SET IT AND FORGET IT: DIAPHYSEAL FRACTURES OF THE HUMERUS UNDERGO MINIMAL CHANGE IN ANGULATION AFTER FUNCTIONAL BRACE APPLICATION

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ABSTRACT

Objectives: To quantify radiographic changes observed in humeral shaft frctures throughout course of treatment with functional bracing.

Design: Retrospective cohort study.

Setting: Level 1 Trauma Center and affiliated Tertiary Care Center

Patients: 72 retrospectively identified patients with fracture of the humeral diaphysis

Intervention: Application of functional brace with radiographs obtained immediately after brace application and at 1 week, 2 weeks, 3 weeks, 6 weeks, 3 months, 6 months and 12 month follow-up.

Main Outcome Measure: Fracture angulation, measured in the coronal and sagittal planes.

Results: 522 radiographs from 72 patients were critically reviewed. All fractures were followed to healing. Sixty-six patients (92%) successfully healed their fractures with non-operative treatment. The average angulation on immediate post-brace X-ray was 12 degrees varus ad 7 degrees procurvatum. At final follow-up, average coronal angulation was 14 degrees and 4 degrees procurvatum. Fracture angulation changed a mean 2 degrees in the AP plane and 3 degrees in the sagittal plane over the course of care. Linear regression determined fracture angulation proceeds toward both varus and recurvatum at 0.01 degrees per day.

Conclusion: Humeral shaft fractures treated non-operatively heal with minimal change in angulation after brace application. If angulation on the post-brace radiograph is acceptable and there is no history of repeat trauma and no cosmetic deformity, radiographs may be utilized less frequently. Patients should be evaluated via history and physical exam at follow-up prior to the 6-week point, at which time regular radiographs (6 week, 3 month, 6 month, 12 month) should commence.

INTRODUCTION

Fracture of the humeral diaphysis is a common injury treated by orthopaedic surgeons. The injury accounts for 1-5% of all fractures in the United States and has an incidence of approximately 14.5 per 100,000 people.[1-3] Non-operative management remains the treatment of choice for the majority of these injuries owing to decreased cost of care, ability of the upper extremity to overcome moderate anatomic deformity, and reliable return to pre-functional status. Treatment requires placing the extremity in a well-molded splint with subsequent advancement to a functional brace at two weeks to allow primary callus formation. This algorithm was popularized in the 1970's when a report by Sarmiento et al. was published detailing 51 patients treated with functional bracing.[4] Functional bracing allows early introduction of functional activity by permitting full range of motion at the shoulder and elbow joints and reliably yields excellent outcomes.[5-15]

Functional bracing for humeral shaft fractures is particularly demanding for both patient and physician. Once the patient is transitioned to functional brace, some physicians opt to follow patients with weekly or bi-weekly plain radiographs for the first 3-6 weeks to ensure angulation remains within acceptable parameters. Despite extensive outcome investigations, no literature exists defining how these patients should be surveilled or what degree of change in fracture alignment is expected or acceptable on week to week surveillance. As such, it is difficult to define what early changes in angulation are allowable versus those which are alarming and require adjustment. If fear of progressive angulation after brace application is alleviated, physicians may opt to obtain radiographs less frequently which serves to diminish

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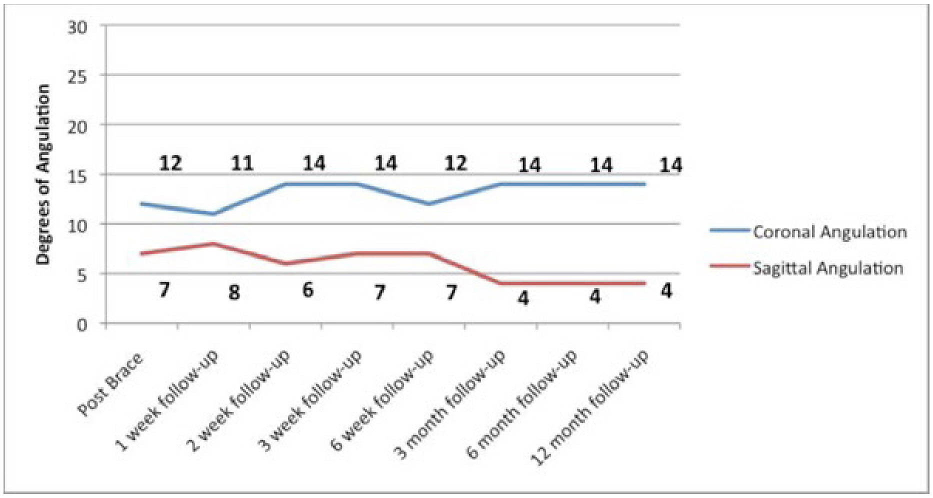

Figure 1. Mean Degrees of Angulation at Follow-up Intervals

patient radiation exposure and cost of care. This study aims to quantify radiographic changes observed in humeral shaft fractures throughout course of treatment with functional bracing. We hypothesize that no clinically significant change in fracture alignment would occur subsequent to application of the brace.

PATIENTS AND METHODS

Patients were retrospectively identified by querying medical records for ICD-9 codes pertaining to humeral shaft fracture treated by traumatologists in our department. Inclusion criteria were: non-operative treatment with functional bracing, isolated humeral shaft injury, X-rays (AP and trans-thoracic lateral) available for analysis on the picture archiving system (PACS), and minimum follow-up through clinical and radiographic union. We identified seventy-two consecutive patients who underwent non-operative management of seventy-two humeral shaft fractures. This cohort received a total of 522 radiographs during their treatment.

Fracture patterns were classified according to O/OTA-system.[16] Fracture angulation and displacement was measured in the coronal and sagittal planes on PACS (Siemens Erhlanger, Germany). In the coronal plane, a line was drawn down the long axis of the humeral shaft; varus angulation was defined by positive values and valgus angulation by negative values. In the sagittal plane, procurvatum was defined by positive values and recurvatum was defined by negative values. Images were evaluated post-brace application and at 1 week, 2 week, 3 week, 6 week, 3 month, 6 month and 12 month follow-up.

Mean coronal and sagittal angulation was calculated for each of the above radiographic intervals. A linear regression was performed for both coronal and sagittal angulation to model change over time.

RESULTS

Seventy-two patients met inclusion criteria and were included in the study cohort. All fractures were followed, at minimum, to fracture healing or decision for surgery. Average length of follow-up was 40 weeks (range 12-56 weeks). Sixty-six patients (92%) successfully healed their fractures with non-operative management in a mean of 15 weeks (range 8-32 weeks, SD 4.1 weeks). Six patients (8%) failed non-operative management and underwent surgical intervention.

The average angulation immediately after brace application was 14 degrees varus and 7 degrees procurvatum. Fourteen patients had a fracture with greater than 20 degrees of varus angulation after initial brace application, of which four (29%) were eventually indicated for open reduction and internal fixation. Mean coronal and sagittal angulation at follow-up are depicted graphically in Figure 1. Fracture angulation changed a mean of 2 degrees in the coronal plane and 3 degrees in the sagittal plane throughout the course of treatment. Clinical radiographs throughout the course of treatment are provided as an example (Figures 2a-2e).

Linear regression was performed investigating fracture angulation change as a function of time. Total days since initial brace application was the independent variable. Linear regression revealed $\beta = 0.01$ (progression towards varus) for coronal alignment and $\beta = -0.01$ (progression towards recurvatum) for sagittal alignment. These results demonstrate that fractures tend towards varus and posterior angulation at approximately 0.01 degrees per day. It should be noted that a standard convention of defining angulation was utilized to obtain these values (varus and anterior angulation defined as positive values, valgus and posterior angulation as negative values).

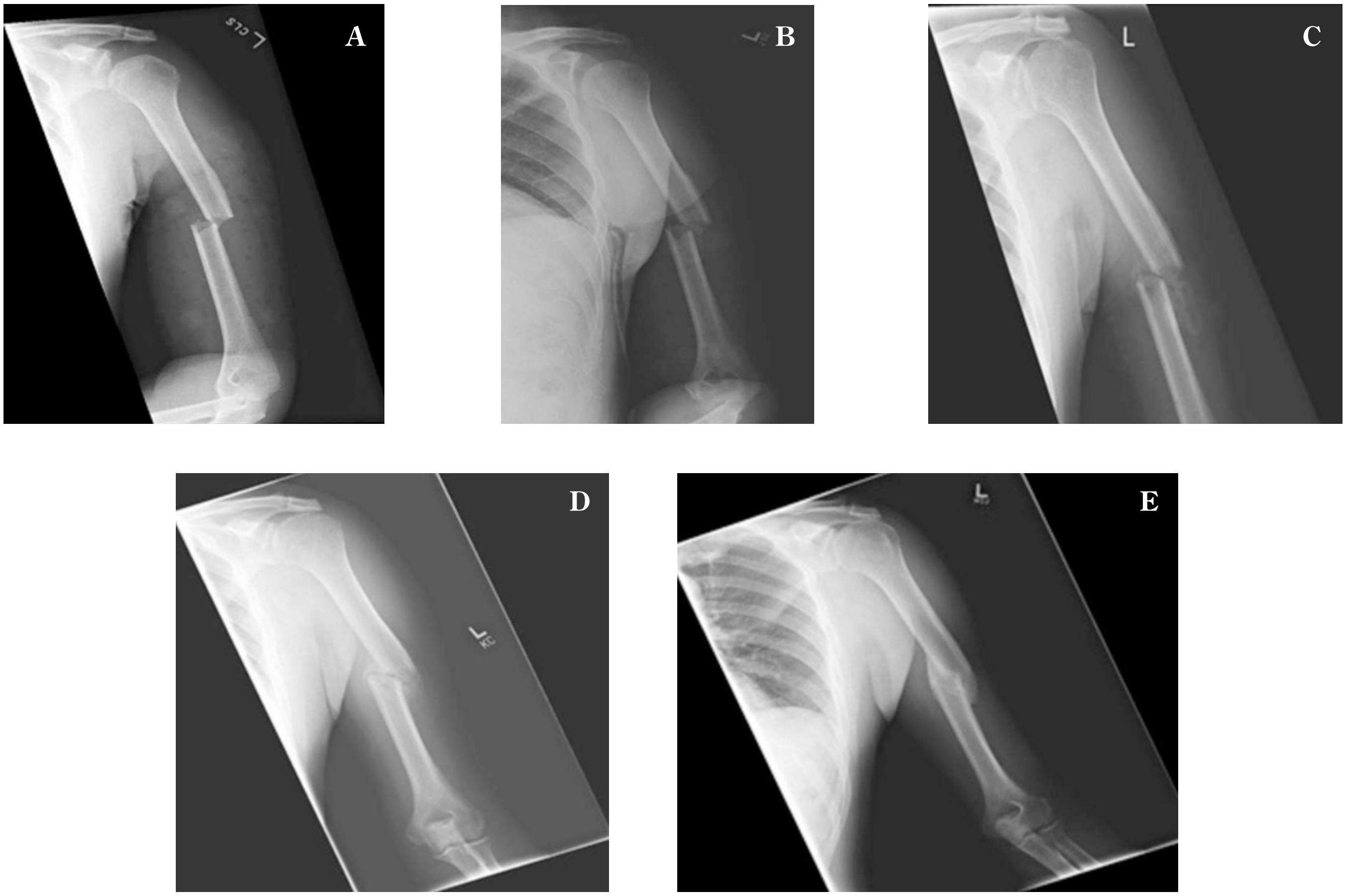

Figure 2 - a.) Immediate post-brace radiograph, b.) 2 week follow-up, c.) 3 week follow-up, d.) 6 week follow-up, e.) 1 year follow-up

Fourteen fractures remained in 20° or greater of varus after brace application. At one- and two-week follow-up, surgical intervention was offered to these patients on the basis of persistent angulation; four patients (29%) elected ORIF and ten patients opted to complete non-operative management. For the non-operative group (n=10), average post-brace angulation was 25° varus and 2° procurvatum. At union, which occurred at a mean of 20 weeks, average angulation was 20° varus and 3° procurvatum. No patient healed with clinical deformity despite radiographically significant angulation. An example is demonstrated in Figures 3a-c.

Six patients (8%) failed non-operative treatment and required surgical intervention. Four patients with significant clinical and/or radiologic coronal deformity noted after brace application, and which failed to improve at follow-up visits, opted for surgical intervention (ORIF) at the two-week time point. For this group (n=4), the mean coronal deformity was 21° varus on post-brace radiograph and 26° varus at two weeks (time of surgical indication). One patient presented at one-week follow-up with complaints of increased pain and obvious cosmetic deformity. She was found to have an acute worsening of angulation between brace application and one week follow-up (12° varus vs. 42° varus, respectively). She was indicted for ORIF. One patient proceeded to nonunion. There was no specific fracture pattern (AO/OTA system16) associated with failure of non-operative treatment.

DISCUSSION

These results demonstrate that humeral shaft fracture angulation changes minimally throughout course of treatment with a functional brace. While it is true that there is a tendency varus and posterior angulation, the overall change is clinically insignificant. Our results support two conclusions: First, fractures in unacceptable angulation should not be expected to significantly "self-correct" following initial application of functional bracing. Second, frequent radiographic evaluation in early stages of treatment is unnecessary since minimal change is expected.

It is commonly taught that active motion of the upper extremity permits realignment as muscles contract around the fracture.[17] Our results demonstrate that it is unlikely for fractures remaining in unacceptable clinical

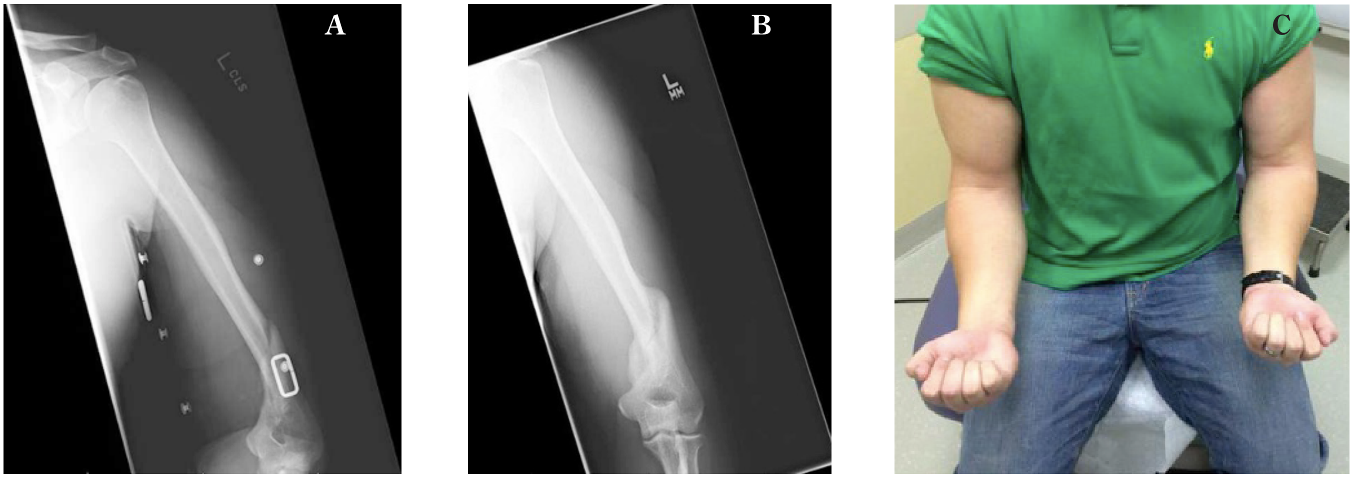

Figure 3 - a.) Post-brace radiograph demonstrating varus angulation > 20º. He opted to complete non-operative management , b.) Radiographs demonstrating healed fracture, c.) There was no clinical deformity despite radiographically significant angulation.

or radiographic angulation after application of the brace to self-correct over the course of treatment. While it is true that some degree of correction occurs in the sagittal plane (provided the fracture is angulated anteriorly), the rate of change is too small to result in significant clinical improvement by the time union occurs. In addition, varus angulation – the most common coronal deformity – may progress slowly throughout treatment rather than diminish.

Varus angulation greater than 20 degrees is an accepted indication for operative intervention, as this level of angulation is thought to result in cosmetic deformity and functional deficit.[2,17] Many studies report that functional bracing reliably yields acceptable results with regards to angulation[4-15] and our results confirm this notion. However, results of treatment appear contingent on radiographic alignment immediately following application of the brace. If the humerus is well aligned on the initial X-ray obtained after bracing, excellent results may be expected. Fractures remaining in unacceptable clinical or radiographic deformity after brace application should not be expected to significantly "self-correct" and operative fixation should be considered. This is supported by the high rate of conversion to operative treatment in our cohort of patients with greater than 20º of varus angulation following brace application (29%).

The cohort of 10 patients who opted to complete non-operative treatment despite persistent significant radiographic deformity represents a treatment "greyzone" and highlights the need for open, comprehensive communication between orthopaedist and patient. For each patient, the risks of continued non-operative treatment (cosmetic deformity and functional deficit) were explained as well as the risks of surgery. When patients elected non-operative management, the need for strict follow-up was stressed to ensure a positive outcome. Physical examination – consisting of visual inspection for cosmetic deformity and range of motion (ROM) assessment while in the brace – was the mainstay of evaluation. With this method of follow-up, all patients were satisfied with their outcome despite suboptimal radiographs.

The minimal rate of change in fracture angulation suggests frequent radiographic evaluation in the early stages of treatment is unnecessary. Provided that adequate cosmetic and radiographic alignment is achieved immediately after application of the brace, the humerus can be expected to remain stable. Patients should still be seen by the physician at weekly intervals in the early stages of treatment but evaluation should rely chiefly on history and physical exam. So long as the patient has not experienced repeat trauma and shows no cosmetic deformity on physical exam, radiographs may be deferred until the usual 6-week time point. Increased radiographic evaluation is warranted in three particular instances: 1) when patients remain in 20º of varus angulation (or greater) after application of the brace and still opt for non-operative management 2) When there is history of repeat trauma to affected extremity 3) A cosmetic deformity or ROM deficit is appreciated in the physical exam.

While anatomic reduction is seldom achieved with non-operative management of humeral shaft fractures, this is rarely necessary to preserve function due to the range of motion provided by the gleno-humeral joint and elbow.[17] As mentioned previously, greater than 20-30 degrees of varus or sagittal angulation is historically accepted as the cutoff for operative intervention in fractures of the humeral diaphysis.[4,5,8-10,12,14,17,18] There has been little debate regarding the validity of these values ever since 1966 when Klenerman published the observation that function is preserved within these measurements.18 The small rate of change in fracture angulation determined in this study suggests it is unlikely for patients with acceptable post-brace angulation to sustain functional impairment.

Our results for average post-brace angulation and final angulation are similar to those reported in the literature.[5,8,9,12,18] Nevertheless, this study should be interpreted in light of its limitations. First, it is rare for AP and lateral X-rays to be taken with the humerus in the exact same position from week to week. Inevitably, there is inconsistency in positioning of the humerus between each X-ray which may have led to minimal differences in measured angulation. It is possible that in some cases the true fracture angulation did not change and difference in humerus positioning created an apparent change in angulation. This may have resulted in less accurate results despite our best efforts to include only true AP and lateral radiographs. Nonetheless, inconsistency in humeral positioning between follow-up X-rays is common and will need to be navigated by the orthopaedist clinically. Second, the mean duration of follow-up is admittedly short (40 weeks). However, all fractures were followed to union, which occurred at a mean of 15 weeks. Given that angulation only occurs in the setting of an ununited fracture, and our mean final follow-up surpassed mean time to union, it is unlikely that our results were adversely impacted.

Functional bracing for humeral shaft fractures provides adequate fracture stabilization and results in minimal change in angulation throughout treatment once the brace is applied. Fracture stability mitigates the need for frequent radiographic evaluation early in the treatment period, and patients should be followed closely with history and physical exam for the first six weeks. Increased radiography is warranted in the case of significant post-brace angulation, repeat trauma or cosmetic deformity. Decreased overall reliance on X-rays will result in less patient radiation exposure and lessen the cost of care. Fractures remaining in unacceptable cosmetic or radiographic deformity after application of the brace should be considered for operative intervention.

REFERENCES

1. Denard A, Richards JE, Obremskey WT, et al. Outcome of nonoperative vs operative treatment of humeral shaft fractures: a retrospective study of 213 patients. Orthopedics. 2010;33(8).
2. Egol KA, Koval KJ, Zuckerman JD. Humeral Shaft Fractures. Handbook of Fractures. 4th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2010: 203-214.
3. Spiguel AR, Steffner RJ. Humeral shaft fractures. Curr Rev Musculoskelet Med. 2012;5:177-83.
4. Sarmiento A, Kinman PB, Galvin EG, et al. Functional bracing of fractures of the shaft of the humerus. J Bone Joint Surg Am. 1977; 59:596-601.
5. Balfour GW, Mooney V, Ashby ME. Diaphyseal fractures of the humerus treated with a ready-made fracture brace. J Bone Joint Surg Am. 1982;64:11-3.
6. Ekholm R, Tidermark J, Tornkvist H, et al. Outcome after closed functional treatment of humeral shaft fractures. J Orthop Trauma. 2006;20:591-6.
7. Kapil Mani KC, Gopal Sagar DC, Rijal L, et al. Study on outcome of fracture shaft of the humerus treated non-operatively with a functional brace. Eur J Orthop Surg Traumatol. 2013;23:323-8.
8. Koch PP, Gross DF, Gerber C. The results of functional (Sarmiento) bracing of humeral shaft fractures. J Shoulder Elbow Surg. 2002;11:143-50.
9. Rangger C, Kathrein A, Klestil T. Immediate application of fracture braces in humeral shaft fractures. J Trauma. 1999;46:732-5.
10. Rutgers M, Ring D. Treatment of diaphyseal fractures of the humerus using a functional brace. J Orthop Trauma. 2006;20:597-601.
11. Sarmiento A, Horowitch A, Aboulafia A, et al. Functional bracing for comminuted extra-articular fractures of the distal third of the humerus. J Bone Joint Surg Br. 1990;72:283-7.
12. Sarmiento A, Zagorski JB, Zych GA, et al. Functional bracing for the treatment of fractures of the humeral diaphysis. J Bone Joint Surg Am. 2000;82:478-86.
13. Sharma VK, Jain AK, Gupta RK, et al. Non-operative treatment of fractures of the humeral shaft: a comparative study. J Indian Med Assoc. 1991;89:157-60.
14. Toivanen JA, Nieminen J, Laine HJ, et al. Functional treatment of closed humeral shaft fractures. Int Orthop. 2005;29:10-3.
15. Zagorski JB, Latta LL, Zych GA, et al. Diaphyseal fractures of the humerus. Treatment with prefabricated braces. J Bone Joint Surg Am. 1988;70:607-10.
16. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. J Orthop Trauma. 2007;21(10 Suppl):S1 133.
17. Bucholz RW. Humeral Shaft Fractures. Rockwood and Green's Fractures in Adults. 7th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2010: 1000-1040.
18. Klenerman L. Fractures of the shaft of the humerus. J Bone Joint Surg Br. 1966;48:105 11.