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ORIGINAL ARTICLE

Outcomes of conservatively treated midshaft clavicle fractures with butterfly fragment

Celal Cagri Baysal, MD[1], Kaan Pota, MD[2], Osman Civan, MD[3], Günbay Noyan Dirlik, MD[4], Hakan Özdemir, MD[5]

[1]Department of Orthopedics and Traumatology, Akhisar State Hospital, Manisa, Türkiye
[2]Department of Orthopedics and Traumatology, Kilis Prof. Dr. Alaeddin Yavaşça State Hospital, Kilis, Türkiye
[3]Department of Orthopedics and Traumatology, Private Mediterranean Health Foundation Life Hospital, Antalya, Türkiye
[4]Department of Orthopedics and Traumatology, Alanya Alaeddin Keykubat University Training and Research Hospital Antalya, Türkiye
[5]Department of Orthopedics and Traumatology, Akdeniz University Faculty of Medicine Antalya, Türkiye

Clavicle fractures represent approximately 2.6 to 4% of all adult fractures and 44% of shoulder fractures, with 75 to 80% involving the midshaft region.[1] Midshaft clavicle fractures are frequently comminuted and multi-fragmentary pattern, typically characterized by displacement and a lack of contact between the main fracture fragments.[2,3] Although the optimal management of displaced midshaft clavicle fractures remains a subject of debate, non-operative treatment is still considered a viable option, even in cases with significant displacement or comminution.[4-6]

The presence of comminution, shortening, and significant displacement in clavicle shaft fractures

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Correspondence: Kaan Pota, MD. Kilis Prof. Dr. Alaeddin Yavaşça Devlet Hastanesi, Ortopedi ve Travmatoloji Kliniği, 79000 Kilis, Türkiye.

E-mail: kaanpota@hotmail.com

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ABSTRACT

Objectives: The aim of this study was to evaluate whether fracture shortening, displacement, and the length of butterfly fragments were reliable radiographic indicators of secondary healing failure in displaced midshaft clavicle fractures with butterfly fragments and to determine whether these radiographic parameters were effective in predicting healing disorders and could be utilized as prognostic factors.

Patients and methods: Between January 2015 and January 2020, a total of 31 adult patients (29 males, 2 females; mean age: 43.6±13.2 years; range, 21 to 74 years) who presented with a closed displaced clavicle shaft fracture with butterfly fragments and were treated conservative using figure of eight bandages were retrospectively analyzed. Shortening, displacement, and butterfly fragment length were measured radiographically at diagnosis. The patients were evaluated at Weeks 4, 6, 12, and 24 after injury. The patients were divided into three groups: patients with unionized fractures, patients with delayed union, and patients with nonunion. In patients where radiographic union was not observed after four to six weeks, the figure-of-eight bandage treatment was continued. Delayed union was defined as the absence of radiographic signs of fracture consolidation within 12 weeks, and nonunion as the absence of fracture consolidation within 24 weeks.

Results: Fractures in 13 (42%) patients healed within 12 weeks, 10 (32.2%) patients had delay healing between 12 and 24 weeks, and eight (25.8%) patients had nonunion. The median shortening was 18.37 (range, 3 to 42.9) mm, while median displacement ratio and butterfly fragment length were 125% (range, 83 to 93%) and 21.7 (range, 12 to 47.2) mm, respectively. No statistically significant difference in shortening was observed among the three groups (p=0.71). There was a significant difference in the amount of displacement between the healed fractures and delayed union groups (p=0.006) and the healed fractures and nonunion groups (p=0.002). There was also a significant difference in the butterfly fragment length between the healed fractures and nonunion groups (p=0.008). For each 1% increase in displacement, the relative risk of delayed union increased by 8%, and the risk of nonunion increased by 10%. A cut-off value of 125% optimally distinguished healed from unhealed fractures (area under the curve [AUC]=0.874). For differentiating delayed union from nonunion, the optimal threshold was 142.5% (AUC=0.713), indicating moderate diagnostic performance.

Conclusion: In adult clavicle shaft fractures with butterfly fragments, butterfly fragment length and clavicle shortening did not affect bone healing. In contrast, displacement was the only significant predictor of impaired bone healing.

Keywords: Butterfly fragment, clavicle fractures, conservative treatment, displacement, nonunion, shortening.

continues to be a subject of clinical controversy. Treatment decisions are often influenced by the orthopedic surgeon's professional background and level of clinical experience.[4,7-9] Although it has been inferred that comminution may be a risk factor for taking longer or failing of bone healing in clavicle shaft fractures, there are no previous studies or detailed data on how the morphologic characteristics of butterfly fragment resulting from comminution affect fracture union.[10,11] In addition to displacement and shortening, evaluating specific characteristics of the butterfly fragment, such as its size, may offer valuable prognostic information and assist in guiding treatment strategies. Moreover, identifying which morphologic patterns are most strongly associated with nonunion or delayed healing could improve preoperative risk assessment and enable more individualized patient management.

In the present study, we aimed to evaluate whether fracture shortening, displacement, and the length of butterfly fragments were reliable radiographic indicators of secondary healing failure (delayed union and nonunion) in displaced midshaft clavicle fractures with butterfly fragments as previously described as AO/OTA type 15.2B fractures.[12] We also aimed to determine whether these radiographic parameters were effective in predicting healing disorders and could be utilized as prognostic factors.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Akdeniz University, Faculty of Medicine, Departments of Orthopedics and Traumatology between January 2015 and January 2020. A total of 389 patients who were diagnosed with a clavicle fracture were screened. Inclusion criteria were as follows: age 18 years or older, presenting with closed, displaced midshaft clavicle fractures accompanied by a butterfly fragment (classified as AO/OTA type 15.2B fractures),[12] treating non-surgically, and completed the full follow-up protocol. Exclusion criteria were as follows: age under 18 years; fractures involving the proximal or distal third of the clavicle; absence of a butterfly fragment; pathological or open fractures; skin tenting due to displacement; presentation more than one month post-injury; neurovascular injury; associated head trauma; concomitant scapular neck or multiple rib fractures; a history of significant trauma to the ipsilateral upper extremity; non-compliance with follow-up visits; and medical contraindications such as cardiac disease, renal failure, or malignancy. Among all patients, 67 adults were identified as having displaced midshaft clavicle fractures with a butterfly fragment. Consequently, 34 patients who were treated conservatively with a figure-of-eight bandage (F8-B) were included in the study. Three patients with irregular follow-up were also excluded. Finally, a total of 31 patients (29 males, 2 females; mean age: 43.6±13.2 years; range, 21 to 74 years) were included. Based on radiological follow-up results, the patients were classified into three groups: healed fractures, delayed union, and nonunion. The study flowchart is shown in Figure 1. Written informed was obtained from each patient. The study received approval from the Akdeniz University Faculty of Medicine Ethics Committee (Date: 26.08.2020, No: 2012-KAEK-20) and was conducted in compliance with the ethical principles outlined in the Declaration of Helsinki.

The standardized approach for treating midshaft clavicle fractures in our clinic is conservative management using either a F8-B or an arm sling, unless there is a definitive indication for surgical intervention. Surgical indications include open fractures, skin tenting, pathological fractures, neurovascular injury, concomitant scapular neck or multiple rib fractures, or a prior history of significant trauma to the same upper limb.[13] A F8-B is preferred in cases of fracture depression or shortening.

Radiographic measurements

Radiographic measurements were performed on standard anteroposterior (AP) view images obtained via X-ray imaging. For each patient, at the time of diagnosis, shortening, displacement, and the length of the butterfly fragment were independently evaluated by two orthopedic surgeons and radiologist using the Picture Archiving and Communication System (PACS; version 21.1, February 2019; Sectra Workstation, Linköping, Sweden). For the reliability testing of measurements performed by three different researchers. The intraclass correlation coefficient (ICC) was calculated for quantitative variables, demonstrating excellent interobserver reliability (ICC=0.80). For qualitative assessments, Cohen's kappa (κ) coefficient was used, indicating a substantial level of agreement among observers (κ=0.75). Images were calibrated using the 25.4-mm stainless steel sphere positioned in the radiographic field of view.

Clavicular shortening was defined as the overlap of the distal and proximal fragments.

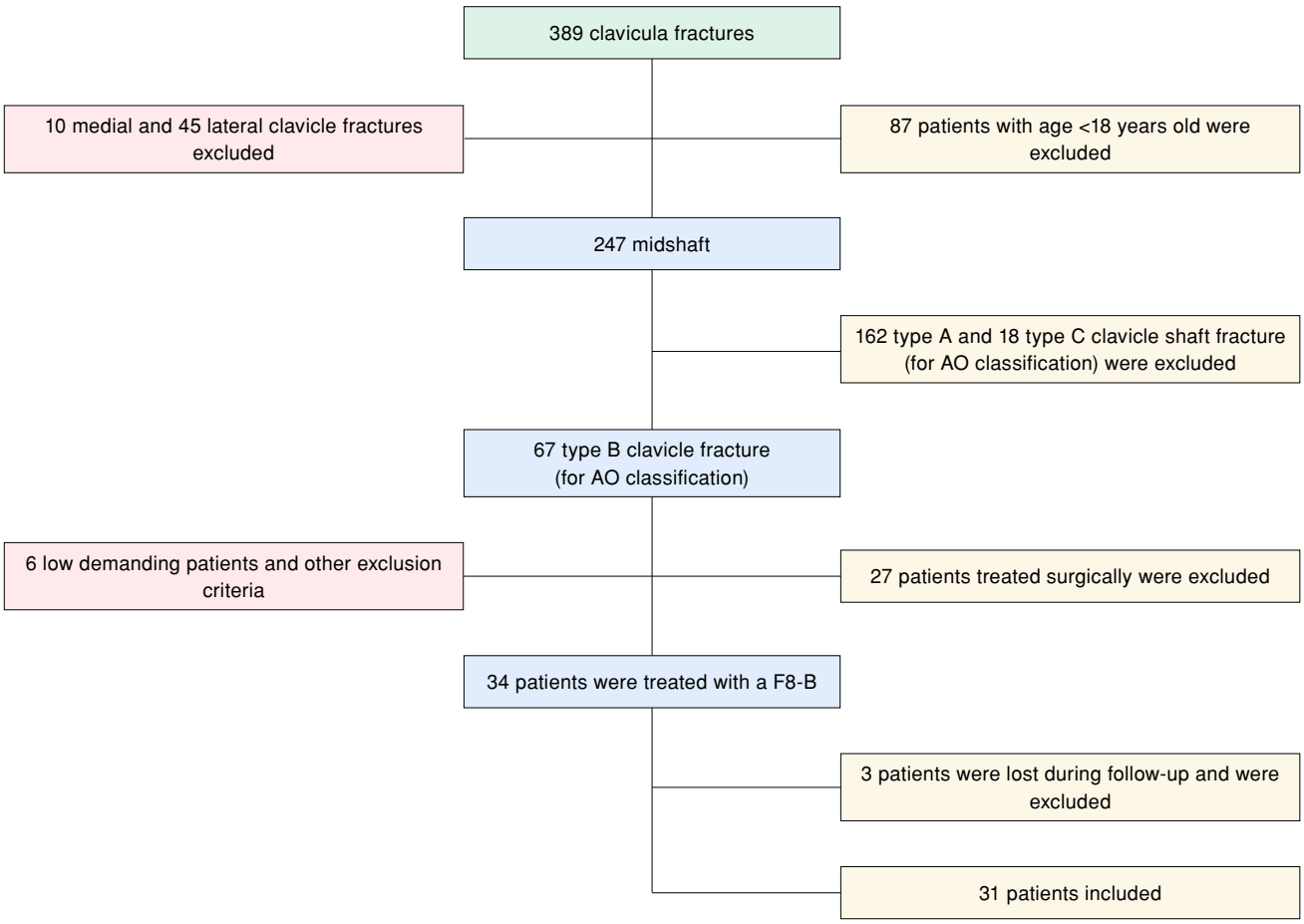


FIGURE 1. Study flowchart.

The method described by Silva et al.[14] was used for its measurement. The amount of shortening was calculated by measuring the distance in mm between the perpendicular projections of two separate points on the medial and lateral fragments, which should have been adjacent before the fracture on a standard AP view, on lines centering the bone shaft (Figure 2a). Fragment displacement was described as the amount of vertical translation. The amount of fragment displacement was calculated as a percentage of the clavicle shaft width at the fracture site in the AP view of the clavicle (Figure 2b). Butterfly fragment length, defined as the measurable length of the intact butterfly fragment cortex line after fracture, was measured in mm (Figure 2c).

Non-surgical treatment and follow-up protocol

As part of our routine clinical protocol, following the initial radiographic evaluation of the fracture, a F8-B was applied for a period of four to six weeks until radiographic signs of healing were observed. Patients were informed to maintain the correct position of the bandage, how to perform daily activities while wearing it. The individuals in the study group were educated about potential complications such as skin irritation, pressure ulcers, brachial plexus compression, and skin tenting. Each patient underwent clinical and radiographic evaluations 14 days after the initial visit to assess the positioning of the bandage and any potential displacement of fracture fragments.

Radiographic follow-up was conducted at Weeks 4, 6, 12, and 24 after injury. In patients where radiographic union was not observed after four to six weeks, the F8-B treatment was continued. Delayed union was defined as the absence of radiographic signs of fracture consolidation within 12 weeks, and nonunion as the absence of fracture

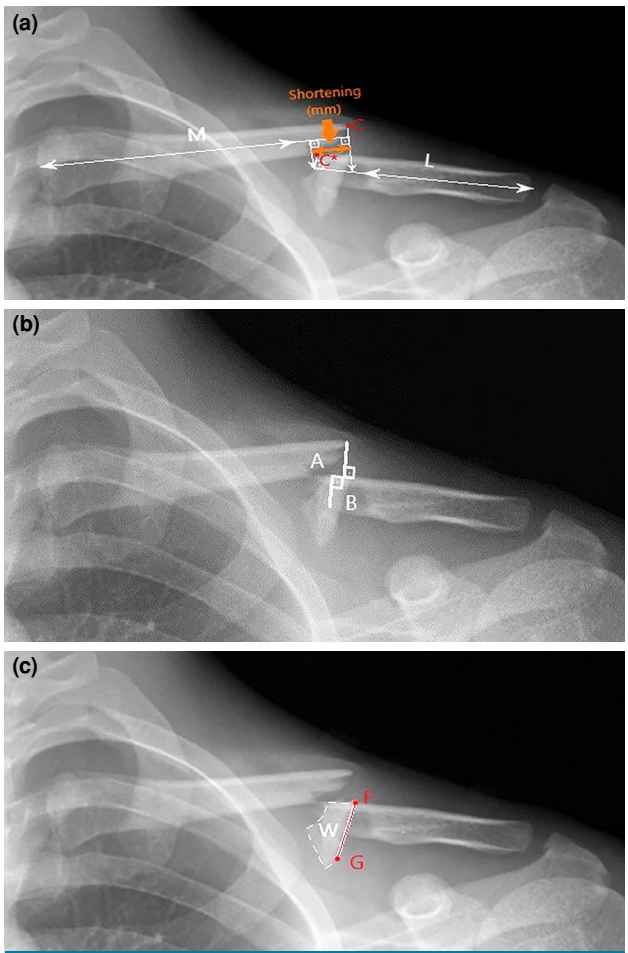


FIGURE 2. (a) Clavicular shortening, **(b)** the amount of displacement *(D=A/B%)*, and **(c)** butterfly fragment length Assessment.

O: overlap; A: distance from cortex to cortex; B = width of the clavicle; C-C*: equilateral points on the medial and lateral main fragment that were thought to be adjacent before the fracture; M: the line centering the most proximal and most distal parts of the medial main fragment; L: the line centering the most proximal and most distal parts of the lateral main fragment; W: butterfly fragment; F-G: farthest discernible points on the cortex of the butterfly fragment; D: displacement.

consolidation within 24 weeks.[15,16] Complications such as nonunion and restricted shoulder range of motion were observed during follow-up.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous data were presented in mean ± standard deviation (SD) or median (min-max), while categorical data were presented in number and frequency. The Kruskal-Wallis test was utilized for quantitative variables to determine the factors that created differences among the groups. Multinomial logistic regression was utilized to examine the multivariate association between a categorical variable and various predictors. The findings from the multinomial logistic regression analysis were presented as Z-coefficients along with their corresponding p-values. For important variables, the relative risk ratio, i.e., risk according to main category, was also taken into account. The McFadden's pseudo-R-square was used to assess the overall goodness-of-fit of the multinomial model. To determine the optimal cut-off value for the binary classifier, receiver operating characteristic (ROC) curve analysis was performed according to the Youden criterion. All analyses were performed with R.[17] A p value of <0.05 was considered statistically significant.

RESULTS

The patient demographics are shown in Table I. Fractures in 13 (42%) patients healed within 12 weeks, 10 (32.2%) patients had delay healing between 12 and 24 weeks, and eight (25.8%) patients had nonunion. The median shortening was 18.37 (range, 3 to 42.9) mm, while median displacement ratio and butterfly fragment length were 125% (range, 83 to 93%) and 21.7 (range, 12 to 47.2) mm, respectively (Table II).

The patients were classified into three groups: healed fractures, delayed union, and nonunion based on the radiological evaluations, patients in the three groups did not differ in terms of age (p=0.45). No statistically significant difference in shortening

TABLE I
Demographic patient characteristics

	n	%	Mean±SD	Median	Range
Age (year)			43.6±13.2	44	21-74
Sex					
Female	2	6.5			
Male	29	93.5			

SD: Standard deviation.

TABLE II
Radiological patient characteristics (n=31)

	n	%	Median	Range
Fractures healed within 12 weeks	13	42		
Delayed union	10	32.2		
Nonunion	8	25.8		
Shortening (mm)			18.37	3-42.9
Displacement (%)			125	83-193
Butterfly fragment length (mm)			21.7	12-47.2

was observed among the three groups (p=0.71) (Table III).

When the amount of displacement was compared among the three groups (p<0.001), a difference was found between the healed fractures and delayed union groups (p=0.006) and the healed fractures and nonunion groups (p=0.002). When butterfly fragment length was compared among the groups (p<0.011), a difference was found only between the healed fractures and nonunion groups (p=0.008) (Table III).

Multinomial logistic regression was performed to determine which factors were associated with a greater risk of treatment failure. Healed fractures were considered as the reference category. The Nagelkerke R-squared value was 0.814 suggesting a good fit for the model.[18] When delayed union was compared to healed fractures, which served as the reference category, only displacement proved to be a significant predictor. For each 1% increase in displacement, the relative risk of delayed union increased by 8%, and the risk of nonunion increased by 10%.

The ROC curve analysis was employed to determine displacement thresholds associated with treatment outcomes. A cut-off of 125% optimally distinguished healed from unhealed fractures (area under the curve [AUC]=0.874), based on Youden's index (Figure 3a). For differentiating delayed union from nonunion, the optimal threshold was 142.5% (AUC=0.713), indicating moderate diagnostic performance (Figure 3b).

In the study groups, four patients exhibited restricted shoulder mobility, while eight patients presented with nonunion complications.

DISCUSSION

In the present study, we evaluated whether fracture shortening, displacement, and the length

TABLE III
Nonunion rate by amount of shortening, displacement, and wedge fragment length (n=31)

Variables	Healed fracture (n=13)			Delayed union (n=10)			Nonunion (n=8)			(Kruskal-Wallis)
	Mean±SD	Median	Range	Mean±SD	Median	Range	Mean±SD	Median	Range	*p*
Age (year)	41.2±13.24	43	21-74	42.5±13.1	44.5	22-59	48.7±14.3	47.5	29-67	0.45
Shortening (mm)		16.96	3-27.1		19.08	5-42.9		20.26	10.5-36.4	0.71
Displacement (%)		105.3	82-145		129.2	101-146		153.5	126-193	**<0.001**
										α: **0.006**
										β: **0.002**
										θ: 0.108
Butterfly fragment length (mm)		17.92	12.6-35		19.01	14.1-29.0		28.8	16.9-44.2	**0.011**
										α: 0.20
										β: **0.008**
										θ: 0.068

SD: Standard deviation; α: Healed fractures *vs.* delayed; β: Healed fractures *vs.* nonunion; θ: Delayed *vs.* nonunion.

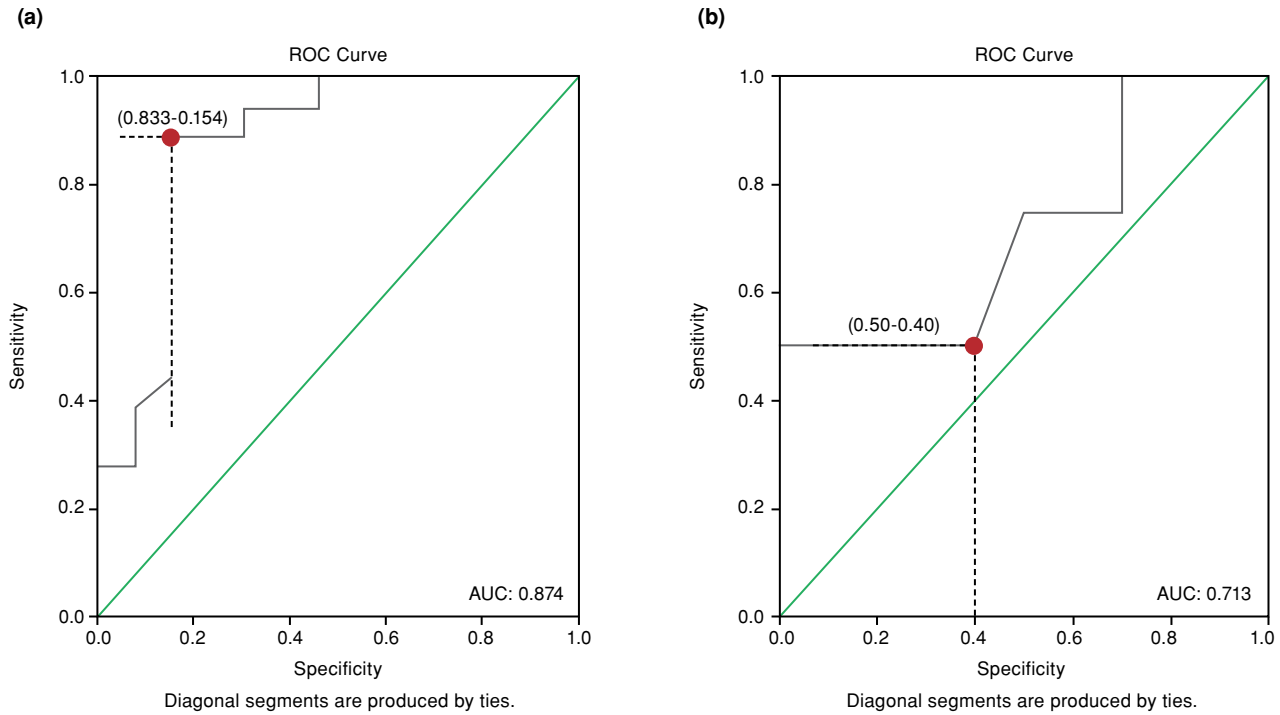


FIGURE 3. ROC curve. **(a)** ROC curve for residual displacement for diagnosis of nonhealing fractures. **(b)** ROC curve for residual displacement for discrimination between delayed union and nonunion.
ROC: Receiver operating characteristic.

of butterfly fragments were reliable radiographic indicators of secondary healing failure (delayed union and nonunion) in displaced midshaft clavicle fractures with butterfly fragments. Our study results showed a statistically significant difference in vertical displacement between healed and unhealed fractures. Furthermore, multilogistic analysis results showed that vertical displacement was the only factor significantly associated with an increased risk of nonunion. In a meta-analysis conducted by Jørgensen et al.[8] involving 2,117 patients with conservatively treated midshaft clavicle fractures, predictive factors for nonunion were assessed. Despite variations in study quality, definitions of displacement, measurement techniques, and cohort sizes among the included studies, All but one identified fracture displacement as a reliable predictor of nonunion. Although our study differs in sample size, our findings align with those of Jørgensen et al.[8] reinforcing the significance of fracture displacement as a prognostic factor for nonunion.

Several studies conducted on conservatively treated patients with midshaft clavicle fractures have demonstrated that displacement resulting in complete loss of contact between the main fracture fragments (100% displacement) increases the risk of nonunion.[10,19,20] Additionally, in the study by Murray et al.,[19] the increase in nonunion risk was quantified based on the amount of displacement measured in mm. In contrast to these studies, our current study measured displacement as a percentage of cortical thickness and established threshold values for both nonunion and delayed union based on this measurement.

A study by Virtanen et al.[21] compared the outcomes of conservatively and surgically treated clavicle shaft fractures. The authors found that, among 25 patients treated nonoperatively, all fractures with vertical displacement less than 1.5 times the clavicle thickness (150%) achieved union, whereas 50% of those with vertical displacement exceeding this threshold resulted in nonunion. In the present study, which included a similar number of patients, a vertical displacement exceeding 125% notably raised the risk of delayed union, whereas a vertical displacement greater than 142.5% was linked to a high likelihood of nonunion. The vertical displacement threshold value for nonunion (142.5%) found in the current study was

close to the lower limit for separation for nonunion determined by Virtanen et al.[21] (1.5 times the clavicle thickness - 150%), although slightly lower. The consensus of both studies and the literature is that patients with clavicle shaft fractures with a vertical displacement of at least as much as the clavicle thickness (100%) have an increased risk of union pathologies. The current study contributed to the literature by showing that after a clavicle shaft fracture with a butterfly fragment (AO/OTA type 15-B2), the treatment period would be prolonged due to the inadequacy of conservative treatment in cases with vertical displacement of more than 125% of the clavicle thickness, and that nonunion is highly likely in cases with vertical displacement of more than 142.5% of the clavicle thickness. The higher nonunion rates after severe vertical displacement above 142.5% may be due to any mechanical factor that disrupts reduction, such as intervening soft tissue or destruction of the surrounding soft tissue around the fracture hematoma due to displaced clavicle main fragments.

Several key studies have contributed to the current understanding of treatment strategies for displaced midshaft clavicle fractures. Zlowodzki et al.[7] performed a systematic review of 2,144 fractures, highlighting the variability in outcomes and the need for evidence-based treatment guidelines. Tamaoki et al.[15] conducted a randomized-controlled trial comparing figure-of-eight harness immobilization to anterior plate osteosynthesis, finding that surgical fixation provided superior functional recovery and lower complication rates. Similarly, Woltz et al.[22] in a multi-center randomized-controlled trial demonstrated that plate fixation significantly reduced nonunion rates and improved functional outcomes compared to non-operative treatment. Collectively, these studies emphasize the benefits of surgical intervention, particularly in cases with significant displacement, while also underscoring the importance of individualized treatment decisions based on fracture characteristics and patient factors. Considering the findings of the present study, it is recommended that conservative treatment be avoided, if the initial radiograph shows vertical displacement exceeding 125% between the main fragments of a clavicle shaft fracture, as this is associated with prolonged healing time. In addition, if the vertical displacement is more than 142.5%, surgical treatment should be the primary option since nonunion is highly probable. Prolonged treatment time would cause labor and economic loss, it would be more appropriate to prioritize surgical treatment options for these types of fracture, especially in young and active patients.

The role of clavicular shortening as a risk factor for nonunion following midshaft clavicle fractures remains a subject of debate in the literature.[7,22] Some studies suggest that significant shortening may impair biomechanical stability, thereby increasing the risk of nonunion.[23] while others report no significant association between shortening and nonunion.[24] In our current study, although the amount of shortening was greater in cases of nonunion and delayed union compared to healed fractures, no statistically significant correlation was found between clavicular shortening and either nonunion or delayed union. This finding is consistent with recent systematic reviews.[22,24] However, it is of utmost importance to note that while clavicular shortening may not be associated with nonunion, it has been reported to correlate with malunion and poorer functional outcomes.[23,25] Therefore, although clavicular shortening may appear clinically insignificant in terms of union status, it should be taken into consideration during treatment planning due to its potential impact on functional outcomes.

While some studies have demonstrated that the characteristics of butterfly fragments influence union outcomes in long bones such as the humerus and femur, no study in the literature has evaluated the potential for union complications in clavicle shaft fractures based on the characteristics of the butterfly fragment.[26-29] Although fragment length was shown to differ between healed and unhealed fractures in the present study, the fragment size alone did not independently a risk of nonunion or delayed union. This may have been due to the fact that the number of patients evaluated was low and that the patients were not distributed to the groups homogeneously. Thus, studying fragment length with more homogeneously distributed groups including more patients than in our study would better elucidate the issue.

The main limitation to the present study is that standard radiographs were used in the evaluation of fractures which does not allow accurate three-dimensional positioning of the main fracture fragments and butterfly pieces. The evaluation of union pathologies was performed only using radiographs; functional and clinical symptoms were not taken into account, which may have increased the number of patients diagnosed with nonunion and delayed union and may have

lowered the vertical displacement threshold value found. Although the mean shortening amount and fragment length differed between the groups, these parameters were not significantly associated with union pathologies. Another limitation is that the number of patients included was low compared to similar studies in the literature and there was no control group.[19] To eliminate these limitations, further studies involving other clavicle types as a control group, evaluating functional and pain scores as well as radiographs, considering the parameter of smoking status, and including more patients distributed homogeneously should be conducted.

In conclusion, our study results showed that shortening and butterfly fragment length did not affect bone healing in F8-B-treated adult midshaft clavicle fractures with butterfly fragments. Displacement between fracture fragments was the most probable indicator of both delayed union and nonunion. Based on these results, we suggest that, in midshaft clavicle fractures with butterfly fragments, neither the length of the butterfly fragment nor the degree of shortening alone have a significant impact on the risk of nonunion or delayed union. In contrast, vertical displacement seems to be the most important prognostic factor in relation to nonunion pathologies.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, control/supervision, critical review: C.C.B., H.O.; Data collection and/or processing, analysis and/or interpretation, materials: C.C.B., K.P.; Literature review: C.C.B., O.C.; Writing the article: C.C.B., K.P.; References and fundings: C.C.B., G.N.D.; Other: K.P., O.C., G.N.D.

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