocity (speed) final.

Figure 1. Photo of high speed camera system.

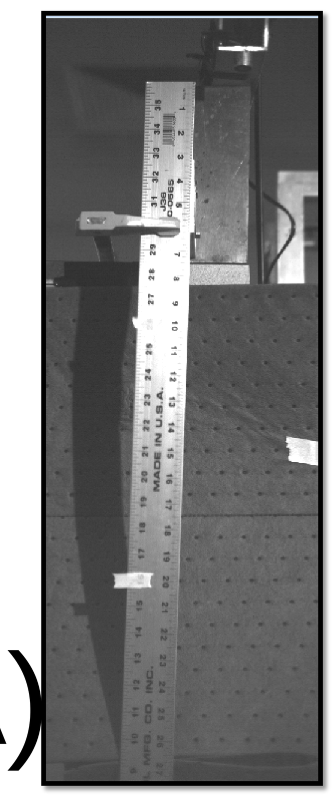
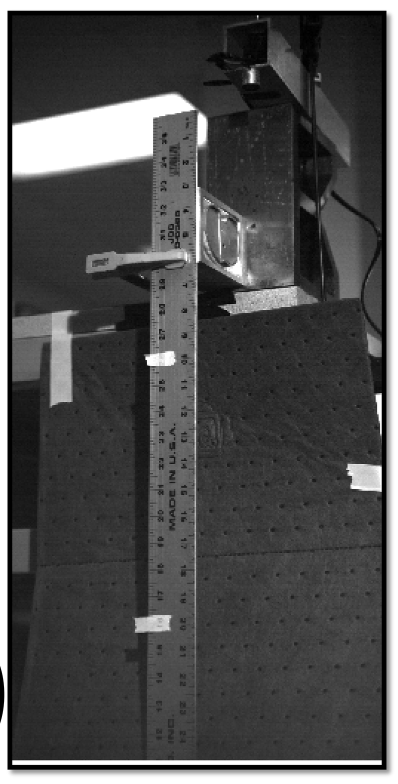
(A)  (B) 

Figure 2. Photo of drop weight in position with (A) as main camera for 1 camera 2D analysis and, (B) as secondary camera for 3D analysis.

RESULTS

The distance from the zero position to 25.4cm, 50.8cm, and 76.2cm had corresponding theoretical speeds of 2.23m/s, 3.16m/s, and 3.87m/s, respectively. The speed values measured from the 1 camera system (2D) were 2.20m/s for the 25.4cm height representing a 1.22% difference from theoretical, 3.14m/s at 50.8cm for a 0.53% difference, and 3.91m/s at 76.2cm for a 0.95% difference. The speed values measured from the 2 camera system (3D) were 2.22m/s at 25.4cm representing a 0.66% difference from theoretical, 3.12m/s at 50.8cm for a 1.20% difference, and 3.87m/s at 76.2cm for a 0.06% difference. For both camera systems, the measured speed for each height was never more than 1.22% different from the theoretical speed value.

An historic publication [1] showed surgeon impact speed between 1.7 and 5.5m/s with our speed measurements within the range of surgical use based on this publication.

The displacement measurements of a non-moving object measured in 2D had less variation providing a variation of only 0.03%.

1 Camera 2D		
Displacement for Measurement (cm)	Expected Speed (m/s)	ProAnalyst Speed (m/s)
25.4	2.23	2.20 ± 0.02
50.8	3.16	3.14 ± 0.02
76.2	3.87	3.91 ± 0.03
2 Camera 3D		
Displacement for Measurement (cm)	Expected Speed (m/s)	ProAnalyst Speed (m/s)
25.4	2.23	2.22 ± 0.02
50.8	3.16	3.12 ± 0.02
76.2	3.87	3.87 ± 0.02
	1 Camera Displacement	
	Caliper Displacement (cm)	Measured Displacement (cm)
	15.24	15.24 ± 0.01

Table 1. Speed value results of 1 and 2 camera analysis for specific drop distances and camera displacement measurements.

DISCUSSION

We show that the variation from theoretical speed is less than 1.22% and the variation of displacement from a known standard is 0.03%. The high speed camera system has been shown to provide accuracy and therefore would be a viable tool to measure orthopaedic surgical strike speed.

The use of a high speed camera system for measuring cadaveric surgical simulations has been published by our group in the past [3, 4] with these results demonstrating validity of the system to theoretically calculated values of speed and displacement. It will be a valuable tool for gaining knowledge on impact mechanics to define parameters for testing of orthopaedic products. Calculations implementing impaction speed, and impulse parameters measured during surgical application will be used to define the energy values to test products, avoiding under- or over-testing.

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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