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Original Article

Mind the gap between the fracture line and the length of the working area: a 2-D finite element analysis using an extramedullary fixation model☆

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ABSTRACT

Objective: To determine the ideal working area for a simple transverse fracture line treated with a bridge plate.
Methods: A 2-D finite element analysis of a hypothetical femur was performed for the quantitative evaluation of a large-fragment titanium alloy locking plate based on the precept of relative stability in a case of a simple transverse diaphyseal fracture. Two simulations (one case of strain and another case of stress distribution) were analyzed in three unique situations according to the von Mises stress theory. Load distributions were observed when the bone was subjected to a single vertical load of 1000 N.
Results: The longer the length of the implant flexion, which coincided with the working area of the plate, the greater the flexion of the implant. The highest concentrations of stress on the plate occurred in the region around the screws closest to the bone gap. The closer the screws to the fracture site, the greater the demands on the plate.
Conclusion: When using a large-fragment titanium alloy locking plate to stabilize a simple transverse fracture based on the precept of relative stability (bridge plate), there must be considerable distance between the proximal and distal screws closest to the fracture line. The farther away this fixation is, the lower the stress on the plate and the greater the dissipation of force in the form of deflection.

☆ Study conducted at the Serviço de Ortopedia e Traumatologia Prof. Nova Monteiro, Hospital Municipal Miguel Couto, Rio de Janeiro, RJ, Brazil.

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Observe a distância entre a linha de fratura e o comprimento da área de trabalho: Análise bidimensional de elementos finitos em modelo de fixação extramedular

Palavras-chave:
Análise de elementos finitos
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RESUMO

Objetivo: Determinar qual é a área de trabalho ideal em uma fratura de traço simples transverso tratada com placa em ponte.

Métodos: Foi feita uma análise bidimensional de elementos finitos em um fêmur hipotético para avaliação quantitativa de uma placa bloqueada para grandes fragmentos feita de liga de titânio, usada com o princípio de estabilidade relativa em uma fratura diafisária de traço simples e transverso. Foram analisadas duas simulações, uma de deformação e outra de distribuição de tensão, de acordo com a teoria de von Mises, em três situações distintas. Foram observadas as distribuições de carga quando o osso foi submetido a uma carga monotônica vertical de 1.000 N.

Resultados: Quanto maior o comprimento de flexão do implante, o que coincidiu com a área de trabalho da placa, maior a flexão dele. A maior concentração de tensão na placa foi observada na região dos parafusos mais próximos do defeito ósseo. Quanto mais próximos os parafusos do foco de fratura, maior a demanda sobre a placa.

Conclusão: Ao usar uma placa bloqueada para grandes fragmentos feita de liga de titânio para estabilizar uma fratura de traço simples e transverso pelo princípio de estabilidade relativa (placa em ponte), a distância entre os parafusos mais próximos do traço de fratura proximal e distalmente deve ser longa. Quanto mais distante essa fixação, menor a concentração de tensão na placa e maior a dissipação de esforços na forma de deflexão.

Introduction

In the skeletal system, the biomechanical environment plays a fundamental role in bone repair and remodeling, in order to meet functional requirements.[1] In this context, the relationship between physical factors and cellular responses is critical; the success of the consolidation process requires the maintenance of appropriate forces on a bone capable of responding adequately.[2] The concept of mechano-regulation, that describes the ratio of the relative deviation of the fracture edges *versus* the width of the initial defect and determines the morphological characteristics of bone repair, has been known for some time.[3] Correct interpretation and application of this concept allows the orthopedic surgeon to choose the best fixation precept and aids in making important therapeutic decisions, such as the reduction method and the type of implant.

Regardless of the fixation precept, in bone tissue repair, the important mechanical characteristics of the final product are its strength and stiffness. Primary healing, usually observed after anatomical reduction of fracture focus and rigid internal fixation with plate and screws (absolute stability), resembles the physiological remodeling of bone; it is a slow process. Its indication is absolute in the management of articular fractures, although its use has now been abandoned in most diaphyseal fractures. As several studies have demonstrated, the axial and cyclic compression forces applied to the diaphysis of the long bones improve healing through the formation of a larger cartilaginous callus and of an earlier bone bridge, maintaining and protecting the fracture reduction, and allowing a certain degree elastic deformation (relative stability) that appears to be quite rational.[4–7] The amount of bone tissue formation depends on this interfragmentary stress.[3,5,8]

Mechanically, when compared with osteosynthesis with an interfragmentary compression plate, extramedullary fixation with a bridge plate undergoes increased flexion and torsion loads, resulting in high stresses on the implant. Therefore, predicting the mechanical performance of a fixation device is paramount and depends on several factors. One of the most important factors is the estimated length of the working area during fracture fixation, defined by the distance between the screws closest to the proximal and distal fracture focus.[9] It is believed that the stress is lower on the plate when the working area is smaller.[10]

Ideally, in a simple transverse line fracture, it is expected that the interfragmentary mobility will be equally divided between the implant and the opposite side of the bone, when an axial load is exerted. However, this type of behavior has been evaluated only under absolute stability, but not in a relative stability model. The present study aimed to examine the stresses and deformations during gradual flexion on a locking plate secured under the precept of relative stability in a simple transverse line fracture. Three configurations of screw placement were envisioned, and the working area varied in distance from the fracture focus. The authors aimed to determine the ideal working area for a simple transverse line fracture treated with a bridge plate.