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A Pre-fabricated Bracing System for the Management of Humeral Shaft Fractures: Experience of a Centre in the United Kingdom

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SUMMARY

Background. The aim of our study is to evaluate the ability of a pre- fabricated humeral bracing system in providing sufficient stability to fracture union and carry out a cost analysis comparing bracing versus surgical fixation for these fractures.

Material and methods. A review of humeral shaft fractures treated with a pre-fabricated humeral bracing system was undertaken.

Results. 20 humeral fractures (20 patients) were included. Mean patient age was 56.8 years (range 16- 89). There were 14 AO type A, 3 type B and 3 type C fractures. Median time interval from fracture to brace application was 8 days (range 0-41). Clinical and radiological union was achieved in 15 humeri (75%). Median time to clinical and radiological union was 80 days (range 32-434). The cost of treating humeral shaft fractures surgically by plating and by humeral bracing was estimated at £2292.99 and £1228 per case, respectively.

Conclusions. 1. A pre-fabricated bracing system is an efficacious and cost-effective modality for humeral shaft fracture treatment. 2. It may, however, lead to a high non-union rate as well as shoulder and elbow stiffness. 3. A prospective randomized trial comparing bracing with internal fixation of humeral shaft fractures is needed.

Key words: pre-fabricated, humeral, brace, fracture

BACKGROUND

Traditionally, fractures of the humeral shaft have been treated non-surgically, though results of surgical treatment for acute humeral fractures are increasingly reported [1]. Iatrogenic injury to the radial nerve, infection, and metal work failure continue to be the main complications of surgical intervention [2,3]. This supports non-surgical treatment for most acute humeral fractures while reserving surgery for specific indications such as open fractures and non-unions [4,5]. Functional bracing of humeral shaft fractures, based on the principles provided by Sarmiento et al, remains the gold standard non-surgical approach [6]. It keeps the fractured fragments aligned, by circumferential compression of the soft tissue envelope, while allowing early mobilization of the shoulder and elbow. Braces available for humeral fractures can be custom made or pre-fabricated (off-the shelf). Pre-fabricated braces allow easier and faster application and use. In cases of fracture in patients with high body mass index or large circumference of the arm, custom made braces are used.

The aim of this study was to evaluate a pre-fabricated humeral bracing system in providing sufficient stability to fracture union and carry out a cost analysis comparing bracing versus surgical fixation for these fractures.

MATERIAL AND METHODS

We undertook a review of all patients with humeral shaft fractures treated with a pre-fabricated humeral bracing system (Promedics Orthopaedic limited) as their primary treatment over a 10 month period, in a teaching National Health Service hospital in the United Kingdom, under the care of the senior author. Humeral shaft fractures in which the functional bracing was used as the primary method of treatment were included. Fractures in which bracing was used for temporary splinting whilst awaiting surgical fixation were excluded (peri-prosthetic, common pathological fractures). Fractures for which a custom made brace was used because of arm size were also excluded.

The brace was applied as early as possible following injury. The bracing system (see Figure 1) comes in 4 sizes and was applied by a senior physiotherapist with a special interest in orthotics. It consists of polypropylene sleeves held together around the arm by Velcro straps. On the lateral side, the sleeve extends over the shoulder flare and has addition straps which run around the chest to provide additional stability to the injured limb (Figure 2). If required, the sleeves are trimmed around the elbow to permit free elbow motion. For 2 to 3 weeks after the injury the limb was placed in the brace along with a collar and cuff and, subsequently, elbow flexion-extension movements were permitted. Patients were instructed regarding the application of the brace and adjustment of the straps to maintain snug fitting while any swelling subsided. The brace was reviewed by the physiotherapist regularly with regard to brace care (via hospital visit, phone or home visit). The fracture was reviewed by the treating clinician at regular intervals. Union was defined as bridging cal-

Fig. 1. Prefabricated brace (Promedics Orthopaedic Limited)

Fig. 2. Posture of the injured limb treated in a pre-fabricated brace

lus on at least 3 cortices on anterior-posterior and lateral radiographs, along with absence of substantial pain or fracture site mobility.

Patients were identified from the orthotics logbook. Clinical records and radiographs of these were reviewed. Fractures were described using the AO classification. Demographics, time interval from injury to bracing, time to union and time interval from injury to diagnosing non-union was also calculated. The cost of treating humeral shaft fractures surgically by internal fixation using plating and non-surgically using the described bracing system was calculated. Costs of disposables, surgical implants, hospital stay, outpatient visits, radiology services and physiotherapy input were obtained from the accounts department at our hospital and costs of various drugs were obtained from the British National Formulary (March 2011 edition). The basic salary of various medical and paramedical professionals was obtained from the pay circular published by the head of doctors and dentists pay, NHS employers [7].

In calculating costs, the following assumptions were made:

- **Surgical treatment:** The theatre model assumed the following: one consultant orthopaedic surgeon, one registrar and one senior house officer as assistant surgeons, one consultant anaesthetist, one operating theatre practitioner, one scrub and one circulating nurse, and one radiographer; the consultant anaesthetist and orthopaedic surgeons being at threshold level 4 with an annual basic salary of £81,502 with the registrar at point 4 with an annual basic salary of £37,448 and senior house at point 2 with an annual basic salary of £31,434 (the hourly cost of these professionals was calculated by considering a 40 hour week, 52 weeks in a calendar year along with the add-on costs at the standard rate of 23.3%. The annual basic salary was divided by 2080 (52×40) to calculate the hourly cost of each medical professional); all non-medical staff being at band 5 level); general anaesthetic administered; antibiotic prophylaxis in the form of three doses of 1gram Flucloxacillin and one dose 80mg Gentamycin; a locking compression plate with eight screws (AXOS, Stryker) as the implant of choice; wound closure carried out using a vicryl no. 1 and a vicryl no. 2 suture, clips and dressing; average surgical time being 3 hours; one Bradford sling, an overnight stay, and one polysling (Promedics) supporting the arm post-surgically; 6 outpatient clinic visit post surgically per case with radiographs obtained at each visit.
- **Prefabricated humeral brace treatment:** The following assumptions were made: single brace used for whole treatment per individual; stockinette used under the brace required to be changed for hygiene reasons 12 times per individual; collar and cuff sling used to support the limb while in the brace; 3 slings required per case; 6 outpatient visits required per case; 9 appointments with physiotherapist, with first appointment lasting 45 minutes and subsequent appointments 25 minutes each.

RESULTS

Twenty five patients (25 humeri) had functional bracing for humeral shaft fractures during the examined period. Of these, 2 had a pathological fracture, 2 periprosthetic fractures and 1 was treated with a custom-made brace. After excluding these, 20 were left for inclusion. Demographics and fracture description of the patients are shown in Table 1. All cases were followed at least until fracture union or until the decision for surgical treatment was taken. Median follow up time from injury was 104 days (range 32 -434).

Median time between fracture occurrence and brace application was 8 days (range 0 to 41). Fifteen (75%) fractures united clinically and radiologically. Most cases required regular physiotherapist assistance to pursue bracing. Seventy-five percent of patients required 5-10 physiotherapy sessions and the rest more than 10 sessions. Most commonly the brace required a refit and stockinette change at each physiotherapy consultation. Four required small size humeral brace, seven medium, five large and four extra-large.

Median clinical and radiological union time for cases whose fracture united was 80 days (range 32-434). Median time to decision for surgical fixation from the date of injury, in cases of impaired union, was 104 days (range 42-278). The decision of undertaking surgical fixation was based on clinical (pain and mobility on the fracture site) and radiological (absence of callus) findings. This was done by the treating clinician in consultation with the patient.

Union was achieved in completely displaced (see Figures 3a, 3b, 3c and 3d) and segmental fractures. Three patients had union time of more than 150 days. Two of these 3 patients sustained repeated injury after brace application and were thus kept in brace for longer. One patient had segmental fracture and union time was 434 days for both fracture sites to unite. This case was labelled as delayed union.

Five fractures (25%) did not unite. Table 2 compares patients whose fracture united and those not uniting. One patient developed radial nerve palsy at the time of fracture. This recovered completely in 4

Tab. 1. Background data of the patients included in the study (n=20)

Gender	
Male	10 (50%)
Female	10 (50)%
Median Age (range)	56.8 years (range 16- 89)
Side	
Left	10 (50%)
Right	10 (50%)
Fracture location	
Proximal third	2 (10%)
Middle third	8 (40%)
Distal third	2 (10%)
Junction of proximal and middle third	6 (30%)
Multilevel (Segmental)	2 (10%)
Fracture type	
AO Type 12A	14 (70%)
AO Type 12B	3 (15%)
AO Type 12C	3 (15%)

Tab. 2. Comparison between united and non-united fractures

Demographics	**Union achieved**	**Failure to unite**
Male Gender	9	1
Mean Age in years (range)	58.2 (16-88)	52.9 (33-89)
Left: right	8:7	2:3
Fracture type		
AO type 12A	11	3
AO type 12B	3	0
AO type 12C	1	2
Mean time from injury to brace in days	9.4	12.6
Brace size		
Small	4	Nil
Medium	4	3
Large	4	1
Extra Large	3	1
Fracture Location		
Proximal third	1	1
Middle third	7	1
Distal third	1	1
Junction of proximal and middle	5	2
Multilevel (Segmental)	1	Nil

Figure 3a and 3b. Antero-posterior and lateral radiographs of 46-year-old male, immediately after the injury, showing AO type 12A1 fracture of left humeral shaft. 3c and 3d. Antero-posterior and lateral radiographs of the same patient showing cortical bridging and union

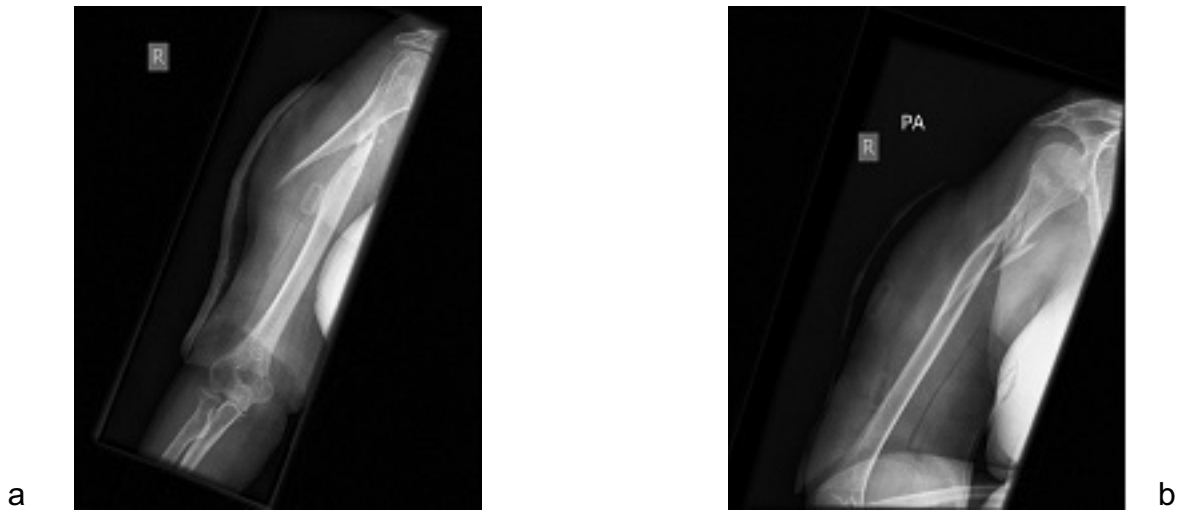

Fig. 4a and 4b. Radiographs of a 75-year-old female showing humeral shaft fracture displaced in abduction

Tab. 3. Breakdown of the cost involved for surgical treatment of humeral shaft fractures

Anesthetic disposables (Number used*cost per item (£)): Veinflon (1*0.86), ECG dots (3*0.03), Tagaderm dressing (1*0.31), Long circuit/ patient (1*6.61), Suction tubing (1*0.75), Yankeur (1*0.26), 3-way extension (1*0.77), Anaesthetic breathing system (1*6.5), IV giving set (1*1.15), Oropharyngeal airway (1*0.24) Oxygen mask (1*0.55), Catheter mount (1*0.85), Endotracheal tube (1*1.15), Patient warming system (Bair Hugger)(1*18.1) –Total £ 38.2
Drugs (Number used*cost per item (£)): Lignocaine 0.5% 10mls (2*1.06), Propofol 20 mls (5*3.46), Fentanyl 100mcg (1*0.3) N-Saline 1 litre (1*0.97), Flucloxacillin (3*4.9), Gentamycin (1*1.48) – Total 36.87
Surgical items (Number used*cost per item(£)): Surgical drapes (1*6.67), Stockinette (1*1.71), Bandage (1*0.84), Receivers (2*0.25), Gallipots (2*0.11), Blade no. 23 (2*0.06), AXOS humeral plates (1*63), Cortical screws (8*13), Vicryl suture no. 1 (1*2.9), Vicryl suture no. 2 (1*2.87), Skin Clips pack (1*4.27), Opsite dressing (1*0.15), Bradford Sling (1*9), Polysling (1*17) – Total £ 213.25
Postoperative care (Number used*cost per item(£)): Ward stay (1 day*250), Outpatient clinic appointments (6*143), Radiographs during outpatient visits (6*33) – Total £ 1306
Staff cost (Number of hours* Cost per hour(£)): Surgeons(3*48.21), Anaesthetist (3*48.21), Nurse (3*19.13), Radiographer (3*19.13), Operating theatre person (3*19.13), Assistant surgeon 1 (Registrar)(3*22.19), Assistant surgeon 2 (Senior House officer)(3*18.63), Pre-op assessment (3*19.13), Post-operative recovery (3*19.13) - Total – £698.67

Tab. 4. Breakdown of the cost involved in pre-fabricated brace treatment for humeral shaft fractures

	Cost per item (£)	Number	Total cost (£)
Outpatient visits	143	6	858
Orthotics	21.60 per hour	4 hours	88.2
Travel cost	-	-	10
Radiographs	33	6	198
Promedics Humeral brace	58.80	1	58.80
Stockinette changes	12	1	12
Collar cuff sling	3	1	3

months without surgical intervention. Four developed restriction of shoulder movements, 1 restriction of elbow movements and 1 restriction of both shoulder and elbow movements. All recovered normal motion with physiotherapy.

The cost of surgical fixation of humerus shaft fractures was estimated at £2292.99 and the cost incurred for brace treatment at £1228 per case. Details of the itemized estimated costs are shown in Tables 3 and 4. Fifteen cases treated with prefabricated braces incurred a cost of £18420. Five cases of non-union treated by surgical fixation after a trial of non-surgical treatment would cost £17604.95. If all 20 cases were primarily treated surgically the total cost incurred would have been £45859.80.

DISCUSSION

A non-union rate of 2 to 20% was previously reported with non-surgical methods of treatment other than functional bracing for humeral shaft fractures. Such methods included hanging casts, sling or swathe or U plaster slings [8]. Sarmiento et al. described functional bracing for humeral shaft fractures in 1977 [6] . In the original study, 49 humeral fractures were treated with prefabricated polypropylene sleeves. The study group included 11 gunshot cases and 2 pathological fractures secondary to breast cancer metastasis, with only 1 case developing non-union. Sarmiento et al reproduced a similarly high union rate in a larger series of humeral diaphyseal fractures [9]. Subsequently, functional bracing was described in extra-articular distal humeral fractures with a 96% union rate [10]. Good results were shown in cases of open fractures and those with nerve injuries. Encouraging results were reproduced by other authors [11].

Surgical treatment of humeral shaft fractures has undergone major evolution over the past decade. Paris et al. reported a consolidation rate of 94.2% in 156 humeral fractures treated with plating within 6 days of injury [12]. An et al. reported a union rate of 100% for mid-shaft humeral fractures treated by open reduction and plate fixation or with minimally invasive plate osteosynthesis [13]. However surgical complications are frequently reported. Loyald et al. reported 10.2% metal work removal rate after open reduction and internal fixation of humeral fractures [2]. Radial nerve palsy following surgical fixation is another major complication to be considered [12,13]. However, 90% of iatrogenic radial nerve palsies may be transient and reversible [12]. Functional bracing of humeral fractures is not complication-free. There have been reports of skin and soft tissue related complications associated with the brace [11,14,15]. In our study, no such complications were observed probably due to the regular monitoring of braced patients by a dedicated physiotherapist with a special interest in orthotics.

Most fractures in our study united (75%), however, the union rate in our study was lower than that previously reported [10]. The 5 cases with non-union

may be related to fracture configuration and site. Three of these involved the proximal humeral shaft with the proximal fragment abducted due to the unopposed deltoid action. This increased the demand on the brace to control and maintain alignment (see Figures 4a and 4b). Another proximal humeral shaft fracture did not unite though no significant abduction of the fragments was observed. Comminution and soft tissue interposition could have played a role in this case. One patient sustained a distal humeral fracture which underwent atrophic nonunion. It was stabilized with a plate and screws 3 months following the initial injury. At surgery, bone fragments were found subcutaneously signifying a high energy injury leading to extensive soft tissue disruption.

The cost of brace treatment was estimated to be much lower than surgical treatment of humeral shaft fractures. Such findings, however, should be approached with caution as the low cost of bracing might be compensated by a long time to union and the personal costs incurred to patients, which were not examined in this study. In contrast, if a patient develops a complication following surgery, the loss of working hours and other personal costs incurred by patients could be much higher.

There are certain limitations with this study. We did not record various characteristics of our subjects that could have been instrumental in causing nonunion such as personal history of smoking or alcohol intake. This is a retrospective analysis and objective scoring for the function of the limb was not recorded as this is not a part of our routine clinical practice. In addition, alignment of the fracture fragments was not assessed, as radiographs in this study were not standardized. However, we have no cases of malunion that impaired clinical function. We also acknowledge that our cost evaluation was based on certain assumptions and the list of items enumerated is not exhaustive. A full cost analysis would also include personal cost and societal cost in addition to direct treatment cost.

CONCLUSIONS

1. A pre-fabricated bracing system is an efficacious and cost-effective modality for humeral shaft fracture treatment.
2. It may, however, lead to a high non-union rate as well as shoulder and elbow stiffness.
3. A prospective randomized trial comparing bracing with internal fixation of humeral shaft fractures is needed.

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