OSTEOTOMY STANDARDIZATION FOR BIOMECHANICAL TESTING OF FEMORAL NECK FRACTURES

Stephen Hunt MD, P.Eng, Andrew Murphy B.Eng.
Memorial University of Newfoundland

INTRODUCTION

Biomechanical testing of orthopedic implants is often preformed upon synthetic bone substitutes because it offers a reasonable surrogate to human bone [1]. It allows the investigators to highlight the subtle mechanical differences between orthopedic constructs without the potentially confounding effect of human bone variability. Despite the tremendous scope of biomechanical research there is very little standardization of biomechanical testing with respect to sample preparation. Fractures are often modeled with osteotomies (saw cuts through the bone) to provide consistent and repeatable conditions to test different orthopedic hardware configurations.

Clinically, fractures are grouped qualitatively into fracture patterns and are classified by schematic diagrams or general dimensional groupings. Consequently, there is considerable inter-laboratory variability of osteotomies when creating these simulated fractures. Individual researchers correctly interpret the fracture classifications however tolerances – if listed – tend to be very large, and very different models can be created despite adhering correctly to the fracture classification.

We propose that standardization of fracture models for biomechanical testing will help researchers compare findings between laboratories and experiments, make it easier to communicate fracture geometry, and allow orthopedic constructs to be tested against a known standard. Ultimately we would like to improve researchers confidence in biomechanical testing. Specifically, we have taken commercially available synthetic femurs, defined anatomic landmarks to be used for dimensioning, and created osteotomies using a purpose built jig. We have included dimensioned drawings of the jig with the intention that other laboratories can use this reference system for sample preparation.

METHODS

Synthetic full-length femurs were used for this study. The samples were 4th generation Sawbones (Pacific Research Laboratories Inc, Vashon WA) which are a composite bones that are commonly used and have been validated for orthopedic biomechanical testing [2].

Jig Design

A 3-D surface profile of the synthetic bone was imported into a solid modeling software package (Solidworks 3D CAD 2011, Solidworks Corp., Concord MA). Commonly referenced anatomical angles were compiled from published literature [3]. The 3D model of the femur was dimensionally validated against these values. Anatomical and biomechanical axes were defined as listed in Table 1.

Description	**Reference Value**	**Measured Value**
MNSA – Medial Neck Shaft Angle	130^0 (124^0-136^0)	125^0
MPFA – Medial Proximal Femoral Angle	84^0 (80^0-89^0)	83^0
aLDFA - anatomic Lateral Distal Femoral Angle	81^0 (79^0 -83^0)	83^0

Table 1

Surface landmark for definition of the anatomic and biomechanical axes are listed in Table 2.

Reference	Anatomical Reference
Biomechanical Axis	Starting point: Greater trochanter at flare along parting line Exit Point: Center of hole at superolateral aspect of intercondylar notch
Lateral Condyle	Most distal aspect of lateral femoral condyle in the axial plane
Greater Trochanter	Most lateral aspect of greater trochanter in the sagittal plane
Lesser Trochanter	Most posterior aspect of lesser trochanter in the coronal plane.

Table 2

Once landmarks and biomechanical axes were defined, a custom jig was modeled and dimensioned drawings were produced (Figure 1).

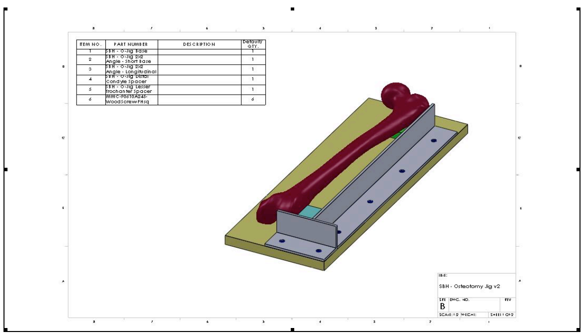

Figure 1 – Dimensioned assembly drawings

A full-scale prototype of the jig was manufactured using materials listed on the drawing (Figure 2). All femurs were imaged with an x-ray before being cut.

Figure 2 – Jig with sample femur

<u>Femoral Osteotomy</u>

For the purposes of this study a Pauwel's III vertical femoral neck fracture was modeled. Pauwels III fractures are defined as fractures that make an angle of 50^0-90^0 from horizontal. Clinically they are defined as fractures that are primarily loaded in shear. Precisely, we defined a vertical femoral neck fracture to be parallel to the anatomic axis of the femur. This represents clinically observed fractures in young trauma patients with strong bone [4]. Clincally, vertical neck fractures are observed to exit the femoral neck just proximal to the lesser trochanter [5].

Osteotomies were created using a sliding compound mitre saw (Hiatachi C10FSH, Hitachi Koki Asia Co, Hong Kong) with a 10" saw blade (LU77M010, Freude, NC) (Figure 3).

Figure 3 – Femur undergoing femoral neck osteotomy

A Pauwell's III (86 degree) femoral neck fracture was created [6]. Using the jig that was constructed the compound mitre saw must be angled 6 degrees clockwise to align with the anatomic axis. The resultant angle of the osteotomy is 86 degrees from horizontal. The jig was marked and positioned such that the saw kerf was centered distance of 90.5mm medial from the topmost edge of the jig. This distance was calculated to ensure that the femoral neck was osteotomized just proximal to the lesser trochanter. The jig was firmly affixed to the saw table using clamps. The femur was positioned on the jig and clamped in place.

Care was taken to ensure that the synthetic femurs were not deformed by the clamping process. The mitre saw depth was set allow a complete cut of the femoral neck without cutting the jig. The femoral neck cut was completed without difficulty. All femurs were x-rayed for a second time following being cut.

Dimensional Verification

Radiographs of the femurs taken before and after the cutting operations were analyzed (Figure 4). The femoral neck osteotomy angles were measured using x-ray viewing software (Centricity, GE HealthCare, UK)

Figure 4 – Dimensional Verification of Osteotomy

RESULTS

All models osteotomized using this jig were accurate to within +/- 0.5 degrees as measured on Xray. Direct measurement of the samples with a digital caliper revealed all osetotomies to be accurate to within +/- 0.2mm when measured from lateral cortex of the greater trochanter

Femur	**Deviation from Anatomic Axis**	**Distance from lateral trochanter (Calculated-measured)**
1	0.50	0.1
2	0.20	0.0
3	0.50	0.3

Table 3

DISCUSSION

Using a 3D solid model was very useful in creating a dimensionally accurate osteotomy jig. The tolerances of 0.4 degrees and 0.2mm are well within the required range for most biomechanical testing. The higher variability in the angular measurements can be attributed to projection error and the limitations of making precise measurements from x-rays

This jig has been developed for a single commercial synthetic bone product. It has not been tested on other commercial products and is not intended to be used with other manufacturers products. If the synthetic bone manufacturing process changes then modification of the jig may be necessary. As of the date of publication of this article – there have been no such changes.

The jig was no configured to create comminution. Clinically, fracture comminution is commonly observed and has a significant effect upon stability. Modification of the osteotomy to model comminution is an opportunity for future research.

We hope that other engineers will precisely describe their sample preparation methods so that similar protocols can be developed for preparation of biomechanical samples.

DISCLOSURE

No financial interests to disclose. Pacific Research Laboratories Inc. provided the synthetic bone samples for this study

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