Biomechanical comparison of locking plate, non-locking plate, and crossed screws in first metatarsophalangeal arthrodesis

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Summary
Stiffness and durabilty of locking plate, non-locking plate, and crossed screws constructs were compared in a synthetic model of first metatarsophalangeal fusion. The non-locking plate construct was stiffer and more durable than either crossed screws alone or a locking plate.

Background
The recent addition of locking plates to the array of options available for first metatarsophalangeal joint fusion has stimulated considerable interest among surgeons. Unfortunately, limited and conflicting data exist to aid surgeons in selecting the appropriate hardware, especially concerning locked plating systems. Selection of the appropriate implant is important, because construct stiffness has been shown to affect healing rates in numerous applications. Use of synthetic bones permits comparison of three groups without the requirement of matched pairs, since the synthetic bones lack variation in bone density and size found in cadavers.

Purpose
The purpose of this study was to evaluate the stiffness and durability of a new locked plating system when compared to two crossed screws alone, or a 1/3 tubular plate with a single crossed screw.

Method
A total of 24 Sawbones® first metatarsals and phalanges were divided into three groups: two crossed screws (CS); one crossed screw with a 1/3 tubular non-locking plate (NLP); and one crossed screw with an X-type locking plate (LP). All hardware was manufactured by Synthes USA. The base of each metatarsal was anchored in an Instron® materials testing machine. The load was applied to the phalanx in a plantar to dorsal direction, varying from 1-100N for 1000 cycles. This load was selected to simulate ambulation in the post-operative period.

Construct stiffness (slope of the force/displacement curve between 20N and 98N) was determined at pre-selected cycles. The number of cycles completed prior to catastrophic specimen failure was also recorded. Stiffness and cycles completed were analyzed by one-way ANOVA, and pairwise comparison was performed using the Student-Newman-Keuls method. Significance was set at p=0.05.

Results
The NLP group completed 1.8 and 2.4 times more cycles prior to failure compared to the LP or CS groups, respectively. No difference was detected in cycles to failure between the LP and the CS groups. Mean NLP stiffness was 49 percent greater than CS at all cycles and greater than LP by an average of 25 percent, beginning at cycle 50. LP was stiffer than CS by 46 percent at cycle 500. All failures involved a fracture of the bone, primarily through the base of the phalanx.

Discussion
Construct stiffness is critical, as fusions rely on lack of motion at the fusion site. Early failure and lower stiffness of the locking plates in this study were surprising findings because the rigid screw-plate interface of the locking plate appears to provide an inherently stiffer construct. Failure of the locking plate was consistently observed as a fracture of the phalanx through the distal screw tracts of the locking plate. This may have been due to undesirable concentration of force in the phalanx. Locking plates of other designs may not perform in a similar fashion.

Conclusion
The greater durability and stiffness of the 1/3 tubular plate in this study lends support to its continued use and that locking plates may not be the ideal construct for this application; however, further study is needed before final recommendations may be rendered.

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