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A biomechanical model of percutaneous distal metatarsal osteotomy: load transmission influencing successful follow-up

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Introduction

Symptomatic hallux valgus is a common clinical problem. Current trends for treatment are toward percutaneous or mini-invasive procedures, among these a mini-invasive distal metatarsal osteotomy (SERI) demonstrated to be effective in correcting the deformity with minimal surgical trauma and satisfactory results [1]. Conflicting with previous clinical studies, a recent paper [2] reported discouraging short-term radiographic results by using a theoretically similar osteotomy and fixation device.

The hypothesis of the present study is that conflicting clinical outcomes are associated to different loading conditions imposed by the surgical procedure to the metatarsal. Thus, a biomechanical model of metatarsal osteotomy was designed, in order to investigate relevant biomechanical variables.

Methods

The pin, inserted in the metatarsal to stabilize the osteotomy, was modelled as beam. If a flexion moment M_f is imposed to the beam, a deflection y is observed (Figure 1).

The deflection y results from the applied moment and the geometrical and mechanical characteristics of the beam:

$$\frac{d^2 y}{dx^2} = \frac{M_f}{EI}$$

Where E is the Young Modulus of the material, and I is the moment of inertia of the section opposing to flexion. For a circular section (radius *r*) of the beam:

$$I = \frac{\pi r^4}{4}$$

A specific software tool was developed for the quantification of M_f from the radiographic post-op images. The tool was preliminarily used to analyse radiographs from three subjects.

The quantified moment corresponds to the reaction moment induced by the pin into the proximal section of the metatarsal. Thus, specific compressive load distribution at the osteotomy interface can be quantified by means of FEM analysis.

Results

The magnitude of compressive force depends on a solid connection of the pin to the phalanx of the toe and to the head of the metatarsal, allowing elastic deflection of the pin. Moreover, the applied moment strongly depends on the radius of the pin: a change of 20% in the radius, results

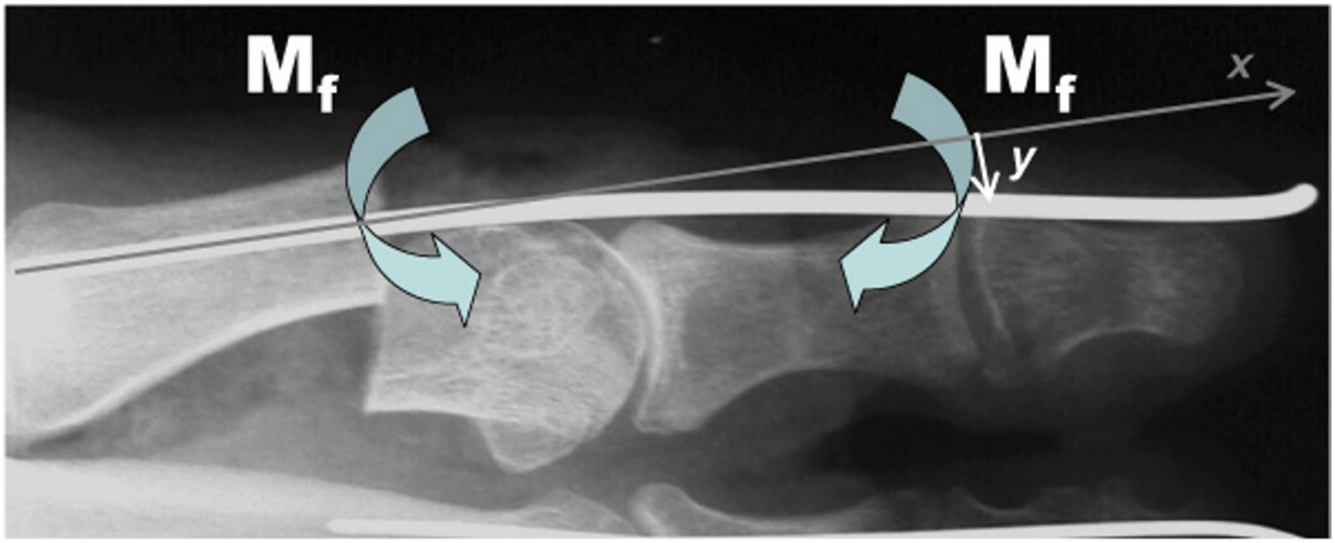

Figure 1
Sketch of the deflexion y induced to the beam by the flexion moment Mf.

in a reduction of approximately 60% if the moment of inertia, thus of the applied moment.

Conclusion

Although several macroscopic technical differences between the techniques are evident, the biomechanical model proposed pointed out some mandatory characteristics for the efficacy of fixation in SERI procedure: the deflexion imposed to the pin implies the generation of a contact load distribution at the interface of the osteotomy, which is likely to induce an appropriate healing of the resection. In this context, the anchorage of the pin to the toe and the head of the metatarsal in appropriate points is of fundamental importance, for load transfer and freedom of deflexion, as well as the radius of the pin.

The designed software is meant to quantify the induced loads in a large group of subjects, in order to correlate the loading with the outcome.

References

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