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Optimizing compression: Comparing eccentric plate holes and external tensioning devices

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ABSTRACT

Objective: Elimination of interfragmentary motion in fracture fixation using plates to impart compression and promote primary bone healing through absolute stability has been well described as a reliable and successful method to treat simple transverse and short oblique fracture morphologies. Our hypothesis is that dynamic compression plating augmented by external compression techniques would produce and maintain a significantly greater amount of compression than using the plate alone.
Methods: Simple transverse diayphyseal fractures were simulated in nine 4th generation composite bone models. A load cell was placed within the transverse fracture osteotomy and stabilized and compressed using either eccentric screw placement in a dynamic compression plate alone or augmented with an opposite segment Verbrugge clamp or articulated tensioning device (ATD) compressing using a screw outside of the plate. Dynamic plate compression was evaluated independently and in conjunction with the external compression techniques. Statistical analyses were carried out using a linear mixed effects model and pairwise comparisons between conditions with a significance set at a *P*-value <0.05.
Results: Both of the external compression techniques (Verbrugge and ATD) achieved significantly higher compression than the plate compression technique alone with 78% ($P < 0.001$) and 134% ($P < 0.001$) more compression respectively. The measured compression across the osteotomy after screw application and removal of external compression decreases by 17% for the Verbrugge device ($P = 0.215$) and by 22%, after removal of the ATD device ($P = 0.038$). For both techniques, adding additional screws in eccentric (load) position further increases compression.
Conclusion: Plate compression is a reliable method for inducing compression across transverse and short oblique fractures. Augmenting plate compression technique with external compression techniques (Verbrugge clamp or ATD) allows for a significantly greater compressive load to be achieved. Compression lost after removal of the external compression device indicates that the maximal compression attainable across a fracture may not be reliably maintained with standard dynamic compression plating techniques.

Introduction

Osteosynthesis using plates for fracture compression and primary bone healing is a reliable and successful method to treat simple transverse and short oblique diaphyseal fracture morphologies [1]. Mechanical compression across a fracture interface minimizes relative motion between fracture fragments and prevents microinstability and resorption, subsequently eliminating strain and maximizing the static preload [2–6].

Interfragmentary compression can be achieved with the dynamic compression design of plates via eccentric screw placement along a sloped interface. Sliding of the screw along the inclined slope at the edge of the hole during insertion produces a collinear translation of the plate, inducing compression across the fracture site [7,8]. This technique can be used either alone or in tandem with external compression techniques to apply additional load across a fracture.

Creating and maintaining compression across a fracture site with dynamic compression plating technique relies upon maintenance of the frictional interface between plate and bone [9]. Increasing frictional force serves to prevent slippage of the plate and loss of compression, however, related ischaemia does occur in the periosteum under the plate with indeterminate clinical effect [1]. Plate designs have addressed these ischaemia

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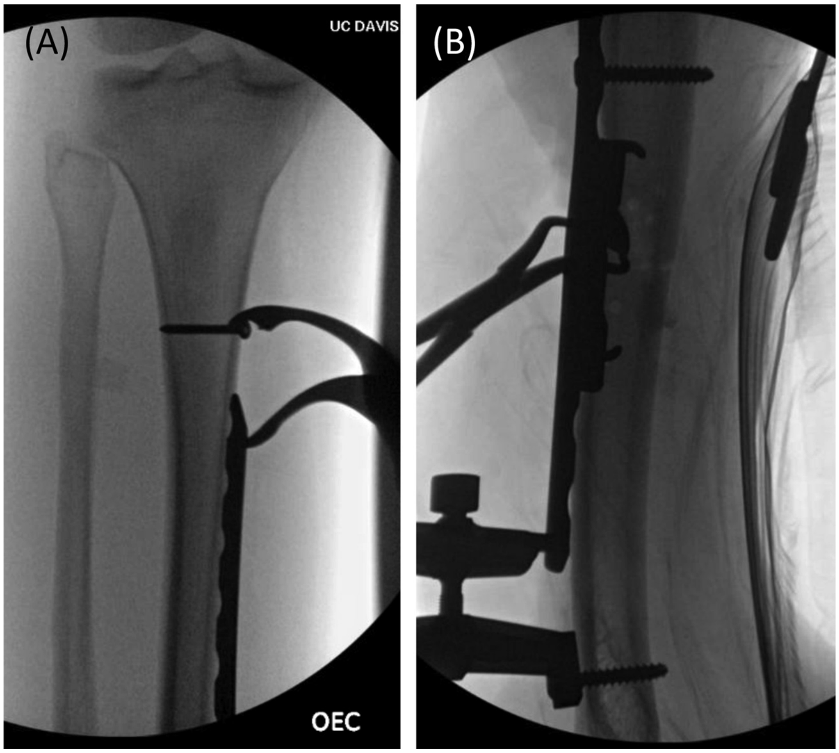

Fig. 1. Intraoperative fluoroscopic imaging of external compressive devices used to increase load across simple fracture patterns. Verbrugge clamp (A) and articulated tensioning device (B) applying compression through unilateral plate anchorage and a screw outside of the plate.

concerns with decreased plate-bone contact areas. Modern compressive plate designs including those with locking options when used with a standardized dynamic compression technique, do not significantly alter the amount of compression that can be applied across a fracture [10]. Additionally, use of an external compression device (such as a clamp or mechanical compression device) to augment compression produces a significantly greater magnitude of compressive force across the fracture site (Fig. 1).

Quantification of compression using standard techniques, including external mechanical compression devices, has not been performed. While physiologic stability is desired, the parameters for optimal compression remain elusive. Increased stability as a result of increased interfragmentary compression optimizes primary bone healing, and the magnitude of compression decreases linearly after the first week of fixation [4,9]. Mechanical interfragmentary compression does not lead to significant cortical necrosis [11].

Our aim was to quantify the compression between offset screw placements and external compression devices. We selected a transverse diaphyseal femoral fracture (OTA 32-A3.2) using three different compression techniques including compression plating with eccentric screw placement, external compression with a pull technique (clamp to screw post outside of the plate), and external compression with an articulated tensioning device. We quantified fracture compression before and after application of compression with each technique.

Materials and methods

We used fourth generation composite femoral sawbones (Pacific Research Laboratories, Inc. (Sawbones), Vashon Island, WA). We created a transverse osteotomy simulating an OTA 32-A3.2 fracture using a table saw and cutting guide. Osteotomies were created in identical locations in all specimens.

We used a load cell (Interface Inc., Scottsdale, AZ) with custom articulating end pieces to measure compressive force (Fig. 2A and B). The end pieces allowed for uniform specimen loading with respect to both cortical contact of bone segments and plate position.

We used a ten-hole, 4.5 mm narrow LCP plate (Synthes Inc., West Chester, PA) for all samples. We examined the plates for

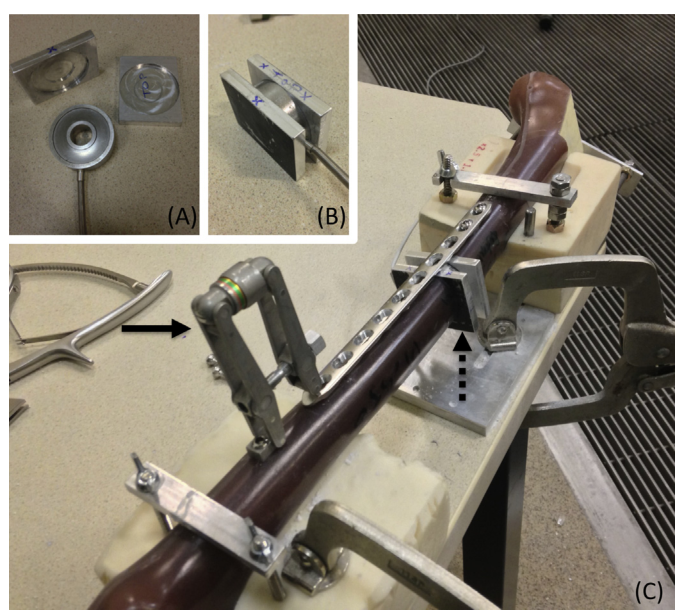

Fig. 2. Load cell components for force measurements shown separately (A) and assembled (B) with custom machined endplates. Fully assembled testing setup (C) shown with articulated tensioning device in place (solid arrow). The load cell is interposed within fracture site and compression plate is spanning both fracture and load cell (dashed arrow).