Hinge Pin Reduces Fracture Risk in Medial Opening Wedge Procedures

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Objective

A high tibial osteotomy (HTO) is performed by a partial cut with a bone saw from medial to lateral, leaving the lateral cortex intact, serving as a bone bridge and a hinge point during osteotomy opening. The intraoperative prevention of contralateral cortex fracture during wedge opening is essential to avoid an unstable postoperative situation with insufficient primary stability. The HTO hinge pin system as well as the iBalance® HTO system provide a drill hole for stress homogenization and fracture risk reduction. This reduces high stressed regions around the notch at the end of the planar cutting.

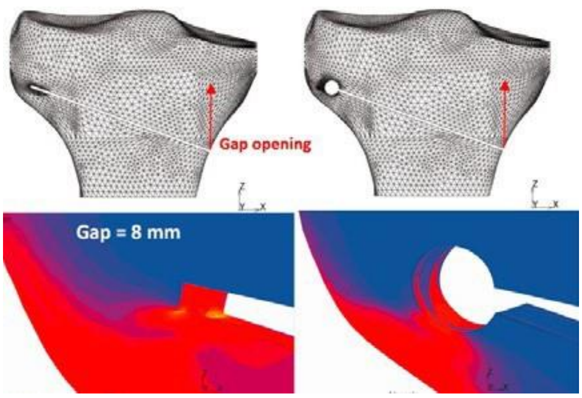
A tibia model with a planar cut and sharp cutting edges as well as a hole at the end was used for a finite element analysis (FEA) to assess the stress behavior during HTO gap opening. FEA results were verified due to a standard experimental setup with artificial cortical bone material.

Materials and Methods

For FEA, a tibia model with a planar cut and sharp cutting edges as well as a model with a drill hole (5 mm) at the end of the planar cut [1] were prepared, leaving a 10 mm bone bridge intact. The tibia model consisted of a 3 mm cortical shell filled with linear elastic, isotropic and homogeneous cancellous bone. The Young's modulus for the cancellous bone was set at 1.150 MPa with a Poisson's ratio of 0:3. Cortical bone mechanical properties were used with a Poisson's ratio of 0:3 (according to Lee et al. [2]). Gap opening was done with a translation vector along the z-axis on the medial cortex. Von Mises stress around the cutting tip over the gap opening was observed.

a)

b)



c)

Gap	Cut	Hinge Pin	Stress Reduction [%]	Gap	Cut	Hinge Pin	Stress Reduction [%]
1 mm	72.1	44.7	38	9 mm	175.0	102.5	41
2 mm	81.3	71.2	12	10 mm	189.1	107.0	43
3 mm	92.9	73.4	21	11 mm	202.4	111.3	45
4 mm	107.1	77.3	28	12 mm	215.0	115.5	46
5 mm	121.8	82.2	33	13 mm	227.0	119.6	47
6 mm	135	87.5	36	14 mm	238.5	123.7	48
7 mm	148.6	92.7	38	15mm	249.6	129.4	48

Max. von Mises stress [MPa] Risk of fracture

Figure 1: FEA models (a) with von Mises stress results over the gap opening (b/c).

[1] Kessler et al. (2002), CORR 395: 180-85
[2] Lee et al. (1997), Bone 21 (1):119-25

For the purpose of FEA verification, standard experiments with test samples (n=3) made out of 3 mm thick 40 pcf cortical bone substitute material (Sawbones Europe AB, Sweden) were fabricated, containing a definite, similar cut (saw blade thickness 1.27 mm) to the FEA models with sharp cutting edges and a drill hole at the end. Tensile load was applied until crack initiation and load displacement curves were assessed.

Results

Fig. 1 shows both tibia cut and hinge pin FEA models (Fig. 1a) with von Mises stress results during gap opening (Fig. 1b/ c). Maximum von Mises stress values at the end of the planar cutting (Fig. 1b) are reduced for the hinge pin compared to the standard cut model for all gap opening levels (Fig. 1c). The reduction of higher stresses by homogenization is most significant at the hole created at the end of the planar cut at increased gap opening levels. Within the cut model, high stresses are located in the area of the sharp cut edges. According to the cortical ultimate strength value (77 MPa) used for FEA simulation, the fracture risk arises after a 2 mm gap opening for the cut model and 4 mm for the hinge pin model. The experimental results with the standard test setup (Fig. 2) revealed a mean max. gap opening value of 3.44 mm ± 0.20 mm for the cut model group with sharp cutting edges until fracture. The hinge pin samples reached a mean max. gap opening value of 5.52 mm ± 0.51 mm and therefore exhibit a + 60.5 % increased gap opening level compared to the cut model group.

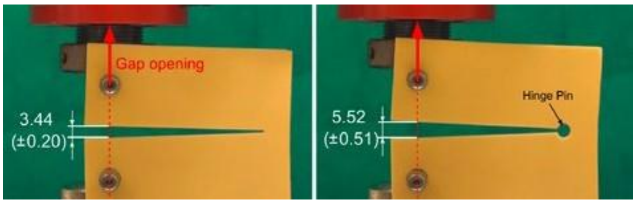


Figure 2: Experimental test setup with mounted sharp cutting edge (left) and hinge pin (right) specimen.

	Cut	Hinge Pin	Difference
Mean failure load [N]	12.4 (SD ± 0.8)	18.9 (SD ± 0.5)	+ 52.5%
Mean max. gap [mm]	3.44 (SD ± 0.20)	5.52 (SD ± 0.51)	+ 60.5%

Table 1: Experiment test results

Mean failure load for the cut model group was 12.4 N (SD ± 0.8 N) and 18.9 N (SD ± 0.5 N) for the hinge pin group.

Conclusion

The hinge pin technique may help to reduce the risk of fracture to the lateral cortex by stress homogenization in the area of the drill hole by avoiding local high stress concentrations in the region of the sharp cutting notch, which may lead to early fracture.

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