FEMORAL INTRAMEDULLARY NAILING: GEOMETRY OF THE REAMED CANAL

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INTRODUCTION

Intramedullary fixation with femoral nails is a standard treatment modality for femoral shaft fractures. Treatment success and the quality of reduction highly depend upon the geometric conformity between the implant and the reamed canal (Steriopoulos, 1997). Contemporary reaming systems with flexible shafts create reamed canals, which follow the path of least resistance through the intramedullary cavity. Depending on the reamer insertion site (greater trochanter or piriformis fossa), the reamed canal exhibits characteristic curvatures in the sagittal and coronal planes. The characteristic curvature of the intramedullary canal has previously been described only in terms of a single radius, fitted to 2-D radiographic projections of the femoral canal (Harper, 1987; Zuber, 1988). However, despite its crucial implication for implant design, no 3-D assessment of the reamed canal exist to date.

This study employed an experimental technique and mathematical algorithm to quantify the spatial curvature profile of the reamed femoral canal. The spatial curvature profile was quantified in paired femoral cadaveric specimens for reamer insertion through the greater trochanter and through the piriformis fossa. Results of this study provide a scientific basis relevant for implant design and implant insertion alike.

METHODS

Specimens: Eighteen paired, fresh-frozen, human femora from 5 female and 4 male specimens were obtained from Caucasian donors of age 64 ± 11 years.

Reaming: Specimens were reamed using a cannulated flexible reamer (SynReam, Synthes ,USA) over a guide wire to either 13 or 15-mm diameter in 0.5-mm steps depending upon specimen size. Reaming was done in accordance with standard reaming techniques aided by a C-arm fluoroscope (OEC 9600, OEC Medical Systems Inc.). The reamer was inserted through the greater trochanter (GT group, 12-mm lateral from tip) and through the piriformis fossa (PF group) in right and left specimens, respectively.

Intramedullary canal digitization:
Each specimen was aligned on a digitizing workstation, which consisted of a non-metallic table with an integrated electromagnetic motion tracking system (PcBird, Ascension Technology, Burlington, VT). A local coordinate system was defined by aligning the femoral shaft axis along the y-axis, the posterior aspects of the femoral condyles with the x-axis, and by placing the femur dorsal side down parallel to the x-y plane.

The centerline of the reamed femoral canal was traced by retracting a motion-tracking sensor through the reamed canal. For this purpose, the sensor was mounted on the tip of a flexible shaft while the outer diameter of the sensor was matched to the diameter of the reamed canal. Over 500 3-D data points were obtained per canal tracing.

Spatial Curvature Profile:
A custom Matlab software (Mathworks, Natick, MA) algorithm was generated to compute the apparent magnitude and orientation of curvature along the digitized canal pathway. A circle with center P_C was fitted to each triplet of points P_{i-1}, P_i, and P_{i+1} (fig. 1a). The radius vector $\underline{R_i} = \underline{P_C} - \underline{P_i}$ of the circle depicted the apparent magnitude and orientation of the reamed canal curvature at

point P_i. Plotting radius vectors for each successive P_i along the reamed canal pathway yielded the spatial curvature profile.

For result presentation, the curvature magnitude, $C_i = 1/|\underline{R_i}|$ and orientation, λ_i (fig. 1b), in the transverse plane were extracted from the spatial curvature profile over 5-95% of the reamed canal length.

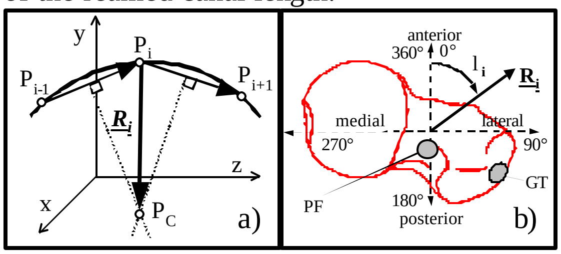

Figure 1: a) 3-D curvature calculation and b) definition of λ_i with PF and GT insertion sites

Differences between GT and PF groups were analyzed with a paired, two-tailed Student's t-test for both C_i and λ_i, along the canal length.

RESULTS

The spatial curvature profile yielded an antero-lateral curvature in the proximal region and an antecurvature in the diaphysis of the femur for GT specimens (fig. 2).

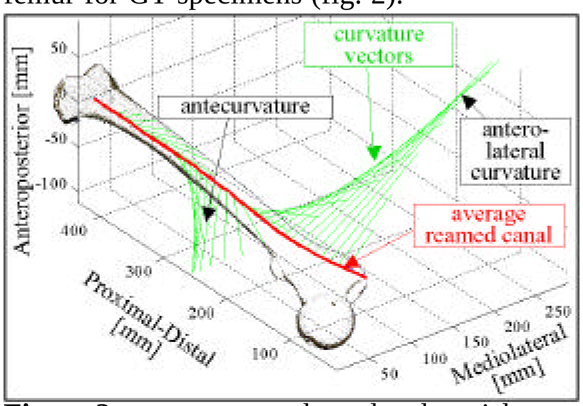

Figure 2: average reamed canal and spatial curvature profile for GT specimens

GT specimens yielded reamed canal radii of 604 ± 144 mm, 868 ± 190 mm and 2012 ± 2722 mm, while PF specimens yielded radii of 1674 ± 811 mm, 960 ± 266 mm and 1382 ± 760 mm at 25%, 50%, and 75% canal length, respectively. The corresponding curvature distribution along the reamed canal for both GT and PF specimens is depicted in figure 3.

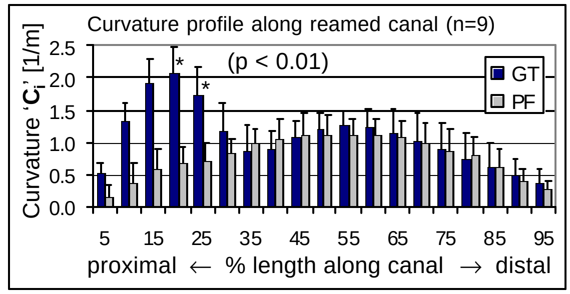

Figure 3: C_i distribution of GT & PF specimens

GT specimens yielded λ_i of 69 ± 16°, 176 ± 12° and 161 ± 60°, while PF specimens yielded λ_i of 236 ± 54°, 181 ± 13° and 175 ± 13°, at 25%, 50%, and 75% canal length, respectively (fig. 4).

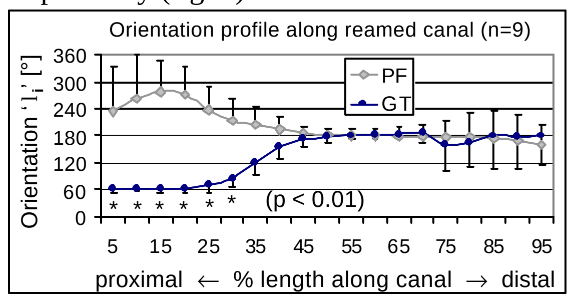

Figure 4: λ_i distribution of GT & PF specimens

DISCUSSION

The spatial curvature profile algorithm was able to quantify a complex canal trajectory in terms of two scalar parameters, C and λ, along the reamed canal. These outcome parameters are directly applicable for the design of intramedullary implants to optimize geometric conformity. The presented data suggest that the distinct insertion sites require intramedullary nails of different shapes to warrant optimal conformity between the implant and reamed canal. However, besides geometric conformity, femoral nail designs have to also account for ease of implant insertion and removal.

REFERENCES

Harper et al. (1987) *Clin Orthop*, **220**:155-161

Zuber et al. (1988) *Unfallchirurg*, **91**:314-319

Steriopoulos et al. (1997) *Acta Orthop Scand (Suppl 275)*, **68**: 123-126

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