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# **Comparison of the effect of locking vs standard screws on the mechanical properties of bone-plate constructs in a comminuted diaphyseal fracture model**

Michaël Verset, Sophie Paliérne, Didier Mathon, Pascal Swider, André Autefage

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**Title of abstract:**

Comparison of the effect of locking vs standard screws on the mechanical properties of bone-plate constructs in a comminuted diaphyseal fracture model.

**Introduction:**

Healing of comminuted diaphyseal fractures is a major consideration in veterinary orthopaedics as they are frequently encountered, demonstrate a high rate of complications and their treatment is often challenging. One of the latest available implant in this indication is the Locking Compression Plate (LCP) in which combined holes accept either standard or locking screws.

Although there are a few clinical and biomechanical studies comparing LCP plates featuring locking screws with non-locking plates, the real advantage of locking screws remains undefined and unquantified. The purpose of this study was to compare the mechanical properties of bone-plate constructs with LCP plates used either with standard screws or with locking screws on an experimental model of comminuted fracture.

**Materials and methods:**

Twelve pairs of ovine tibia were harvested and packed with gauze soaked in isotonic saline solution before freezing (-24°C). After thawing at room temperature, they were kept moistened throughout the experiment. Inclusion criteria were skeletally mature animals belonging to one single breed, similar size of tibia and absence of bone diseases evaluated on radiographs. They were randomly divided into 2 equal groups.

The model of comminuted fracture used was a mid-diaphyseal 5-mm gap created on the left tibia from each pair with an oscillating saw. Fracture was treated with a 8-hole, 4.5-mm, broad stainless LCP plate with 3 bicortical screws in each of the 2 fragments. All plates were similarly contoured to fit the medial side of bone. In group 1 (G1), 4.5 mm self-tapping cortical screws (standard screws) were placed in slightly inner eccentric position (to avoid collapse of the osteotomy site during weight-bearing). In group 2 (G2), 5.0 mm self-tapping locking screws were used. All screws were tightened using a torque-limiting screwdriver at 4 Nm.

Biomechanical evaluations were performed by non-destructive tests at quasi-static displacement rate (1 mm/min) on electromechanical systems. Four-point bending, torsion and axial compression loading conditions were applied one after the other on plated bones and on intact contralateral bones, to serve as a control. Maximum load used for non-destructive tests was about 50% of yield load, as previously assessed by destructive tests on pre-test plated bones. Bending was performed in a latero-medial direction with upper anvils surrounding bone gap (span distance of 30 mm). After embedding of proximal and distal ends in polyurethane casting resin, bones sustained clockwise torsional load, then axial compression load.

For bending and compression on plated bones, 2 monocortical 1.5 mm pins were seated through the lateral cortex (2.5 mm outside the edges of bone osteotomy). A laser scan micrometer allowed continuous measurement of width between pins during tests.

Crosshead displacement, load, angle of rotation, torque and width between pins were recorded at 10 Hz.

Extrinsic stiffness of bone-plate constructs (K) was calculated (i.e. the slope of the load-crosshead displacement curve). Difference between extrinsic stiffness of contralateral tibia and K was divided by extrinsic stiffness of contralateral tibia to obtain stiffness loss (Kr), expressed as a percentage. Slope of the load-pins displacement curve (S) was also calculated. K and Kr provide information on global mechanical properties of plated or intact bone, whereas S is a reflection of interfragmentary motion during load thus providing information on local mechanical properties close to the osteotomy gap.

Results were statistically compared between the 2 groups by a 2-way ANOVA and Tukey's Post Hoc tests, for each loading condition. Significance was set at  $P < .05$ .

## Results:

In 4-point bending tests, there were no significant differences between group 2 and group 1 for K (G2:  $321.9 \pm 65.2$  kN/m, G1:  $286.0 \pm 36.6$  kN/m;  $P=.85$ ), for Kr (G2:  $55.4 \pm 10.4\%$ , G1:  $64.5 \pm 3.9\%$ ;  $P=.07$ ) and for S (G2:  $292.0 \pm 84.3$  N/mm, G1:  $271.4 \pm 36.2$  N/mm;  $P=.59$ ) (figure 1).

In torsion tests, there were no significant differences between group 2 and group 1 for K (G2:  $133.3 \pm 18.7$  Nm/rad, G1:  $117.2 \pm 18.0$  Nm/rad;  $P=.59$ ) and for Kr (G2:  $44.0 \pm 10.3\%$ , G1:  $55.0 \pm 10.6\%$ ;  $P=.10$ ) (figure 2).

In axial compression tests, K was significantly lower for group 2 ( $611.1 \pm 104.0$  kN/m) than for group 1 ( $1019.2 \pm 249.5$  kN/m) ( $P=.003$ ) (figure 3). Kr was significantly higher for group 2 ( $66.5 \pm 10.3\%$ ) than for group 1 ( $47.7 \pm 10.8\%$ ) ( $P=.01$ ). There was no significant difference between group 2 and group 1 for S (G2:  $254.6 \pm 72.6$  N/mm, G1:  $438.2 \pm 228.3$  N/mm;  $P=.09$ ).

## Discussion:

Bending stiffness and torsion stiffness were not significantly different using locking screws or standard screws. That is consistent with most other *in vitro* and *ex vivo* studies comparing LCP with LC-DCP plates, performed on synthetic bones.

Compression stiffness with locking screws was about half compared with standard screws, whereas other studies showed no significant difference or significantly higher stiffness for locking screws. It might be related to 2 phenomena: i) the friction forces induced by the screws which compress the plate onto bone in standard osteosynthesis and ii) the limitation of bone displacement by the eccentric position of standard screws that are blocked on the inner part of the plate hole, under axial compression. Anyway, the significant difference of global mechanical properties seems to have no significant effect on the local mechanical properties.

The main limitation of this *ex vivo* study is the only mechanical evaluation, without assessment of bone healing. It has been previously suggested that use of locking screws leads to preservation of periosteal perfusion, allowing better bone healing. The next step of this study is the assessment of mechanical, radiological and histological properties of bone-plate constructs and of bone callus after osteosynthesis and bone healing obtained with use of LCP plates either with standard screws or with locking screws on the same model of comminuted fracture. It should help to make a rational choice of the type of implant to treat comminuted fractures.

## Conclusion:

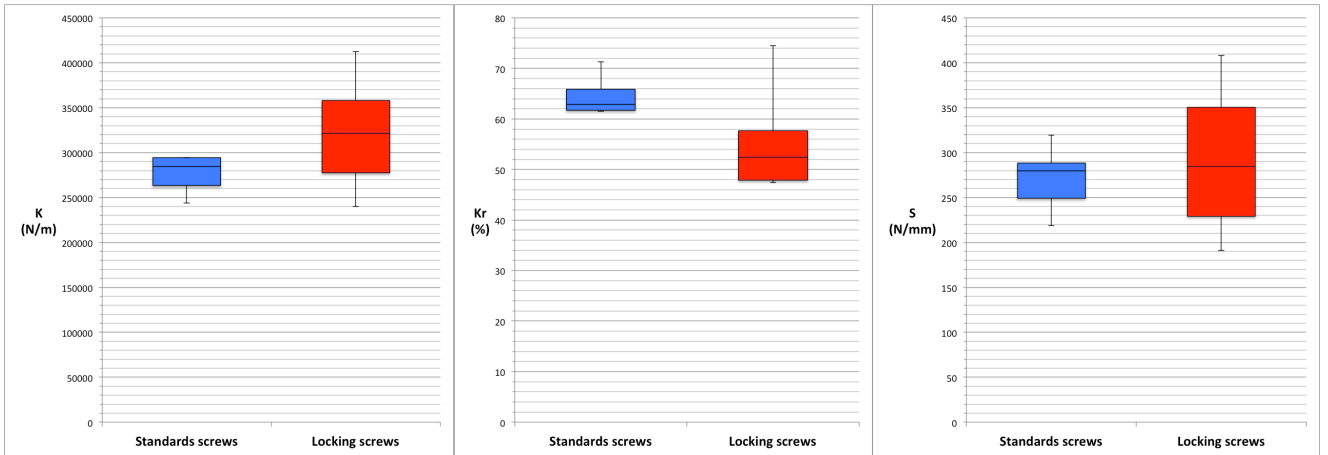
Locking screws had no statistically significant effect on the mechanical properties of LCP-plated bones in 4-point bending and torsion, compared to standard screws. In axial compression, locking screws induced a significant decrease in global mechanical properties without significant decrease in local mechanical properties close to the osteotomy gap.

## References:

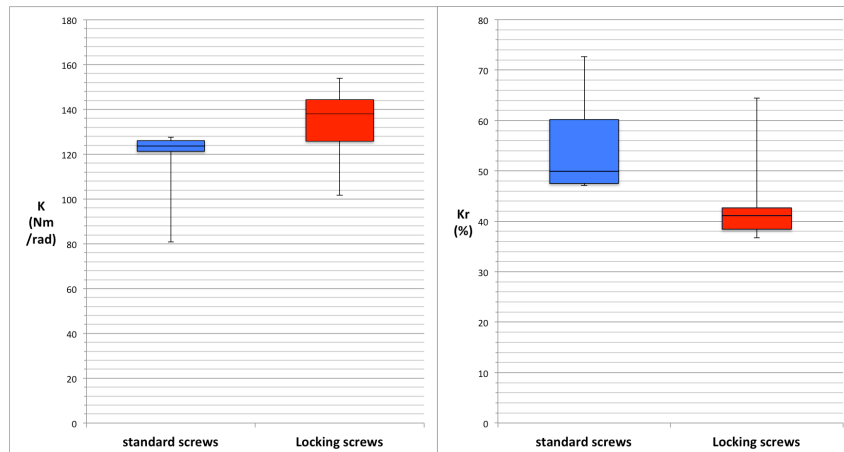
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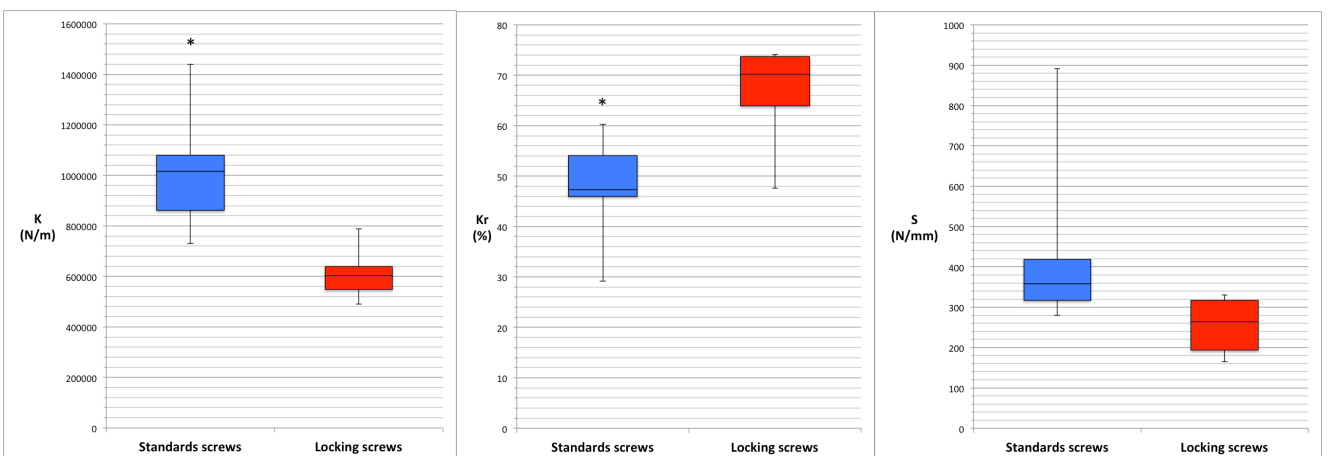
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**Figure 1** Box plots comparing mechanical properties in 4-point bending for the different groups:  
 a) extrinsic stiffness      b) stiffness loss      c) load-pins displacement curve slope  
 Asterisks indicate significant differences between groups ( $P < .05$ ). Whiskers lower and upper limits = 2.5th and 97.5th percentiles.



**Figure 2** Box plots comparing mechanical properties in torsion for the different groups:  
 a) extrinsic stiffness      b) stiffness loss  
 Asterisks indicate significant differences between groups ( $P < .05$ ). Whiskers lower and upper limits = 2.5th and 97.5th percentiles.



**Figure 3** Box plots comparing mechanical properties in axial compression for the different groups:  
 a) extrinsic stiffness      b) stiffness loss      c) load-pins displacement curve slope  
 Asterisks indicate significant differences between groups ( $P < .05$ ). Whiskers lower and upper limits = 2.5th and 97.5th percentiles.