Reconstruction of large segmental defects at the femur: how does reconstruction method affect mechanical properties? A biomechanical analysis

Yazan Kadkoy, Gregory James Schneider, Joseph Anthony Ippolito, Thomas Philip Helbig, Jonathan Rene Lopez, David Paglia, Joseph Benevenia[1]
[1]New Jersey Medical School

INTRODUCTION: Reconstructive options of large intercalary defects at the femur following resection have historically included massive allograft secured with plate and screw fixation. Limitations of allograft reconstruction include weightbearing restrictions, infection risk, and mechanical failure. Mechanical properties of allograft are weakened by processing that devitalizes tissue, increasing fracture risk and diminishing osteoinductive capabilities associated with union and prevention of resorption. Recent alternative options for segmental bone defects have included intramedullary (IM) fixation as with IM nailing and metal intercallary endoprosthesis. Such methods are attractive in that they allow for immediate weight bearing and shorter length of stay in the hospital, however they have been shown to have poor torsional stability. Newer novel devices for intramedullary fixation included photodynamic bone stabilization systems (PBSS). This system employs a balloon to inject a polymer which fills the entire intramedullary space and hardens allowing for greater fixation of the IM canal. Despite the large number of reconstruction methods, there has yet to be a biomechanical study assessing these fixation methods at the femur.

METHODS:

In a preliminary study, we compared the biomechanical properties of 30 paired human cadaveric femurs in which a 7 cm segmental defect was reconstructed. One femur was reconstructed using a standard of with bulk allograft fixed by a double plate construct (15). The remaining femora were repaired with either a intramedullary endoprosthesis (5), an IM nail and a single plate (5) or a PBSS with a single plate(5). The endoprosthesis used is a Ti_6Al_4V cylinder that is fixed in the bone defect by proximal and distal cemented intramedullary rods. The bulk allograft was fixed within the defect using a 11 hole 4.5mm plate and 10 hole 4.5 mm narrow plate (90-90 double plate). IM nail group was fixed with a lateral entry femoral nail and a lateral 11 hole 4.5mm plate. Nail diameter was determined by audible chatter during reaming and all femur in the IM group were reamed to 1.5-2mm above the nail diameter used. The PBSS group was fixed with a 280 mm balloon filled to a maximum of 17 mm] as well as a lateral 11 hole 4.5mm plate. Femora in the PBSS group were reamed to 1.5-2mm above audible chatter. Matched pair femurs were tested by cyclical medial-lateral and anterior-posterior bending (300-800N), cyclical axial compression (300-800N), cyclical torsion (-6Nm to +6Nm), and internal rotation to failure (Figure 1). Normalized data from paired match femora were compared with ANOVA.

RESULTS: When paired samples were tested in anterior-posterior bending, the IDSF displaced a smaller distance over 100 cycles of creep ($p=0.037$) than the double plate construct and had a higher elastic stiffness ($p=0.002$). When comparing the IM nail and PBSS groups, there were no statistical differences detected. The medial-lateral bending parameters were similar between the double plate construct and the IDSF and IM nail group. When compared to the PBSS group, the double plate had a smaller change in displacement per cycle ($p=0.032$). In axial compression, there were no differences detected in displacement, stiffness or observed creep for all constructs. In cyclic torsion, the IDSF had a smaller angular displacement than the double plate ($p=0.03$) construct. When samples were tested to failure in torsion, the IDSF also had a higher torsional rigidity ($p=0.005$) and a smaller angular displacement ($p=0.03$) than the double plate construct. The double plate was shown to have a higher torsional rigidity when compared to the IM group ($p=0.027$), but not the PBSS group.

DISCUSSION AND CONCLUSION: Preliminary data suggests that intercalary endoprosthetic reconstruction provides superior stability in bending and torsion compared to intercalary allograft reconstruction with single or double plate fixation. In the case of bulk allograft fixation, the use of PBSS seems to have increased torsional stability when compared to the IM nail. These methods of fixation may be useful for younger patient population where the incorporation of an allograft is advantageous. Future work will focus on alternative methods of fixation of bulk allograft as well as testing of various segmental defects.