Is plating of mid-shaft clavicular fractures possible with a conventional straight 3.5 millimeter locking compression plate?

Wolfgang GRECHENIG[1], Nima HEIDARI[2], Ottmal LEITGOEB[1], Walter PRAGER[1], Wolfgang PICHLER[1], Annelie M. WEINBER[2]

[1]Departments of Traumatology, and [2]Pediatric and Adolescent Surgery, Medical University of Graz, Graz, Austria

Objective: Current literature describes improved clinical outcomes and a minor rate of pseudoarthrosis following operatively treated clavicular fractures. We investigated the feasibility of using a standard 3.5 mm AO locking compression plate (LCP) of adequate length for the stabilisation of mid-shaft fractures of the clavicle.

Methods: The length and acromial and diaphyseal curvature depths were measured in 49 cadaveric clavicles. We then assessed how well the 6, 7, 8 and 9-hole plates fit on the clavicles.

Results: The mean clavicular length was 155±12 mm, with a mean acromial curvature of 18.1± 3.7 mm and a mean diaphyseal curvature of 12 mm±4 mm. The optimum plate for the clavicle was a 7-hole LCP, providing adequate fixation in 48 of the 49 clavicles.

Conclusion: The described technique for plate osteosynthesis of the clavicle with AO locking compression plate is feasible and results in a biomechanically strong construct for mid-shaft fractures. With the use of a locking plate, comminuted fractures may be bridged without a reduction in the strength of the construct.

Key words: Clavicle; fracture; locking compression plate; osteosynthesis.

Prior to the mid 1990s, the clinical results of conservatively treated mid-shaft clavicular fractures were reported as very good, and the rate of pseudoarthrosis as extremely rare.[1,2] This is not the common view currently held by many experts, as malunion is associated with residual deficits in shoulder strength and endurance. Recent studies have identified risk factors for progression of clavicular fractures to nonunion.[3,4] There is an association between clavicular shortening and reduced abduction and strength.[5] This is a significant problem in patients, whose jobs or sports require overhead activities. Recent studies report better clinical outcomes and reduced rates of pseudoarthrosis after surgical treatment of clavicular fractures.[6,7] The techniques describe osteosynthesis by either superior or anteroinferior placement of the plate. Some authors advocate the superior plate position as more biomechanically stable, while others have shown good clinical results with 3-dimensional contouring of reconstruction plates.[8] Although easier to contour, reconstruction plates are mechanically weaker.[9] Angularly stable implants have mechanical benefits because they do not require contouring or direct contact with the bone (Fig. 1).[10] Anatomically
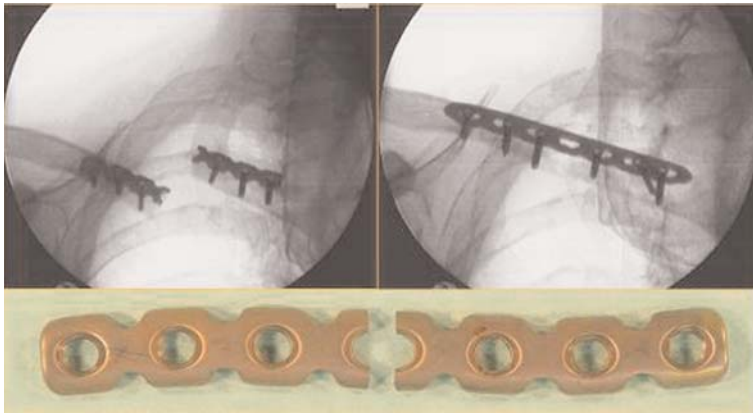
pre-contoured locking plates are now available for fixation of clavicular fractures. They are more costly than standard dynamic compression plates (DCP) and reconstruction plates. A recent study has shown, while these plates fit in the medial three-fifths of the clavicle, they do not fit as well laterally.[11]

We investigated the feasibility of using a standard 3.5 mm AO locking compression plate (LCP) for the stabilization of mid-shaft clavicular fractures. These inexpensive implants are more stable than the reconstruction plates and reduce the likelihood of implant failure.

Materials and methods

For this study, a total of 49 cadaveric clavicles were used. We performed the following three measurements for each clavicle using an osteometric board (Fig. 2):
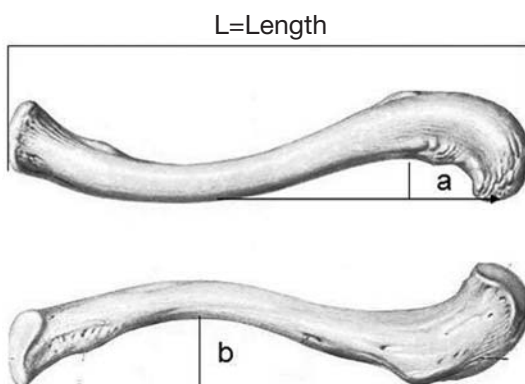

Fig. 2. Anatomical measurements of the clavicle. The top image shows the cranial surface of the clavicle with length (L) and acromial curvature (a). The bottom image is of the caudal surface of the clavicle with the diaphyseal curvature (b) indicated.

1. Length (L) was measured as the distance between the sternal and acromial ends of the clavicle.

2. Acromial curvature (a) was measured as the rectilinear distance from a line connecting the anterior tip of the acromial end of the clavicle and the anterior apex of its diaphyseal curve to the apex of the concavity of the acromial end of the clavicle.

3. Diaphyseal curvature (b) was measured as the rectilinear distance from a line connecting the posterior aspect of the sternal end of the clavicle with the posterior aspect of the convexity of the acromial end to the apex of the concavity of the medial diaphyseal curvature.

We then assessed how well four different lengths of standard 3.5 mm AO locking compression plate fit on all of the 49 clavicles. These included the 6-hole (85 mm), 7-hole (98 mm), 8-hole (111 mm) and 9-hole (124 mm) plates. The plates were positioned on the superior aspect of the clavicle so that the middle third was bridged by the plate. The clavicle was then drilled and the plate screwed onto the bone. A plate was accepted as a good fit if three screws could be safely applied through either side of a mid-shaft fracture. In the case of the presence of comminution, or a butterfly fragment, two screws were also acceptable when they were positioned through the middle of the bone. We also recorded the distance (in millimeters) between the plate and the bone at the medial and lateral ends of the plate.

Results

Our research was performed on 49 clavicles (29 left and 20 right). The mean length was 155±12 mm, the mean acromial curvature was 18.1±3.7 mm and the mean diaphyseal curvature was 12±4 mm.

In 48 of the 49 clavicles, the optimum clavicular plate was a 7-hole LCP, providing adequate fixation with either two or three screws placed in the middle of the bone on either side of a mid-shaft fracture (Fig. 3). In only one clavicle, the shortest in this series, the optimal fixation was achieved with a 6-hole LCP. Interestingly, the 6-hole plate was a good fit in 5 (10.2%) clavicles. In 37 (76%), clavicles an 8-hole LCP, and in 27 (55%), a 9-hole plate were safely applied.

In 17 clavicles (34.7%), the plate stood off the superior surface of the bone medially by a mean of 2.47±1.28 mm. In 18 (36.7%) clavicles, the plate stood off the superior surface of the bone laterally by a mean of 2.72±1.13 mm. In 5 (10.2%) clavicles, the plate stood off the superior surface of the bone in the middle by a mean of 2.80 ± 1.30 mm (Fig. 4). In 49 clavicles (100%), the plate reached the acromial end, and in 40 (81.6%), the plate reached the sternal end of the clavicle.

Discussion

Traditionally, fractures of the clavicle have been treated conservatively. Early studies reported very low rates of non-union. Neer, in a series of 2235 patients with midshaft fractures, found that only 0.13% of the patients had non-union.[2] Another non-union rate of 0.8% was reported by Rowe in his series of 566 fractures.[1] Hill et al. showed a 15% rate of non-union in displaced mid-shaft fractures, with up to 31% unsatisfactory results.[4] A study by McKee et al. demonstrated an association between clavicular shortening and reduced range of motion at the shoulder, as well as reduced endurance and strength.[5] This can be improved by a correctional osteotomy of the clavicle, which can lead to a better functional outcome.[12] A more unusual complication of clavicular malunion includes thoracic outlet syndrome.[13,14] Robinson et al. reported on the risk factors leading to non-union.[3] They found advancing age, female gender, fracture comminution and displacement to be predictive factors of non-union. Although another study by Nowak et al. did not show gender as a risk factor, they confirmed lack of bony contact on radiographs, advanced age, and comminution as the risk factors for non-union.[15] A review of the current literature has failed to provide a definitive method of fixation for the fractures of the middle-third of the clavicle.[16]

There is supporting evidence, favoring operative treatment of clavicular fractures, particularly in high demand patients, requiring overhead activity for their job or sporting activities. A recent randomized multi-center trial has demonstrated faster union,

Fig. 3. Clavicle osteosynthesis with a 7-hole LCP. [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]
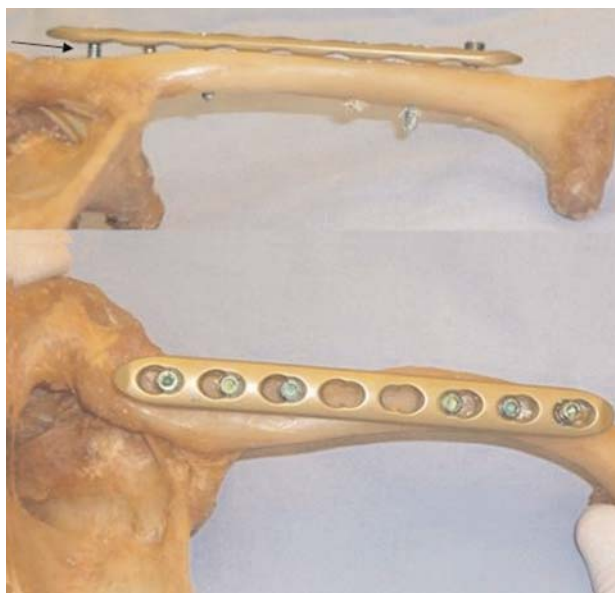

Fig. 4. The longer plates stood off the cranial surface of the clavicle (arrow). [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

improved function and patient satisfaction following open reduction and internal fixation.[6,7]

The AO reconstruction plate can be easily contoured. Some authors advocate three-dimensional contouring of this plate, with the plate contoured to fit the acromial end on its superior surface and then sweeping over onto the anterior surface at the sternal end.[9] However, this technique's main disadvantage is the fatigue failure risk, compared to the standard 3.5 mm LCPs.

Anatomically pre-contoured locking clavicle plates are available. They come in different shapes and sizes for varied clavicular anatomies. In a recent study, Huang et al. demonstrated while these plates fit in the medial three-fifths of the clavicle, they do not fit as well laterally.[11] Our anatomical study confirmed the varied shape of the clavicle in both of its curvatures as well as its length. Data presented in this study shows that in all of the specimens (49 clavicles) a straight, standard 3.5 mm LCP can be applied without contouring. This technique has not been previously described and we are not aware of any clinical reports of its use. It requires placement of three screws (uni- or bicortically) in the medial and lateral ends of the clavicle, on either side of the fracture. The 7-hole plate was sufficient in 48 of 49 clavicles (98%) with the fracture being within one centimeter from the middle of the clavicle. In 5 of 49 clavicles (10.2%) it was possible to a use a 6-hole plate. Comminuted fracture extending over 2 cm could be bridged with a 8 or 9-hole plate, but insertion of 3 locking screws was not possible in more than 50% of these cases. Although it is feasible to place only two locking screws on either side of the fracture, there is no evidence supporting this technique in the literature.

The limitation of the current study was that it was performed on intact cadaveric clavicles. Further clinical studies are required to compare the outcome of this technique with those already established. This technique is most suitable for the middle-third fractures, which make up 76% of all fractures of the clavicle.[17]

Clavicular shortening and malunion can lead to a poor clinical outcome in patients with clavicular fractures. There is a tendency to perform surgical fixation for these fractures, especially in those who perform a great deal of overhead activities. In principle, the technique described here for plate osteosynthesis of the clavicle is feasible and results in a biomechanically strong construct for mid-shaft fractures.[9,18] Although we did not perform biomechanical testing of the specimens in this study, the biomechanical advantage of locking plates has been previously shown.[19] With the use of this locking plate, comminuted fractures may be bridged without weakening the construct. However, in longer and more curved clavicles, this technique becomes more complicated, with increasing tendency for the plate to stand off the bone. In these circumstances, it may be prudent to revert to other implants, such as reconstruction plates.

Conflicts of Interest: No conflicts declared.

References

1. Rowe CR. An atlas of anatomy and treatment of midclavicular fractures. Clin Orthop Relat Res 1968;(58):29-42.

2. Neer C. Non-union of the clavicle. J Am Med Assoc 1960;172:1006-11.

3. Robinson CM, Court-Brown CM, McQueen MM, Wakefield AE. Estimating the risk of non-union following non-operative treatment of a clavicular fracture. J Bone Joint Surg Am 2004;86:1359-65.

4. Hill JM, McGuire MH, Crosby LA. Closed treatment of displaced middle-third fractures of the clavicle gives poor results. J Bone Joint Surg Br 1997;79:537-9.

5. McKee MD, Pedersen EM, Jones C, Stephen DJ, Kreder HJ, Schemitsch EH, et al. Deficits following non-operative treatment of displaced midshaft clavicular fractures. J Bone Joint Surg Am 2006;88:35-40.

6. Altamimi SA, McKee MD; Canadian Orthopaedic Trauma Society. Non-operative treatment compared with plate fixation of displaced midshaft clavicular fractures. Surgical technique. J Bone Joint Surg Am 2008;90 Suppl 2 Pt 1:1-8.

7. Canadian Orthopaedic Trauma Society. Non-operative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. J Bone Joint Surg Am 2007;89:1-10.

8. Celestre P, Roberston C, Mahar A, Oka R, Meunier M, Schwartz A. Biomechanical evaluation of clavicle fracture plating techniquees: does a locking plate provide improved stability? J Orthop Trauma 2008;22:241-7.

9. Shen JW, Tong PJ, Qu HB. A three-dimensional reconstruction plate for displaced midshaft fractures of the clavicle. J Bone Joint Surg Br 2008;90:1495-8.

10. Robertson C, Celestre P, Mahar A, Schwartz A. Reconstruction plates for stabilization of mid-shaft clavicle fractures: differences between non-locked and locked plates in two different positions. J Shoulder Elbow Surg 2009;18:204-9.

11. Huang JI, Toogood P, Chen MR, Wilber JH, Cooperman DR. Clavicular anatomy and the applicability of precontoured plates. J Bone Joint Surg Am 2007;89:2260-5.

12. Chan KY, Jupiter JB, Leffert RD, Marti R. Clavicle malunion. J Shoulder Elbow Surg 1999;8:287-90.

13. Chen DJ, Chuang DC, Wei FC. Unusual thoracic outlet syndrome secondary to fractured clavicle. J Trauma 2002;52:393-8.

14. Fujita K, Matsuda K, Sakai Y, Sakai H, Mizuno K. Late thoracic outlet syndrome secondary to malunion of the fractured clavicle: case report and review of the literature. J Trauma 2001;50:332-5.

15. Nowak J, Holgersson M, Larsson S. Can we predict long-term sequelae after fractures of the clavicle based on initial findings? A prospective study with nine to ten years of follow-up. J Shoulder Elbow Surg 2004;13:479-86.

16. Lenza M, Belloti JC, Gomes Dos Santos JB, Matsumoto MH, Faloppa F. Surgical interventions for treating acute fractures or non-union of the middle third of the clavicle. Cochrane Database Syst Rev 2009:CD007428.

17. Nordqvist A, Petersson C. The incidence of fractures of the clavicle. Clin Orthop Relat Res 1994:(300):127-32.

18. Iannotti MR, Crosby LA, Stafford P, Grayson G, Goulet R. Effects of plate location and selection on the stability of midshaft clavicle osteotomies: a biomechanical study. J Shoulder Elbow Surg 2002;11:457-62.

19. Wagner M. General principles for the clinical use of the LCP. Injury 2003;34 Suppl 2:B31-B42.