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Distal-third clavicle fracture fixation: a biomechanical evaluation of fixation

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Background: Approximately 25% of distal clavicle fractures are unstable. Unstable patterns have longer times to union and higher nonunion rates. Stable restoration of the distal clavicle is important in decreasing the nonunion rate in distal clavicle fractures. The purpose of this study was to biomechanically compare operative constructs for the treatment of unstable, comminuted distal-third clavicle fractures in a cadaveric model using a locking plate and coracoclavicular reconstruction. We hypothesized that the combination of coracoclavicular reconstruction and a distal clavicle locking plate is biomechanically superior to either construct used individually.

Materials and methods: An unstable distal clavicle fracture was created in 21 thawed fresh-frozen cadaveric specimens. The 21 specimens were divided into 3 treatment groups of 7: distal-third locking plate, acromioclavicular (AC) TightRope (Arthrex, Naples, FL, USA), and distal-third locking plate and AC TightRope together. After fixation, each specimen was cyclically tested with recording of displacement to determine the stiffness and stability of each construct, followed by load-to-failure testing in tension and compression to determine the maximum load.

Results: The combined construct of the locking distal clavicle plate and coracoclavicular reconstruction resulted in increased stiffness, maximum resistance to compression, and decreased displacement compared with either construct alone.

Conclusion: Greater fracture stability was achieved with the combination of the AC TightRope and locking clavicle plate construct than with either alone, suggesting a possibility for increased fracture-healing rates.

Level of evidence: Basic Science Study, Biomechanics, Cadaveric Model.

Keywords: Distal clavicle fracture; biomechanical; locking plate; TightRope

Distal-third clavicle fractures account for 21% to 28% of all clavicle fractures and constitute a higher proportion of complications related to clavicle fracture treatment.[44,51] Distal-third clavicle fractures tend to occur mostly in elderly individuals as a result of simple falls.[19,52] Approximately 25% of distal clavicle fractures are unstable.[44,51] Stable fracture patterns typically heal well without surgical management; however, unstable patterns have longer times to union and higher nonunion rates. For adequate visualization of a distal clavicle fracture, a Zanca radiograph is often helpful, along with a 10-lb stress view

Ethical committee: Approved by the Clinical Research Center for use of cadavers (study 08-002C).

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to analyze for integrity of the coracoclavicular (CC) ligaments.[53] Stable fixation of the distal clavicle is essential for proper support of the suspensory mechanism of the upper limb.[8,39] Historically, open reduction and internal fixation were not recommended, even though most authors have agreed that treatment by external support in adults is associated with several weeks of painful disability, prolonged rehabilitation, and loss of productivity.[4,8,55,65] Neer[41,42] found that although these fractures are rare, they account for nearly 50% of clavicle nonunions. Neer classified distal fractures as follows: (1) type I fractures occur lateral to the CC ligaments, usually with minimal displacement; (2) type II fractures occur more medial to the CC ligaments and usually result in significant displacement; (3) type IIa fractures have both the conoid and trapezoid ligaments still attached to the distal fragment; (4) type IIb fractures involve rupture of the conoid ligament with the trapezoid ligament remaining intact; and (5) type III fractures are intra-articular fractures of the acromioclavicular (AC) joint.[41] Type II distal fractures have the highest rate of nonunion,[41,42,45,54] and the rate of nonunion is high with both nonoperative and operative management.[52,54] For those fractures requiring surgical care, the operative procedure varies according to the type and location of the fracture.[17,65] Because there is no agreement on the standard of operative care for these injuries, the orthopedic surgeon continues to deal with a significant dilemma. From a biomechanical perspective, the importance of the CC ligaments in controlling superior migration has been elucidated.[34,37,38,50,54] Stable restoration of the distal clavicle is important in decreasing the nonunion rate in fractures involving the distal clavicle. Proposed treatments include CC screws,[4,34,62] tension bands,[7,10,25,56] Kirschner wires,[19,31] hook plates,[20,28] nonlocked plates,[29] and locked plates.[21,24,28,47,64]

Despite multiple methods of fixation for unstable distal clavicle fractures, no single surgical technique has been shown to be superior.[1,5] Transacromial wire fixation has been associated with high rates of complications including nonunion, AC arthrosis, symptomatic hardware, and Kirschner wire migration into the cervical spine, trachea, vascular structures, lung, and abdomen.[3,14,26,30,31,33,35,49,59] Tension band techniques have had mixed results.[11,26] Several case series have reported successful union rates with open reduction and internal fixation of the proximal clavicle fragment to the coracoid process such as with a cannulated screw, but such procedures do require additional surgery for hardware removal before screw failure.[4,13,16,23,34,62] Satisfactory results have been obtained with use of the Knowles pin placed transacromially, especially with CC ligament repair or reconstruction.[7,10,15,60] Transacromial fixation with a threaded Knowles pin is more secure than that with a smooth pin and avoids medial pin migration, although there was asymptomatic radiographic lucency around the pin and asymptomatic lateral migration of the pin at the time of removal.[15]

Small series have reported successful techniques for CC repair or reconstruction.[6,9,18,32,43,46,48,56,61,63] These all address the superiorly directed forces. The use of plates has evolved in the care of distal clavicle fractures. Earlier in distal clavicle fracture repair, small locking plates, such as distal radius locking plates, were successfully used to secure the distal fragment without disrupting the AC joint.[25] There are now contoured locking plates designed for the distal clavicle. However, the plates do not oppose the superiorly directed forces and can result in complications including periprosthetic fracture, screw loosening, deep infection, and malunion, albeit these are not common.[1] A more common complication is prominent hardware necessitating removal after union.[1] AC hook plates have also been used successfully to treat distal clavicle fractures that are too small for distal screw purchase. In limited series, hook plates have been more successful when compared with other methods of fixation.[17,22,30] However, these plates have been associated with complications, including acromion fracture, osteolysis of the acromion, and rotator cuff tear.[28] The hook plate also commonly requires an additional surgery for removal.[27,40,57] A systematic review of 425 cases by Oh et al[47] found no clear evidence for a superior fixation method, but the study noted higher complication rates with K-wires with wire tension band fixation, as well as the hook plate.

To date, although limited data are available, acromial hook plating has the most supportive evidence. Acromial hook plates prevent superior translation of the clavicle while providing stable fixation of the fracture. The downside to the hook plate is related to its position under the acromion, causing osteolysis, fracture, and occasionally, rotator cuff tears. We propose using the TightRope (Arthrex, Naples, FL, USA) to add fixation to the coracoid in addition to a distal clavicle locking plate. This method should both achieve stable fixation of the fracture and oppose the superiorly directed forces on the clavicle while avoiding complications of the subacromial hook.

The purpose of this study was to compare operative constructs for the treatment of unstable, comminuted distal-third clavicle fractures in a cadaveric model. The study has 3 arms: (1) distal-third clavicle superior locking plate (109 mm in length) (Smith & Nephew, Memphis, TN, USA); (2) AC TightRope; and (3) combination of the distal-third locking plate and AC TightRope. We hypothesized that the combination of the AC TightRope and distal clavicle locking plate is biomechanically superior to either construct used individually in the treatment of unstable distal-third clavicle fractures.

Materials and methods

Twenty-one fresh-frozen cadaveric specimens were divided into three groups of seven. Before device implantation and testing, each specimen was allowed to thaw for 24 hours at room temperature, and all soft-tissue attachments were removed. Radiographic evaluation of each specimen was used to ensure the absence of prior