

A Biomechanical Comparison of First Metatarsophalangeal Arthrodesis Using Crossed Screws and Shape-Memory Staples in Various Configurations

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Introduction/Purpose: Arthrodesis of the first metatarsophalangeal joint (MTPJ) is a commonly performed procedure for the treatment of hallux rigidus. A range of fixation methods have been used. Most recently, the shape-memory staple has been described. Made from an equiatomic alloy, the staple changes its shape when heated to body temperature so as to provide compression across the arthrodesis.

We aimed to determine load to failure, cyclic loading and failure characteristics of different staple configurations compared to crossed screws.

Methods: A cadaveric porcine model was used to simulate first MTPJ arthrodesis. Five forms of fixation were tested: single vertical staple; single horizontal staple; paired staples in orthogonal superior-inferior and medial-lateral configuration (0-90° to sagittal plane); paired staples in an oblique orthogonal configuration (45-135° to sagittal plane); two crossed screws. Using a materials-testing machine, specimens were loaded in dorsiflexion to simulate weight bearing. Cyclical loading was performed from 5-40N at a rate of 0.5Hz for 1000 cycles. Plantar gapping, shear and creep were measured. Specimens were then loaded to failure in order to generate a load-displacement curve. The mechanism of failure was noted for each group.

Results: Single staple configurations failed at very low loads. Single vertical staples failed at a mean load 15N±5N and single horizontal staples at 19N±3N.

Mean failure load for paired 0-90° staples was 43N±9N which was significantly lower than the paired 45-135° staples which failed at 141N±25N ($p < 0.001$) and crossed screws, which failed at 180N±67N ($p < 0.001$). There was no significant difference between the 45-135° staples and crossed screws.

Cyclic testing demonstrated plantar gap formation of 0.2mm±0.1mm in the crossed screw specimens and 0.4mm±0.4mm in the 45-135° staple specimens. However, stapled specimens demonstrated more shear compared to crossed screws (mean 1.0mm±0.5mm compared to 0.14mm±0.4mm, $p < 0.01$). Furthermore, crossed screw specimens showed mainly plastic deformation whereas stapled specimens showed combined plastic and elastic deformation.

Conclusion: First MTPJ arthrodeses fixed with single staples failed at very low loads and cannot be recommended. The widely accepted 0-90° orthogonal staple configuration proved to be significantly less strong than two crossed screws. However, changing staple position to an oblique configuration at 45° and 135° to the sagittal plane significantly improved stability, rendering the construct as strong as crossed screws. Nevertheless, none of the constructs would have been strong enough to withstand full weight-bearing in the immediate post-operative period.