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ORIGINAL ARTICLE

Initial management of humeral shaft fractures with functional splints versus coaptation splints

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Abstract

Purpose Humerus shaft fractures are commonly acutely immobilized with coaptation splints (CS), which can be difficult to apply and poorly tolerated by the patient. Functional splints (FS), which work on the same principle as functional braces, are an alternative to CS. The purpose of this study was to directly compare CS and FS in terms of application and fracture reduction.

Methods A retrospective review identified humeral shaft fractures managed nonoperatively with initial immobilization in a FS ($n=19$) versus a CS ($n=15$). In addition, 13 residents completed a blinded survey on splint application.

Results The FS and CS groups did not differ in initial fracture angulation and translation on anteroposterior (AP) and lateral radiographs. Post-splint application, there was no clinically relevant difference in fracture angulation/translation between groups, and this persisted at the subsequent follow-up visit. All residents reported that the FS was easier to apply and took less time.

Conclusion This study results demonstrated the FS results in similar reductions in humeral shaft fractures as CS. A survey of residents found that the FS was easier to apply, took less time, and was better tolerated by patients. Subsequently, we prefer the FS over the CS for the acute management of humeral shaft fractures.

Keywords Humerus shaft fracture · Coaptation splint · Functional brace · Sarmiento brace · Functional splint

Introduction

Humeral shaft fractures are common and can frequently be treated successfully with a prefabricated functional brace as described by Sarmiento, which allows gravity and circumferential compression to maintain alignment of the fracture [1–5]. Upon initial evaluation in the emergency department, the standard of care for acute immobilization of humeral shaft fractures is a coaptation splint (CS). A functional brace is then applied at the patient's follow-up visit. There are several limitations of using a CS during the initial phase of care: these splints are subjectively burdensome to apply, can be poorly tolerated by patients, and can require sedation to perform valgus molding to prevent varus malalignment [6, 7].

Pal et al. [8] described the use of functional splints (FS) for the definitive management of humeral shaft fractures in a resource-limited setting where prefabricated braces were unavailable. The FS works on the same principles as functional braces, allowing circumferential pressure and gravity to reduce the fracture. With use of the FS alone, the author reported a 98% union rate at an average of 11 weeks. As such, the FS may be a viable alternative to the CS for the initial management of humeral shaft fractures.

Our orthopedic department recently adopted the FS as our preferred method of initial immobilization. The purpose of this study was to review our experience with the FS and compare it to a historical cohort of patients treated with the CS.

Methods

After institutional review board approval, a retrospective review was performed at an urban-level one-trauma center to identify all closed diaphyseal humerus fractures initially managed nonoperatively in a FS or CS. Patients were excluded for being lost to follow-up, having no post-splint

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radiographs, and for not being initially treated in a splint. Patient age, gender, BMI, fracture location, AO/orthopedic trauma association (OTA) fracture classification, and transverse versus non-transverse fracture patterns were reviewed [9]. Injury, post-splint, and follow-up radiographs were reviewed on the electronic imaging system to measure maximum fracture translation and angulation on anteroposterior and lateral humerus radiographs.

Orthopedic surgery residents placed all splints in the emergency department. Instructions for FS application were given to all residents taking call. The arm was first wrapped with soft roll in standard splint fashion. Four plaster slabs, 10 sheets thick and 3 to 5 cm wide, depending on the size of the arm, were placed anterior/posterior and medial/lateral running the length of the humeral shaft (Fig. 1). These were overwrapped with non-compressive splint dressing followed by a compressive splint dressing. The patients were instructed to re-wrap the compressive wrap if it became loose prior to their first follow-up visit.

CS were placed in the standard fashion with soft roll being applied from the elbow to the shoulder, followed by a long plaster slab, 10 thick by 4–5 cm wide, from the crease of the axilla, around the elbow, and over the shoulder [8]. The splint was then overwrapped with non-compressive splint dressing. If varus deformity was present, valgus molding was applied, with or without sedation, depending on patient discomfort.

After splint placement, anteroposterior (AP) and lateral radiographs were taken to assess fracture reduction (Fig. 2). Radiographs were repeated at the next follow-up visit prior to splint removal. Patients were then placed into a functional brace. A dedicated orthopedic trauma physical therapist applied the brace and instructed each patient on daily compression and elbow/wrist range of motion exercises.

Upon completion of the retrospective study, all residents who applied the FS were asked to complete an anonymous survey that included questions on the ease of splint application, time to apply each splint, and how each splint was tolerated by patients.

Parametric versus nonparametric statistical tests were used based on the presence of normally or non-normally distributed data as determined by the Shapiro–Wilk W test. Parametric continuous data are presented as mean and standard deviation while nonparametric continuous data are presented with the median and interquartile range (IQR). The Student-T tests and Wilcoxon rank-sum test were used to compare parametric and nonparametric continuous variables between groups, respectively. The Fisher Exact test was used to compare categorical variables due to low cell counts (<5 events per cell). The difference in means/medians along with the 95% confidence interval (CI) was calculated. The 95% CI for the difference in medians was calculated using the Hodges-Lehmann estimator. A p-value less than 0.05 was considered statistically significant. All analyses were carried out using JMP Pro version 14 statistical software (SAS; Cary, NC).

Results

Chart review identified 55 consecutive patients with humeral shaft fractures. Patients were excluded for having no follow-up ($n=11$), no post-splint radiographs ($n=1$), and for not being initially managed in a splint ($n=9$) leaving 34 patients for analysis. Average age was 38 years (range, 13–77), 19 (56%) were male, and the average BMI was 25 (range, 18–34). Fractures included the proximal shaft in 5 (15%), middle shaft in 18 (53%), and the distal shaft in 11 (32%). CS and FS were used in 15 (44%) and 19 (56%) patients, respectively. Union occurred in 31 (91%) patients at an average of 12 weeks (range, 5–19). There were 3 (9%) patients who requiring surgical fixation, including one patient with

Fig. 1 Demonstration of functional splint placement: splint padding followed by anterior/posterior and medial/lateral slabs. A non-compressible dressing is then placed followed by a removable compressible dressing that can be removed and re-wrapped if loosening occurs

Fig. 2 Radiographs of a 19-year-old male, with a prior history of lateral condyle open reduction and internal fixation, who sustained distal humeral shaft fracture from a ground-level fall. Anteroposterior and lateral radiographs of the humerus at the time of injury (**a**, **b**), post-functional splint placement (**c**, **d**), post-functional brace placement (**e**, **f**), and at 6-month follow-up (**g**, **h**), respectively

a midshaft AO/OTA type C fracture in the FS group for the degree of fracture displacement at 7 weeks and two patients in the CS group with distal shaft AO/OTA type A transverse fractures for nonunion at 17 weeks and 20 weeks, respectively.

The FS group was on average older than the CS group, but otherwise did not differ in gender, BMI, fracture location, or initial fracture angulation/translation (Table 1). After splint application, the FS group had less correction of fracture coronal translation (− 0.4 mm) compared to the CS group, but had similar correction of coronal/sagittal angulation and sagittal translation (Table 2). At the follow-up visit, there was no difference in fracture reduction in terms of coronal and sagittal angulation/translation between CS and FS (Table 3).

Table 1 Comparison of functional and coaptation splint groups

	Functional splint ($n=19$)	Coaptation splint ($n=15$)	Difference, 95% confidence interval	p-value
Age	44 ± 19 (range, 18–77)	32 ± 10 (range, 19 to 55)	12, 1 to 23	0.02*
Female	9 (47%)	6 (40%)	7%, − 25% to 38%	0.7
BMI	25 ± 5 (range, 18–35)	27 ± 5 (range, 18–35)	− 1.8, − 5 to 1.6	0.2
Fracture location	Proximal: 4 (21%) Middle: 11 (58%) Distal: 4 (21%)	Proximal: 1 (6%) Middle: 7 (47%) Distal: 7 (47%)		0.2
AO/OTA fracture classification	A: 11 (58%) B: 6 (32%) C: 2 (10%)	A: 6 (40%) B: 5 (33%) C: 4 (27%)		0.4
Transverse fractures	6 (32%)	6 (40%)	− 8%, − 38% to 21%	0.7
Fracture coronal angulation (°)	9.6 (4–19)	15.7 (8–23)	− 5, − 12 to 2	0.1
Fracture coronal translation (mm)	1.1 (0.6–1.6)	0.8 (0.7–2)	− 0.001, − 0.4 to 0.5	1.0
Fracture sagittal angulation (°)	9.9 (5–19)	9.9 (4–26)	− 0.6, − 8 to 5	0.7
Fracture sagittal translation (mm)	1 (0.6–1.4)	0.8 (0.4–1.3)	0.1, − 0.3 to 0.4	0.7

Parametric continuous data are presented as mean ± standard deviation and nonparametric continuous data are presented as median (interquartile range)

*A p-value < 0.05 was considered statistically significant

Table 2 Improvement in fracture alignment after splint placement

	Functional splint ($n=19$)	Coaptation splint ($n=15$)	Difference, 95% confidence interval	p-value
Δ AP angulation (°)	3.9 (− 1.9 to 8.9)	4.0 (1.6–10)	− 2, − 8 to 4	0.5
Δ AP translation (mm)	− 0.08 (− 0.3 to 0.4)	0.2 (0.03–1.4)	− 0.4, − 1.4 to − 0.02	0.04*
Δ Lateral angulation (°)	6.2 (-0.8 to 18)	1.1 (0.1–11)	1.2, − 6 to 13	0.7
Δ Lateral translation (mm)	0.3 (− 0.1 to 0.6)	0.1 (− 0.05 to 0.2)	0.2, − 0.1 to 0.6	0.1

Nonparametric continuous data are presented as median (interquartile range)

*A p-value < 0.05 was considered statistically significant

Table 3 Improvement in fracture alignment at subsequent follow-up visit

	Functional splint ($n=19$)	Coaptation splint ($n=15$)	Difference, 95% confidence interval	p-value
Δ AP angulation (°)	3.9 (0 to 7)	4.7 (− 5 to 17)	− 0.7, − 11 to 6	0.7
Δ AP translation (mm)	0.3 (− 0.07 to 0.8)	0.2 (− 0.04 to 0.8)	0.01, − 0.6 to 0.5	0.9
Δ Lateral angulation (°)	7.5 (− 5 to 11)	3.2 (− 6 to 20)	− 0.5, − 13 to 8	0.9
Δ Lateral translation (mm)	− 0.1 (− 0.6 to 0.7)	0.3 (− 0.1 to 0.6)	− 0.2, − 0.8 to 0.4	0.5

Nonparametric continuous data are presented as median (interquartile range)

Splints were applied by a total of 21 residents, 13 of which applied at least one FS. All 13 of these residents completed the survey (Table 4). All of the residents reported that the FS was easier to apply and 11 of the 13 reported that the FS was better tolerated by patients. The remaining two residents believed there to be no difference in patient tolerance between splint types. The mean (± standard deviation) reported placement time for FS and CS was 13 ± 7 min (range, 5–30 min) and 24 ± 11 min (range, 10–50 min), respectively.

Table 4 Resident survey

Resident	Which splint is easier to place?	How long does a functional splint take to place? (mins)	How long does a coaptation splint take to place? (mins)	Which splint is better tolerated by the patients?
1	Functional splint	15	25	Functional splint
2	Functional splint	10	30	Functional splint
3	Functional splint	10	20	Functional splint
4	Functional splint	15	30	Functional splint
5	Functional splint	10	20	Functional splint
6	Functional splint	30	50	Functional splint
7	Functional splint	5	15	Functional splint
8	Functional splint	5	10	Functional splint
9	Functional splint	5	15	No difference
10	Functional splint	20	40	Functional splint
11	Functional splint	20	20	No difference
12	Functional splint	12	20	Functional splint
13	Functional splint	7	15	Functional splint

Discussion

This retrospective review of humeral shaft fractures initially managed nonoperatively found that the FS is a viable and preferable alternative to CS. These findings were generalizable as all fracture locations and classifications were included and were similar between treatment groups. Fracture reduction, immediately after application and at subsequent follow-up, was similar between the two splint groups, with the exception that the FS group had less correction in fracture coronal translation, but this difference was small (−0.4 mm) and likely not clinically relevant. Additionally, residents reported that they preferred the FS, found it easier to apply, took less time, and were better tolerated by patients.

Three (9%) of the 34 patients managed nonoperatively were ultimately treated with surgery. This conversion rate is similar to that seen in modern series, which has demonstrated failure rates ranging from 10 to 30% [10–12]. Potential risk factors for failure of conservative management include female sex, obesity, and simple AO/OTA type A fracture patterns located proximally or distally; all factors that can accentuate varus deformities resulting in nonunion or unacceptable angulation [10–12]. Our cohort included a majority of males with normal BMIs, which could help explain the low failure rate observed.

The FS applies the same principles as functional braces, using hydrostatic compressive forces and gravity to the upper extremity [13–15]. A potential downside of CS is the subsequent immobilization of the elbow and shoulder, joints where even short-term immobilization can lead to joint stiffness and reduced range of motion [16]. In contrast, the FS is similar in design to the prefabricated brace allows for immediate mobility of the shoulder and elbow joints. Application of CS can be difficult, especially when working without an assistant, as orthopedic trainees often are, on uncooperative or combative patients. The process molding the CS to avoid varus deformity can also be painful and poorly tolerated by patients. FS are subjectively easier to apply by one person and do not require molding, making them an efficient alternative for the on-call resident. Immediate immobilization with a prefabricated brace is also a viable alternative; however, the availability of these braces in the emergency department is limited in many institutions, including our own [15, 17].

The FS does have several limitations. Like the CS, splint loosening can occur. It is imperative that patients and caregivers are instructed on daily overwrapping of the compressive dressing. This study is also limited by the small sample size; however, based on the narrow confidence intervals of the differences in fracture angulation and displacement between the two splint groups there is unlikely to be a clinically relevant difference identified with a larger group of patients. The study is limited by its retrospective nature and lack of patient-reported outcome measures. Patient-reported outcomes would be necessary to determine which splint is better tolerated by patients.

Our reliance on survey data from residents is also subjective and potentially biased. We attempted to control for bias by making the survey blinded. Despite the subjective nature of the resident survey data, the unanimous preference residents had towards the functional splint is telling. The reported time it took to place each splint also had a wide range, likely secondary to recall bias and differences in resident efficiency. The standard deviation of the reported times for splint application between FS and CS splints was similar (7 vs. 11 min) suggesting that a real difference in splint application times exists. A more accurate

difference in splint application time would need to come from prospectively collected data.

Conclusions

This study demonstrated that FS application results in similar reductions in humeral shaft fractures as CS. A survey of residents found that the FS was easier to apply, took less time, and was better tolerated by patients. Subsequently, we prefer the FS over the CS for the acute management of humeral shaft fractures.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

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