LOAD DISTRIBUTION BETWEEN A TITANIUM MESH CAGE AND AN INTRAMEDULLARY NAIL USED FOR THE RECONSTRUCTION OF A LONG SEGMENTAL DEFECT OF THE TIBIA

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Introduction: Many methods of reconstructing segmental defects of the tibia following severe trauma have evolved from bone grafting,1 vascularized flaps,2 bone transport3 and recently, grafting with a titanium cage over an intramedullary nail4. Only the latter method allows for immediate weight bearing of the limb, but the biomechanics of the construct have yet to be defined.

Purpose: To evaluation of the mechanical roles of a titanium mesh cage and an intramedullary nail in the reconstruction of significant segmental defects of the tibia.

Methods: Five Generation III Sawbones tibias had 10 cm defects produced in the mid-shaft. A cage was placed in the defect and the nail locked while the construct was subjected to 1000 N compression. Brackets with 3 LED's were attached to each bone fragment to track the 6 degrees of freedom of movements of each during loading. Strain gages were mounted on the cage in 4 solid squares at 90° to each other, in the mid section of the 10 cm long cage coupling the proximal and distal ends. Each cage was calibrated for axial load and bending moment transmitted by placing known loads across the isolated cage prior to implantation. From the strain measurements, an estimate of the bending moment transmitted through the cage was made and compared to the moment applied to the defect. Tekscan pressure transducers, #6220, were applied to both ends of the cage to map the contact compression stress through the cage-bone interfaces. From these maps the force transferred was calculated and the peak compression stresses recorded. A vertical compression load was applied to each construct in load control at 0.25 Hz to a peak of 500 N along the axis of the nail and at and to produce varus, valgus, anterior bowing and, finally, recurvatum moments by altering the 10 mm load leverarm. The moment at the cage-bone interfaces for each peak load applied was calculated by adding the change in leverarm due to displacements of each fragment to the initial 10 mm offset of the vertical compression load to the axis of the nail. Thus the moment at each interface, which was larger than the 5 NAm moment applied at the ends of the bones, could be estimated.

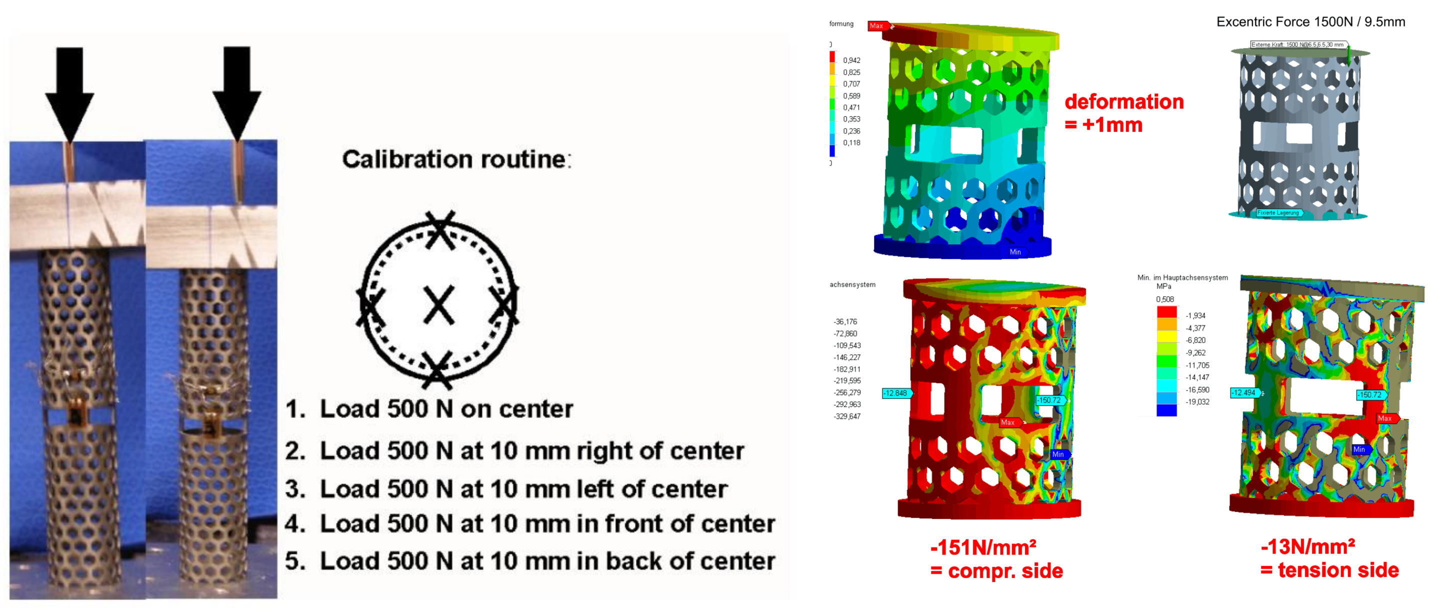
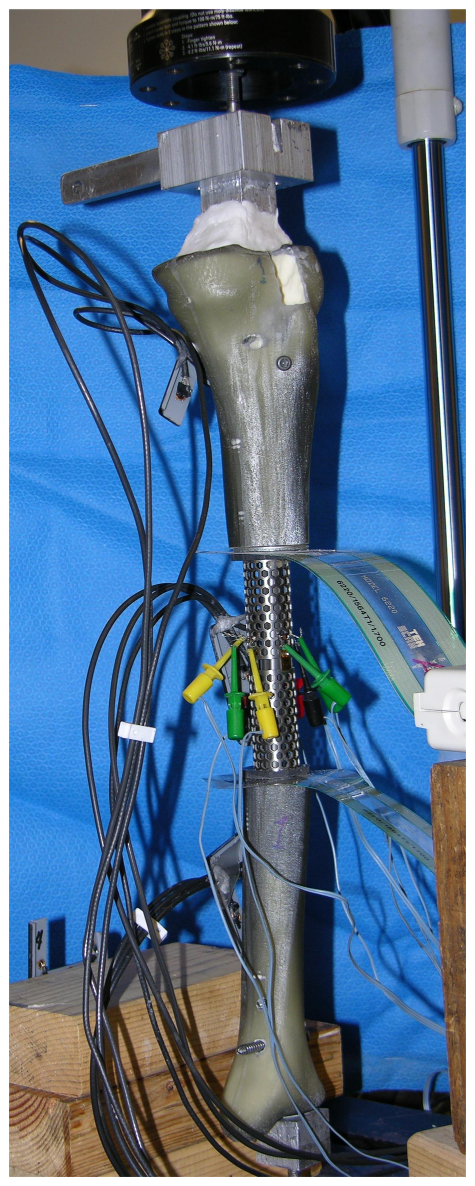


Figure 1 – Controlled loading of the cages served as calibration for compression and bending loads interpreted from strain measurements and validated by FEM



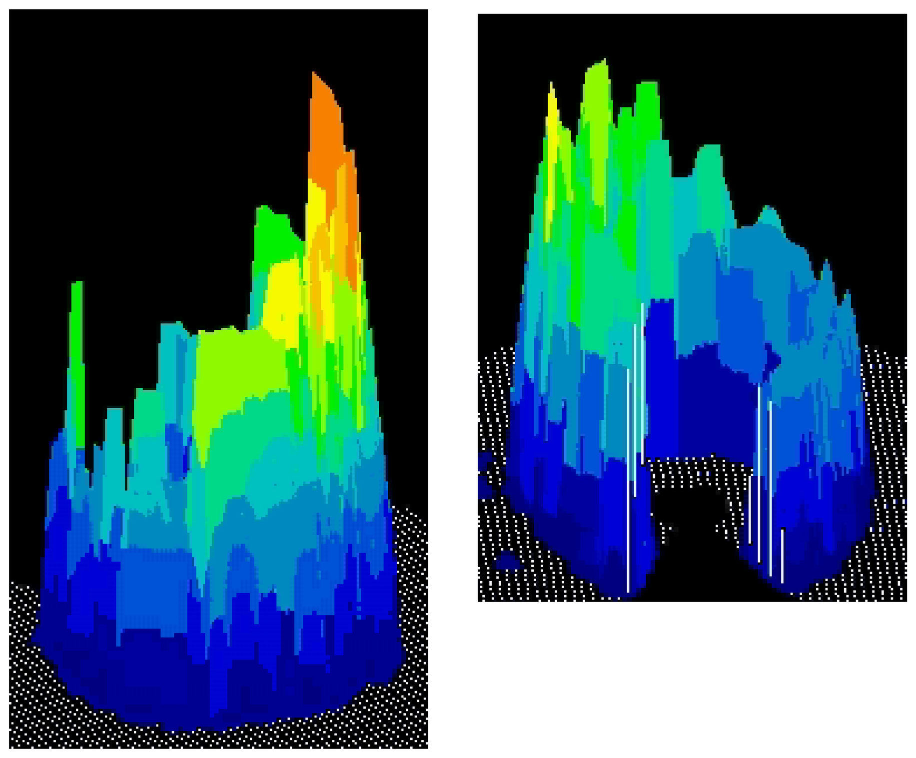


Figure 3 – From Tekscan pressure profiles and strain measures, the loads and moments transmitted through the cage were estimated.

Figure 2 - the titanium cage fills a 10 cm defect, with Tekscan pressure maps at each end and strain gages in the AP and ML planes. Loading included axial compression, eccentric compression to create varus, valgus, recurvatum and anterior bowing moments combined with compression.

Table 1 - angulation across defect in the plane of the applied moment

Plane	Varus	Valgus	Recurvatum	Anterior Bow
Mean	1.31°	2.26 °	0.54 °	2.34 °
SD	0.66	0.12	0.57	0.96

Results: The angulations for the bone fragments as measured by the LED's were minimal in the planes other than the plane of loading for each load condition. The total angulations between the proximal and distal fragments in the plane of loading are shown in Table 1.

From the angulation of the individual bone fragments and their known length, coupled with the fact that the MTS loads remained vertical at all times throughout the cycle, the increase in moment at the interfaces could be estimated. The moment at the proximal cage-bone interface increased 22.2% ("8.1%) in varus loading; 39.9% ("3.0%) in valgus loading; 4.2% ("5.1%) in recurvatum loading; and, 45.1% ("19.2%) in anterior bow loading. The moment at the distal cage-bone interface increased 22.5% ("15.8%)in varus; 36.8% ("2.4%) in valgus; 14.4% ("14.4%) in recurvatum; and , 34.2% ("14.1%) in anterior bowing.

Estimating the average moment transmitted by the cage from the strain gage readings and comparing this to the average moment transmitted at the bone-cage interfaces showed that the % of the applied moment that was carried by the cage in valgus was 47.2% ("34.0%); in varus, 75.7% ("24.4%); anterior bowing, 51.0% ("34.1%) and recurvatum, 51.4% ("27.8%). Under the assumption that the nail must carry the rest of the moments transmitted across the defect, with the exception of varus loading, the nail bore more than half of the moment being transmitted.

Comparing the total force transmitted across the defect estimated from the cage strain measurements compared to the loads applied by the MTS, in axial load 64.2% ("13.0%) was taken by the cage; in varus, 104.8% ("19.9%); in valgus, 97.1% ("21.3%); in anterior bowing, 112.8% ("21.7%); and in recurvatum, 58.6% ("5.9%).

The pressure maps also showed much more load transferring across the interfaces and much higher peak pressures in anterior bowing than in recurvatum, varus and valgus loading. The calculated total force transmitted from the pressure maps were slightly smaller in general than the estimates from the strain gages. But each map had a "dead space" for the wire connections, so the map did not completely measure the contact area, see Figure 2.

Conclusion: The estimates of moments transmitted by the cage and the nail, show almost equal load sharing for the moments applied in valgus, anterior bowing and recurvatum. Only in varus loading did the cage carry most of the moment transmitted across the defect. The axial load transmission was carried primarily by the cage for all loading conditions

Bibliography: 1. Georgiades GM, J Trauma 1995;38:910-914; 2. Hertel R, J Bone Joint Surg [Br] 1995;77:914-919; 3. Green SA. Clin Orthop 1994;301:111-117; 4. Lindsey RW, Yale J Biol Med 1993;66:157-163