THE BIOMECHANICAL EVALUATION OF PLATES USED FOR THE INTERNAL FIXATION OF DISTAL FEMUR FRACTURES

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Introduction: Internal fixation of distal femur fractures has been accepted over non-operative treatment, yet the choice of implant is still debated. Stabilization of any fracture contributes to fracture union, early pain-free weight bearing, and optimal patient outcome. Newer implants have been designed to provide increased stability relative to those products currently in use. The purpose of this study was to compare five different distal femoral plate types of fixation under both axial and torsional loading to determine the stiffness of each construct. The hypothesis of this study was that the newer plates with locking mechanisms for the screws to the plate, and plates with an array of distal points of screw placement would have mechanical properties greater than the DCS plate.

Methods: Five different distal femoral plating systems were tested: the LISS Plate (Synthes-USA, Paoli, PA), the condylar buttress plate (CBP, Zimmer Inc., Warsaw, IN), the perlock plate (PLP, Depuy-Ace Inc., Warsaw, IN), the locking condylar plate (LCP, Synthes-USA, Paoli, PA) and the dynamic condylar screw plate (DCS, Synthes-USA, Paoli, PA). The DCS plate has been referred to in the literature as the gold standard for mechanical testing. The DCS plate design is a linear construct with 2 to 3 distal points of screw placement distally and supports the fracture as a fixed angled device in the coronal plane. The LISS and CBP do not contain any type of locking screw distally and does not support the fracture as a fixed angle device. The PLP and LCP each have locking screws which are designed to convert the fixation to a fixed angle type of device. Each plate was mounted on biomechanical synthetic composite femur bones (Sawbones, Inc) using standard implantation techniques. A 1 centimeter supracondylar gap osteotomy was created 6 cm proximal to the femoral condyles. This served to standardize the fracture modeling for all specimens. Displacement transducers (LVDT) were attached adjacent to the osteotomy to record the change in the osteotomy space during axial loading. Axial and rotational displacements were tested on a servohydraulic materials testing machine (MTS 858), and on a custom designed torsional testing system. Testing was not done to plate failure. Axial loading was carried out to 700N at a rate of 10 N/sec, while torque was applied to a maximum of 22 Nm at a rate of 3 Nm/sec. Each plate-femur construct was tested sequentially three times each in axial and torsional loads. The data was collected and a mean value was calculated for each testing series. At the end of one series of axial and torsional testing the implants were removed and re-implanted on new sawbones. The testing was repeated in this fashion for a total of six times. Each type of fixation was compared to the others using a student’s t-test of different means.

Results: The slope of force versus linear displacement and force versus angular displacement was calculated for the axial and torsional testing respectively. The toe region of all graphs was curvilinear. This was attributed to subclinical motion between the plate and sawbone. A consistently linear region for the torsion graphs was noted between 5 and 17 Nm. The slope of this region was calculated and compared between plates. See figure 1. The slope of the axial data was also calculated after the end of the curvilinear toe region. Figure 2 is the slope data from their initial linear region of the graphs starting from 30 Newtons and through 100 Newtons. The axial slopes were calculated and compared for each sequential 100 Newton region of the graphs. In all regions of the graph of force versus displacement the order of stiffness between the plates (CBP stiffest, PLP least stiff) remained the same as the 30-100 Newton slope data (figures not shown.). Within each particular type of plate the slope values decreased as the amount of axial load increased. Meaning the greatest stiffness for all plates were noted in the initial loading zone and steadily decreased as the loads reached 700 Newtons.

The stainless steal constructs include the DCS, CBP, and ICP. Titanium constructs include the LISS and PLP. Not surprisingly the stainless steal constructs were stiffer than the titanium plates. The LISS plate is over twice the thickness of the PLP and this was evident in the testing data. Axial stiffness was greatest for the CBP and least for the PLP. The CBP demonstrated the greatest torsional strength. The DCS, LISS and the LCP were similar in torsion, and the PLP was the least resistant to torsion. See figures 1 and 2.

Discussion: Newer plates with multiple distal screw holes and locking mechanisms between the plate and screws compare favorably to the DCS plate. Only the Zimmer CBP out performed the DCS plate. Interestingly, the screws do not lock to this plate. It is the stouter of the five plates which may have a clinical impact in terms of wound closure and patient satisfaction secondary to potential retained hardware irritation.

The new Synthes plate with locking mechanisms for the screws has been reported to be most advantageous for osteoporotic bone. This was not a component of this study. Despite the poorer performance of the LCP in this study using composite femur bones, the LCP may ultimately out perform all other available plates in the osteoporotic setting.

The torsional and axial plate stiffness properties are important in providing fracture stability. A plate with little mechanical strength may fail before bony union. A plate with too much stiffness may in theory prevent all motion at the fracture site and ultimately hinder healing. The ideal balance between plate flexibility and stiffness is still unknown. The Zimmer plate could in clinical application actually be too stiff for bony healing.

One of the testing limitations in this study was the difficulty in maintaining a true unidirectional axial load. The point of loading was through the femoral head mimicking the point of contact between the femoral head and acetabulum in vivo. Pillow blocks were added to the MTS testing setup to keep the system unconstrained when each specimen was axial loaded and for the less stiff constructs significant displacements made loading difficult. For the less stiff plates it was difficult to reach 700N loads because of deformation of the plate at the level of the osteotomy.

Conclusions: Three of the four newer supracondylar plates compare favorably to the Synthes DCS plate. Only the Depuy-Ace plate performed significantly below the other plates. The Depuy-Ace plate reported in this study has been replaced by a second generation Depuy-Ace perlock plate. This newer plate was not available for testing during this study. Future studies would include testing the plates to failure, possibly a cyclic testing model, and possibly an animal model. A prospective randomized clinical trial would also provide valuable in vivo data.