BIOMECHANICAL COMPARISON OF INTERNAL FIXATION TECHNIQUES FOR SEGMENTAL DEFECTS OF THE HUMERAL DIAPHYSIS

INTRODUCTION
Segmental defects of the humeral diaphysis in the setting of disseminated malignancies present a challenging problem for fixation. The goal of surgical intervention is to provide immediate stable fixation allowing rapid return to function and maximal pain relief, while minimizing complications.

The purpose of this study is to directly compare the biomechanical properties of a second generation modular intercalary humeral spacer (segmental defect replacement (SDR) system) to that of modern humeral intramedullary interlocking nails combined either with cement (IMN) or with an intercalary allograft (allograft nail composite (ANC)) for fixation of segmental defects of the humerus.

METHODS
Twelve pairs of fresh frozen humeri were prepared in a standard fashion. Prior to defect creation, each specimen was completely skeletonized, sized, and radiographed. A 5 cm mid-diaphyseal segmental defect was then created using transverse saw cuts.

The paired specimens were randomly divided into two groups. Group one compared in alternating right and left specimens the SDR to the IMN. The SDR (Howmedica, Rutherford, New Jersey) has mated portions which, when joined and secured with two locking bolts, created a standard 5 cm spacer, and 9 mm diameter stems which varied in lengths from 50-100 mm. Each specimen was individually sized and cemented into the corresponding humeral segment. In the contralateral specimen, the Alfa humeral nail (Howmedica) was introduced in an antegrade fashion and locked with single proximal and distal screws. Cement was then hand-packed around the nail and the adjacent intramedullary canal at the level of the defect. Group two compared the SDR with the ANC. The ANC specimens were prepared using the same humeral nail and method of intramedullary fixation except that the defect was filled by the matched 5 cm intercalary allograft bone segment without cement. Radiographs prior to testing revealed complete cement mantles filling the proximal and distal canals in each of the SDR specimens and appropriate lengths of the SDR stems and the intramedullary nails.

Each specimen was tested in external rotation torsion to failure at 30 degrees/second on a biaxial MTS testing machine. Failure of the specimen was defined as either fracture or 45 degrees rotation without obvious fracture. Specimens were examined visually and radiographically for their failure mechanism. Initial data derived from the failure curves included peak torque and rotation at failure. An independent measures ANOVA at p<.05 (Duncan’s method) was used to compare the four sets of humeri from groups 1 and 2.

RESULTS
Figure 1 summarizes the peak torque and rotation at failure.

The SDR of group 1 failed at a statistically greater torque (mean 41.4 ± 9.3–43.3 N-m) of group 1 or the ANC (mean 9.8 ± 2.5 N-m, range 6.3–13.8 N-m) of group 2. The SDR of group 2 also had a statistically greater failure torque (mean 41.4 ± 7.0 N-m, range 34.9–52.4 N-m) than the IMN or the ANC. Additionally the IMN of group 1 had a statistically greater torque than the ANC of group 2.

DISCUSSION
For segmental destructive lesions of the humerus, this study has shown that reconstruction with a cemented metallic intercalary spacer (SDR) provides greater torsional resistance over intramedullary nail fixation supplemented either with segmental cement (IMN) or intercalary allograft (ANC) reconstruction. Additionally, the IMN can support a greater torque than the ANC.

Few studies have evaluated reconstructive options for segmental humeral defects.1,2 In one earlier laboratory study using a segmental defect model, segmental reconstruction with a first generation intercalary humeral spacer proved biomechanically superior in resisting torsional and bending loads to either plates and screws or Rush rods (1). Each type of fixation was accompanied by cementing of the defect and the adjacent intramedullary canal.

Theoretical advantages of the SDR compared to intramedullary nails for fixation of segmental humeral defects are threefold. Placement of the SDR is done through a single incision without rotator cuff violation. A second advantage is better access to the intramedullary canals for improved cementing. Excellent cement mantles were achieved in each of the SDR specimens, no doubt contributing to the superior stability of this construct. A third advantage is avoidance of proximal migration, a problem sometimes encountered with humeral nails in this setting.

For patients with segmentally destructive lesions of the humerus in the setting of disseminated malignancies, the SDR offers biomechanical and theoretical advantages over intramedullary fixation to restore immediate stability, enable rapid return to function, and to minimize potential complications.

REFERENCES:

**Mayo Clinic and Mayo Foundation, Rochester, MN.