Low-Profile Dual Small Plate Fixation Is Biomechanically Similar to Larger Superior or Anteroinferior Single Plate Fixation of Midshaft Clavicle Fractures

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Background: Limited biomechanical data exist for dual small plate fixation of midshaft clavicle fractures, and no prior study has concurrently compared dual small plating to larger superior or anteroinferior single plate and screw constructs.

Purpose: To biomechanically compare dual small orthogonal plating, superior plating, and anteroinferior plating of midshaft clavicle fractures by use of a cadaveric model.

Study Design: Descriptive laboratory study.

Methods: The study used 18 cadaveric clavicle specimens (9 pairs total), and 3 plating techniques were studied: anteroinferior, superior, and dual. The dual plating technique used smaller diameter plates and screws (1.6-mm thickness) than the other, single plate techniques (3.3-mm thickness). Each of the 9 clavicle pairs was randomly assigned a combination of 2 plating techniques, and randomization was used to determine which techniques were used for the right and left specimens. Clavicles were plated and then osteotomized to create an inferior butterfly fracture model, which was then fixed with a single interfragmentary screw. Clavicle specimens were then potted for mechanical testing. Initial bending, axial, and torsional stiffness of each construct was determined through use of a randomized nondestructive cyclic testing protocol followed by load to failure.

Results: No significant differences were found in cyclical axial (P = .667) or torsional (P = .526) stiffness between plating groups. Anteroinferior plating demonstrated significantly higher cyclical bending stiffness than superior plating (P = .005). No significant difference was found in bending stiffness between dual plating and either anteroinferior (P = .129) or superior plating (P = .067). No significant difference was noted in load to failure among plating methods (P = .353).

Conclusion: Dual plating with a smaller plate-screw construct is biomechanically similar to superior and anteroinferior single plate fixation that uses larger plate-screw constructs. No significant differences were found between dual plating and either superior or anteroinferior single plating in axial, bending, or torsional stiffness or in bending load to failure. Dual small plating is a viable option for fixing midshaft clavicle fractures and may be a useful low-profile technique that avoids a larger and more prominent plate-screw construct.

Clinical Relevance: Plate prominence and hardware irritation are commonly reported complaints and reasons for revision surgery after plate fixation of midshaft clavicle fractures. Dual small plate fixation has been used to improve cosmetic acceptability, minimize hardware irritation, and decrease reoperation rate. Biomechanically, dual small plate fixation performed similarly to larger single plate fixation in this cadaveric model of butterfly fracture.

Keywords: dual plating; clavicle fracture open reduction internal fixation; midshaft clavicle fracture

Clavicle fractures represent up to 10% of all sports-related fractures[32]: 2% to 5% of all fractures in adults and 10% to 15% of all fractures in children. Clavicle fractures are prevalent in athletes, with several high-profile cases from professional cycling and the National Football League (NFL).[7,15,28] The treatment paradigm has changed dramatically over the past decade with expanded surgical indications following numerous high-quality randomized controlled studies reporting improved patient and surgeon-based outcomes, significantly decreased rates of nonunion and symptomatic

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malunion, and shorter time to union with open reduction internal fixation compared with nonoperative treatment.[2,20,25,33,36,44,45] In athletes, high return rate, faster return to play, and excellent patient-reported outcomes have been reported after fixation.[2,18,19,24,31,32,42,45]

Although various fixation methods of midshaft clavicle fractures have been described, plate fixation remains the most established method, including superior plating, anteroinferior plating, and, more recently, dual small plate fixation.[29,35] Plate prominence and hardware irritation are commonly reported complaints and reasons for revision surgeries.[2,33,41] In contrast, higher patient cosmetic acceptability has been reported with small single plate fixation compared with larger, more prominent plates (95% vs 50%,[12] respectively). More recently, excellent clinical outcomes, 100% union rate, and 0% reoperation rate have been reported with dual small plate fixation.[4,29] This has spurred interest in less prominent techniques, including dual small plating, to minimize hardware irritation and reoperation rates.

Favorable biomechanics have been reported with dual small orthogonal plating in a synthetic midshaft clavicle fracture model when compared with a previous study of single-plate constructs.[29] Although numerous studies have compared single plate fixation techniques[3,12,14,17,27,39] and plating versus intramedullary fixation[8,16,37,43] of midshaft clavicle fractures, limited biomechanical data exist comparing dual small plating concurrently with standard superior or anteroinferior single plate fixation. Moreover, most clavicle studies have used a transverse fracture model, which is a less common pattern seen clinically.

The purpose of this study was to compare the biomechanics of 3 methods of plate fixation in a clinically relevant, cadaveric midshaft butterfly fragment fracture model using implants common in modern orthopaedic practice. Our hypothesis was that dual small plate fixation would provide values for axial, bending, and torsional stiffness as well as ultimate failure load that were similar to more common anteroinferior and superior precontoured single plating techniques.

METHODS

Specimen Preparation

The study used 18 match-paired male cadaveric clavicle specimens (9 pairs) with a mean age of 56 years (range, 47-64 years). Institutional review board approval was not required because deidentified cadaveric specimens are exempt from review at our institution. The allocation of treatment choice for each specimen followed a balanced incomplete block design, which is the optimal design in the setting of 3 treatment groups split across right and left specimen pairs. Assuming 6 specimens per group, 2-tailed hypothesis testing, and an alpha level of .05, the sample size was sufficient to detect an effect size between d = 1.5 (randomized complete block design) and d = 1.8 (independent analysis of variance [ANOVA]) with 80% statistical power. Each paired clavicle was randomly assigned to be treated with either the anteroinferior, superior, or dual plate, so that each paired treatment combination occurred the same number of times. Our sample size was determined through a balanced incomplete block design, which achieves a statistical efficiency between that of a randomized complete block design and an independent-samples ANOVA.

Specimens were stored at −20° Celsius and thawed to room temperature before testing. Each clavicle was measured with a ruler to identify the midpoint along the longitudinal axis, and a 2-cm inferior butterfly fracture fragment was created with the apex at this location by use of a mini-sagittal saw after first plating. A butterfly fragment was created to simulate fracture comminution, which is commonly seen clinically with midshaft clavicle fractures. The apex of this butterfly fragment was located at the superior aspect of the clavicle with the butterfly fragment extending 1 cm lateral and 1 cm medial to the apex/midpoint along the inferior surface (Figure 1B). Since no soft tissue stabilizing structures were present, including muscular attachments and periosteum, plating the specimens first allowed for controlled and reproducible osteotomy and reproducible fixation with restoration of length, alignment, and rotation. Moreover, the butterfly fragment could be adequately compressed and reduced with clamps to the plate(s) while maintaining length, alignment, and rotation, thus allowing for more controlled reduction.

Fixation Technique

The 3 treatment groups (n = 6 per group) included (1) superior plating with an 8-hole, precontoured, large bend titanium clavicle plate (98 mm length, 11 mm width, 3.3 mm thickness); (2) anteroinferior plating with an 8-hole, precontoured, titanium clavicle plate (95 mm length, 11 mm width, 3.3 mm thickness); and (3) dual small plating with two 7-hole titanium plates placed orthogonally (85 mm length, 11 mm width, 1.6 mm thickness) (all plates and screws made by Acumed). The dual plating construct

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Figure 1. (A) Right clavicle plated superiorly by use of an 8-hole titanium precontoured clavicle plate (98 × 11 × 3.3 mm) fixed with a total of six 3.5-mm cortex screws placed bicortically and a 2.3-mm interfragmentary (IF) screw for the inferior butterfly fragment. (B) Right clavicle dual plated with a 7-hole titanium 2.7-mm plate (85 × 11 × 1.6 mm) positioned superiorly and another 7-hole 2.7-mm plate positioned anteroinferiorly. A total of four 2.7-mm cortex screws placed bicortically were used for each plate (8 screws total) along with a 2.3-mm IF screw for the inferior butterfly fragment. This image demonstrates the inferior 2-cm butterfly fragment with the apex of the fragment located at the center of the clavicle. (C) Right clavicle plated anteroinferiorly by use of an 8-hole titanium precontoured clavicle plate (95 × 11 × 3.3 mm) fixed with a total of six 3.5-mm cortex screws placed bicortically and a 2.3-mm IF screw for the inferior butterfly fragment.

consisted of 1 plate positioned superior and a second plate positioned anteroinferior. The butterfly fragment was reduced with a reduction clamp, and a drill hole was made perpendicular to the fracture in a superomedial to inferolateral trajectory by use of a 2.0-mm drill bit. While reduction was maintained with the clamp, a single 2.3-mm interfragmentary screw was placed bicortically through the fragment for all specimens across all plating constructs. The interfragmentary screw did not interdigitate with the plate(s). This process remained consistent between all groups. Plates were fixed to the clavicles by use of standard compression plating technique with three 3.5-mm cortex screws placed bicortically in the medial and lateral fragments of both the superior and anteroinferior plating groups for a total of 6 screws (Figure 1A, 1C). For the dual plating group, two 2.7-mm cortex screws were placed through each plate bicortically on either side of the fracture for a total of 4 screws per plate and 8 screws for the construct (Figure 1B). Precontoured 3.5-mm clavicle plates were used to more closely simulate current orthopaedic practice. The dual 2.7-mm plates were standard small plates not specific to clavicle fixation. No implants were reused, and minimal plate contouring was performed by use of standard plate benders. The order of screw placement was consistent for all clavicle specimens in each group. The described use of the small plate fixation (Acumed LLC, LPL Fibula Plates), while not standard for clavicle fixation, was used here to understand how applicable the construct design may be for the dual plating technique.

Biomechanical Testing

Plated clavicles were stripped of all soft tissue at both the medial and lateral ends including the acromioclavicular and sternoclavicular joint soft tissue structures. The central 10 cm of clavicle was left exposed on each specimen, and the remaining medial and lateral portions of the clavicle were potted in poly (methyl methacrylate) (PMMA) (Fricke Dental International). Further, 2 screws were placed in the medial and lateral ends to improve the PMMA hold on the clavicle. For all specimens, the orientation of potting was parallel to the respective end of the clavicle rather than in a straight line parallel to the long axis of the clavicle. This was done to reflect the natural anatomic curvature of the clavicle and ensure that biomechanical loading on each clavicle was done in an anatomic manner. None of the plate-screw constructs overlapped with the potted regions.

Biomechanical testing was performed in a dynamic tensile testing machine with custom-made fixtures (Instron ElectoPuls E10000; Instron Systems). Before loading the clavicles to failure, the initial bending, axial, and torsional stiffness of each construct was determined by use of a nondestructive cyclic testing protocol. The order of the nondestructive tests was randomized for each specimen. For axial and torsional testing, the potted medial end of the clavicle was rigidly mounted to the testing table in a custom fixture and aligned parallel to the actuator. The potted lateral end of the clavicle was mounted vertically to a custom jig attached to the actuator (Figure 2). Nondestructive axial testing was performed by compressing each clavicle between 10 and 315 N at 0.25 Hz for 10 cycles. Nondestructive torsional testing was performed along the long axis of the clavicle by torquing each clavicle between +2 N·m/deg and −2 N·m/deg at 0.25 Hz for 10 cycles. The initial axial and torsional stiffness was measured during the final cycle of the test.

For cyclic bending and load-to-failure testing, the medial end of the clavicle was mounted perpendicular to the actuator in a custom fixture and rigidly fixed to the testing table (Figure 2). The 3-point cyclic bending test was performed by placing a small metal bar directly inferior to the clavicle and 1 cm medial to the fracture site to serve as the fulcrum for the 3-point bending test (Figure 2). The fulcrum was placed 1 cm medial to the fracture site because the butterfly fragment was the weakest point of each construct and tended to fail in pilot testing before any observed failure in the construct. By adjusting the position of the fulcrum, we were able to better assess construct biomechanics. Force was applied through a horizontal bar attached to the actuator at 10 cm distal to the fulcrum. For nondestructive bending, specimens were

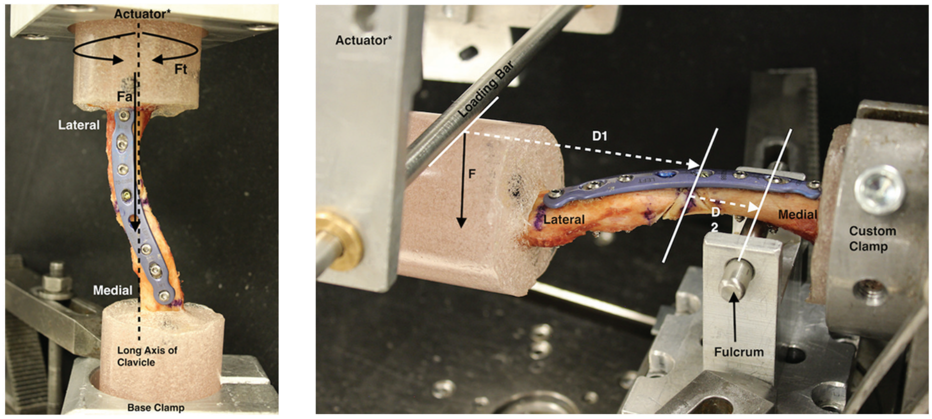

Figure 2. Biomechanical testing setup for nondestructive cyclical axial (N/mm) and torsional (N·m/deg) stiffness testing (left), as well as cyclical bending stiffness (N/mm) and load to failure (N) (right).

cyclically loaded from 10 to 60 N at 0.25 Hz for 10 cycles, and the initial bending stiffness was recorded during the final cycle. To assess the ultimate bending load to failure tests were set up identically to the cyclic bending tests, and specimens were loaded at a rate of 15 mm/min until a fracture was observed either audibly or visually by 2 observers (Z.S.M. and H.W.S.). Ultimate load to failure was calculated algorithmically as the instantaneous peak load value immediately preceding a 5% drop-off in the peak load, which was maintained for at least 0.1 mm of compression.

Statistical Analysis

The experimental design was a balanced incomplete block design (Table 1), and the data were analyzed with the corresponding ANOVA technique. To address the primary hypotheses that plating techniques would differ with respect to construct stiffness and failure load, pairwise group comparisons were made among the estimated marginal means with the Tukey method. All statistical analyses were performed with the statistical package R version 3.5.0.[21,30]

TABLE 1
A Priori Balanced Incomplete Block Design Randomization

Pair	Left	Right
Pair 1	Dual	Superior
Pair 2	Anteroinferior	Dual
Pair 3	Superior	Anteroinferior
Pair 4	Anteroinferior	Dual
Pair 5	Superior	Anteroinferior
Pair 6	Dual	Superior
Pair 7	Anteroinferior	Dual
Pair 8	Dual	Superior
Pair 9	Superior	Anteroinferior

RESULTS

Axial Cyclic Loading

Initial axial stiffness results are listed in Table 2. No significant differences were found in axial stiffness among plating methods (P = .667).

Bending Cyclic Loading

Initial bending stiffness results are listed in Table 3. Anteroinferior plating resulted in significantly higher bending stiffness than superior plating (P = .005). No significant differences were found in bending stiffness between dual plating and either anteroinferior (P = .129) or superior plating (P = .067).

Torsional Cyclic Loading

Initial torsional stiffness results are listed in Table 4. No significant differences were noted in torsional stiffness among plating methods (P = .526).

Three-Point Load to Failure

Failure was determined visually with a fracture and audible break, which was always accompanied by a sudden drop in force measurement. Results are listed in Table 5. No significant differences in load-to-failure values were found among plating methods (P = .353).

Mode of Failure

The most common mode of failure for the superior plating group occurred at the interfragmentary screw through a horizontal split fracture of the butterfly fragment (n = 4). For the anteroinferior plating group, all failures occurred by fracture at the bone-screw interface of at least 1 of 3 screws medial to the butterfly fracture (n = 6). The most common mode of failure for the dual plating group was failure at the bone-screw interface of the most medial

TABLE 2
Axial Stiffness (N/mm) by Plating Technique[a]

	EM Mean	SE	Low CI	High CI	Tukey
Superior	971.35	69.71	806.51	1136.18	A
Dual	1020.01	69.71	855.17	1184.84	A
Anteroinferior	924.60	69.71	759.76	1089.43	A

[a]Techniques that share a Tukey group label are not statistically significantly different from one another ($P > .05$). EM Mean, estimated marginal mean; High CI, upper limit of 95% CI; Low CI, lower limit of 95% CI.

TABLE 3
Bending Stiffness (N/mm) by Plating Technique[a]

	EM Mean	SE	Low CI	High CI	Tukey
Superior	6.75	1.96	2.12	11.38	B[b]
Dual	14.65	1.96	10.02	19.28	AB
Anteroinferior	21.18	1.96	16.55	25.81	A

[a]Techniques that share a Tukey group label are not statistically significantly different from one another ($P > .05$). EM Mean, estimated marginal mean; High CI, upper limit of 95% CI; Low CI, lower limit of 95% CI.
[b]B, anteroinferior plating resulted in significantly higher bending stiffness than superior plating ($P = .005$).

TABLE 4
Torsional Stiffness (N·m/deg) by Plating Technique[a]

	EM Mean	SE	Low CI	High CI	Tukey
Superior	0.58	0.10	0.34	0.83	A
Dual	0.46	0.10	0.22	0.71	A
Anteroinferior	0.64	0.10	0.39	0.88	A

[a]Techniques that share a Tukey group label are not statistically significantly different from one another ($P > .05$). EM Mean, estimated marginal mean; High CI, upper limit of 95% CI; Low CI, lower limit of 95% CI.

TABLE 5
Load to Failure (N) by Plating Technique[a]

	EM Mean	SE	Low CI	High CI	Tukey
Superior	201.03	21.62	149.92	252.15	A
Dual	156.01	21.62	104.89	207.12	A
Anteroinferior	196.86	21.62	145.75	247.98	A

[a]Techniques that share a Tukey group label are not statistically significantly different from one another ($P > .05$). EM Mean, estimated marginal mean; High CI, upper limit of 95% CI; Low CI, lower limit of 95% CI.

screw of the anteroinferior plate (n = 3). Results for the modes of failure are listed in Table 6.

DISCUSSION

The principal finding of this study is that dual small plate fixation is biomechanically similar to superior and anteroinferior single plate fixation with larger precontoured clavicle plates. No significant differences were noted in cyclical axial, bending, or torsional stiffness between dual plating and either superior or anteroinferior single plating. Anteroinferior plating demonstrated significantly higher bending stiffness than superior plating ($P = .005$) but no significant difference compared with dual plating. This study used match-paired cadaveric specimens randomized into testing groups and used a clinically relevant butterfly fragment fracture model to simulate comminution. Although other studies have assessed the biomechanics of single plating with precontoured clavicle plates like those used in our study,[6,13,14,37,39] this study compared the biomechanics of dual small plate fixation with the more common precontoured single plate techniques: superior or anteroinferior. To our knowledge, no prior study has biomechanically

TABLE 6
Mode of Failure by Plating Technique[a]

Clavicle Pair	Fracture at Butterfly	Fracture Bone-Screw Interface
Pair 1		
Dual		Most medial screw of anterior plate.
Superior		Third screw from medial side.
Pair 2		
Anteroinferior		Second screw from medial side.
Dual		Most medial screw of anterior plate.
Pair 3		
Superior	IF screw pullout.	
Anteroinferior		Second and third screws from medial side.
Pair 4		
Anteroinferior		Posterior fracture, screws 1-3 medially.
Dual		Most medial screw of superior plate.
Pair 5		
Superior	Split through IF screw.	
Anteroinferior	Split through IF screw and third screw from medial side.	
Pair 6		
Dual		Fracture between most medial screws of superior/anteroinferior plates.
Superior		Posterior fracture extending from IF screw.
Pair 7		
Anteroinferior		Second screw from medial side.
Dual	Split through IF screw.	
Pair 8		
Dual	Split through IF screw.	
Superior	Split through IF screw	
Pair 9		
Superior	Split through IF screw.	
Anteroinferior	Split through IF screw.	

[a]IF, interfragmentary.

compared single small plate fixation (plates using 2.7 mm screws or smaller) to dual small plate fixation with plates similar to those used in our study.

Although another study has assessed clavicle fracture dual plating,[32] the investigators used a simple transverse oblique midshaft fracture model in synthetic clavicles. Prasarn et al[29] compared dual small orthogonal plating in a synthetic midshaft clavicle fracture to previously published data by their group evaluating single-plate constructs. They reported no significant differences between the dual plating and larger single plating constructs with respect to axial loading or torsion. In 4-point bending analysis, when loaded anteriorly, dual plating was significantly more rigid than a single locked anterior plate but less rigid than a single locked superior plate. When loaded superiorly, the dual plating construct reportedly had similar rigidity compared with a single locked superior plate but was significantly less rigid than a single locked anterior plate. In addition to using synthetic clavicles, the transverse fracture model is an atypical pattern clinically. Moreover, the investigators compared dual plating data with their previously published data on single-plate constructs rather than making a concurrent comparison.

Cosmetic and functional concerns with prominent hardware and efforts to minimize hardware-related complications necessitating revision surgery have spurred interest in lower profile methods of fixation including dual small plate fixation. This method may be particularly beneficial in female patients with bra straps, thinner athletes, or athletes who wear shoulder pads because prominent hardware can cause irritation under this equipment, necessitating hardware removal. In randomized prospective studies, hardware prominence requiring subsequent implant removal was reported in 11.6% of cases,[33] whereas hardware and wound complications were reported in 15% of patients who underwent superior plating.[2] Another study compared outcomes of precontoured versus noncontoured superior clavicle plating with minimum 1-year follow-up.[41] Although noncontoured clavicle plating had more than double the rate of prominent hardware and rate of hardware removal, even precontoured clavicle plating (commonly used in practice today) had a 32.1% rate of hardware prominence and 10.7% rate of hardware removal in that retrospective series. Significantly higher rates of cosmetic acceptability and lower reoperation rates have been reported with small (using 2.7-mm screws) anteroinferior plating compared with larger (using 3.5-mm screws) anteroinferior plating.[12] Likewise, Prasarn et al[29] reported excellent clinical outcomes, 100% union rate, and no requirement for revision surgery at short-term follow-up with dual small plate fixation. Another retrospective review[4] reported 100% union rate at 1 year and 0% reoperation rate with dual plating compared with 91% union rate at 1 year (95.2% at final follow-up) and 5.6% reoperation rate in the single plate fixation cohort. Another study looking specifically at reoperation rate for symptomatic implants after dual small plate fixation similarly reported a low rate of secondary surgery of 3.7% with minimum 1-year follow-up.[5] Moreover, favorable outcomes are reported with dual plating of clavicular nonunions.[10,34]

In addition to lower rate of hardware removal, dual plating has the advantage of less soft tissue stripping and improved conformity of plate to bone with use of a smaller implant, which also allows for less plate prominence. Anteroinferior plating using standard or precontoured plates is preferred by some surgeons to prevent prominence over the superior clavicle, which can be both symptomatic and cosmetically unappealing.[12,33,41] A downside of this technique is detachment of the anterior deltoid. By using a smaller plate anteroinferiorly as part of a dual plate construct, surgeons can minimize anterior deltoid detachment. Another potential advantage of dual plating is less periosteal stripping superiorly and anteroinferiorly because of the smaller footprint of the small plates relative to the larger precontoured clavicle plates. The smaller hardware footprint also allows for an easier repair of the anterior deltoid and improved soft tissue envelope, making hardware coverage easier. The smaller plates can more easily be contoured to the clavicle and are more malleable than larger plates, helping to achieve good conformity to bone, further minimizing hardware prominence. With smaller plates, the initial skin incision can potentially be shorter in length based on fracture complexity and desired exposure. The dual orthogonal plating (plates placed 90° to one another) technique can also help capture comminuted fragments.

The biomechanical noninferiority of dual plating compared with superior or anteroinferior plating suggests that dual plate fixation is a viable option in active patients. In athletes, prolonged recovery and deficit in shoulder strength and endurance are often poorly tolerated, making operative management the preferred treatment for midshaft clavicle fractures with significant fracture displacement, shortening, and comminution. Significantly lower incidences of nonunion and symptomatic malunion are reported for operative treatment compared with nonoperative treatment for displaced midshaft clavicle fractures.[2,20,25,33,36,44,45] Nonunion and malunion can cause significant alterations in the orientation of the scapula and glenohumeral joint,[1,9] resulting in weakness and loss of endurance strength.[23] In the NFL, players with nonoperatively managed, displaced midshaft fractures had a reported refracture rate of 57% compared with 5% with plate fixation.[26] Likewise, refracture at the site of a united angular malunion has been reported in adult athletes[11] and pediatric patients at a significantly increased incidence.[22] A recent systematic review of primarily level 2 and level 3 studies reported significantly longer return times and longer return to preinjury level of sport for nonoperatively managed displaced midshaft fractures compared with surgically managed fractures confirmed by meta-analysis of the study results.[32] Several studies have reported excellent clinical outcomes, high patient satisfaction, low nonunion rates (0%-5%), and very high rates of both return to sport (98%-100%) and return to prior level of play (94%-100%) after early rigid fixation of displaced midshaft clavicle fractures with mean return-to-sport time ranging from 45 to 83 days depending on the study.[24,26,31,32,38,42] Excellent outcomes and high return to sport have been reported in elite cyclists[40] and NFL football players.[18]

The current study has limitations. Specimen numbers per group (n = 6) were on the low side and were capable of detecting only a large effect. This study used cadaveric clavicles, and it can be argued that synthetic clavicles provide a more consistent material with which to perform biomechanical studies. Nevertheless, cadaveric specimens provide the benefit of evaluating plating biomechanics through the use of human bone, making the results more realistic, particularly given that randomization was performed. Moreover, the age range of specimens was relatively narrow (47-64 years), and all specimens were from male cadavers to lessen the chance of poor fixation in osteopenic bone from postmenopausal female donors. Clavicles are an optimal bone to assess nonlocking fixation because they are largely composed of cortical bone. Lastly, results may have differed if more rigid small plates had been used. The small plates used in this study for dual plate fixation were similar to one-third tubular plates. Other plate manufacturers make thicker and stiffer plates also composed of stainless steel rather than titanium. Repeating this study with more robust small plates may affect the results.

CONCLUSION

Dual plating with a smaller plate-screw construct is biomechanically similar to superior and anteroinferior single plate fixation using larger plate-screw constructs. No significant differences were found between dual plating and either superior or anteroinferior single plating in axial, bending, or torsional stiffness or in bending load to failure at time zero. Dual plating may provide a viable option for fixing midshaft clavicle fractures and, thus, may serve as a useful low-profile technique that avoids hardware prominence and irritation.

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