Acta Orthop. Belg., 2022, **88**, 151-159

ORIGINAL STUDY

doi.org/ 10.52628/88.1.19

Non operative management of fractures of the humerus Evaluation of a new extension casting method

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Fractures of the humeral shaft represent 2-4% of all fractures and functional bracing is the gold standard in conservative management. Complications like restricted shoulder range of motion and malunion of the proximal shaft fractures have however been reported. We conducted a retrospective chart review of patients treated with the extension casting method over a period of 16 years. Topographically, Garnavos P, M, D, PM and MD fractures and morphologically Simple, Complex and Intermediate fractures were included. Between 2003 and 2019, 74 patients were treated with extension casting. The fractures united at a mean of 10 weeks and there was no case of non-union. Humerus is one of the bones where conservative methodology is still very pertinent. Extension casting gives reproducible and good results. It also addresses patient comfort issues to a considerable extent by allowing shoulder motion and easier maintenance of personal hygiene.

Keywords: Humerus; fracture; non-operative; extension casting.

INTRODUCTION

Humeral shaft fractures are quite common and represent 1-3% of adult fractures *(1, 2)*. Yet management of diaphyseal humeral fractures has been subject to change especially against the ever-improving background of improved surgical safety and techniques *(3, 4)*. Fractures of the humeral shaft resulting from low-energy trauma can be treated successfully with conservative methods *(5)*. Literature supports the fact that closed, acute, and isolated fractures of the humeral shaft do well with non-surgical management *(6)*. However, this evidence is often disregarded, irrationally, because of a desire to achieve an earlier return to normal activities *(4)*. Because of the excellent blood supply and good soft tissue cover these fractures have a strong tendency to unite giving credence to the cynical statement; “Keep two ends of humerus in the same room, and they will unite, so long as an orthopaedic surgeon does not enter the room” *(7)*. Several non-operative methods have been in literature mentioned including skeletal traction,

No conflict of interest was involved in the formulation of this manuscript.
Ethical clearance was obtained.
Availability of data: yes.
There was no funding for this article.
There are no competing interests.

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Velpeau bandage, a sling and body bandage, abduction cast, U slab, hanging arm cast and the functional brace *(4)*. All the former methods have shortcomings and functional bracing has come to dominate the non-operative spectrum *(8)*. However, research does show that residual deformity and joint stiffness are amongst the relative drawbacks of this method of treatment *(9)*.

With the Covid19 pandemic a general reluctance to perform aerosol generating procedures has to be factored into any orthopaedic decision-making process. Therefore, there is a resurgence in interest in non-operative methods *(8, 10)*. In the pursuit of improving the conservative fracture care new methods have to be discussed and exhibited. This paper describes the biomechanics, technique and results of one such method i.e. extension casting of fractures of the humeral shaft.

MATERIAL AND METHODS

This study was carried out over sixteen years by the senior author on a large number of patients. Records were reviewed and 74 patients whose radiological and clinical record was intact were included in this study. Patients with topographic Garnavos class M, MP and MD and morphologic class S, I and C were included in this study *(11)*. All patients were treated by extension casting (Keeping the elbow in extension and forearm in supination) by the senior author.

Assessment criteria

1. **Time to union.** This was defined, clinically, by the absence of tenderness and abnormal movement at the fracture site. Radiologically, union was said to have occurred in the presence of cortical continuity or bridging across at least three out of four cortices as seen on the anteroposterior and lateral views.
2. **Coronal and sagittal plane alignment and deformity.** Angles were calculated between the axes of the proximal and distal fragments.
3. **Combined shoulder, elbow and wrist movement.** The range of motion was expressed as a percentage of normal movements of the opposite side to assess the functional results. We measured the shoulder movements on the opposite side and added up all the movements. As an example, if a patient had 180-degree flexion, 50-degree extension, 150-degree abduction, 40-degree adduction, and 80-degree degrees of internal and external rotation, his combined movement would add up to 500 degrees. If the affected shoulder had a total range of motion of 450 degrees then the range of motion of that the shoulder would be 90% of the normal side. The same formula was applied for elbow and wrist movements.

The cast was applied with the patient sitting comfortably. If the patient was apprehensive, an ὰ 1 portal block is administered. A stockinette was applied extending from metacarpo-phalangeal joint to the axilla. An additional 25 cm was added at the proximal end. This upper part was split, and the two ends tied across the neck as a necklace. This prevented slippage of the straight extension cast, especially in obese patients (Figure 1,2 and 3).

Very light padding was used over the stockinette and the cast was applied. Either conventional plaster of Paris or a light fiberglass plaster cast was used. The cast was applied as light as possible to avoid distraction without compromising its strength. This was essentially achieved by applying just two layers of fibreglass or four layers of the conventional plaster. The forearm was placed in full supination with palm facing forward in all cases. This was done to keep the forearm interosseous tissues stretched to ensure good post cast range of motion as also to enable better assessment of reduction and carrying angle during the reduction maneuvers.

The cast extended from the anterior fold of axilla to the distal part of the forearm in cases with Garnavos topographical P, M, PM and MD cases *(11)*. The proximal part was moulded to the contour of the deltoid. In cases with MD type fractures the cast extended from just above the deltoid insertion to the distal forearm. The proximal extent of the cast in D cases was just proximal to the deltoid insertion.

All patients were encouraged to move the shoulder early and actively to achieve abduction and forward flexion as in a "rifle butt movement manoeuvre". This also helped to avoid the development of any hand swelling. Patients were encouraged to exercise the hand regularly also.

Figure 1. — The initial extension cast (Top row). Final cast is shown in the bottom row.

Figure 2. — Early shoulder range of motion in the extension cast.

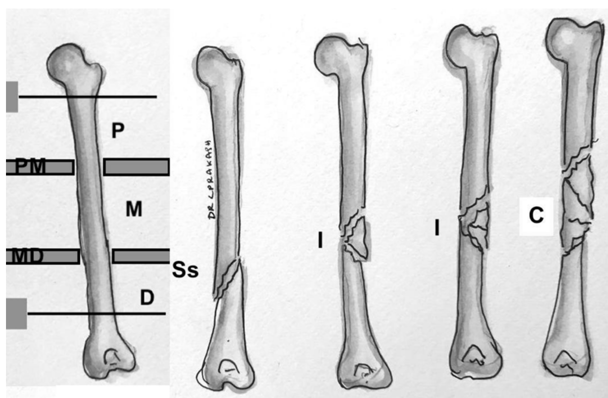

Figure 3. — The Garnavos classification of humeral shaft fractures.

Between 3 to 6 weeks when the fracture became sticky, an arm cylinder from axilla to the flexion crease of the elbow was applied. We kept the plaster longer in simple fractures. This allowed institution of early elbow movements. However, sling use was discouraged. The arm cast was retained until radiologic fracture union.

RESULTS

74 patients were treated by this method including 60 males and 14 females. The age of the patients ranged from 19 to 70 with a mean age of 45.5. Out of these, 58 patients were treated on day of the injury while 16 patients had a delay in treatment ranging from 2 to 11 days due to various reasons. Topographically there were 13 P, 25 M, 17 D, 10 PM and 9 MD fractures. Morphologically there were 28 [S]simple (18 St and 10 Ss), 17 [I]intermediate and 29 [C]complex fractures according to the Garnavos classification. The full-length cast was applied from 4 to 6 weeks with a mean of 5 weeks. All casts were converted to the above elbow cast when the fracture became sticky. All fractures united radiologically within a time range of 8-18 weeks. The mean time to union was 10 weeks.

Radiological evidence of a fluffy callus appeared at an average of 35 days and bony union was achieved at an average of 10 weeks across the series.

The final assessment showed that the shoulder function was 92% of the normal side. Elbow function was 94 % and wrist function was 100% in the patients as compared to the opposite side.

External rotation restriction was less than 10 percent on an average in comparison to the normal side (Figure 3, 4, 5 and 6).

Coronal plane deformity ranged from 6 to 20 degrees with a mean of 7 degrees and sagittal plane deformity ranged from 4 to 10 degrees with an average of 5 degrees. These deformities did not affect function in any manner. The angulation of the MD fractures was not significantly different.

The complications that we encountered included 3 cases of cast slippage in relatively obese patients. The casts were applied in mild flexion of the elbow. And 2 cases of complex regional pain syndrome.

We did not encounter any case of radial nerve palsy induced by cast application. All cases of trauma induced radial nerve palsy had been excluded because as we did not want any bias in results in terms of range of motion of the wrist and elbow. The absence of a cast induced radial nerve palsy could be due to less pressure of the fracture callus from behind due to a relaxed triceps. But obviously a larger series can clarify this finding further.

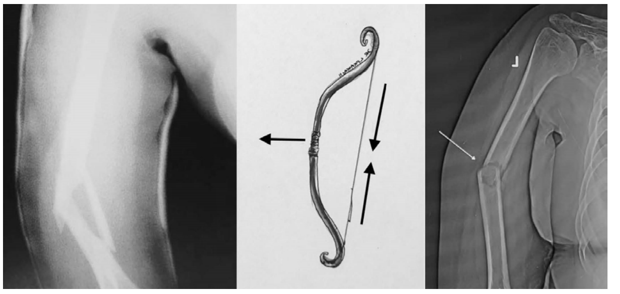

Figure 4. — The Bowstring phenomenon.

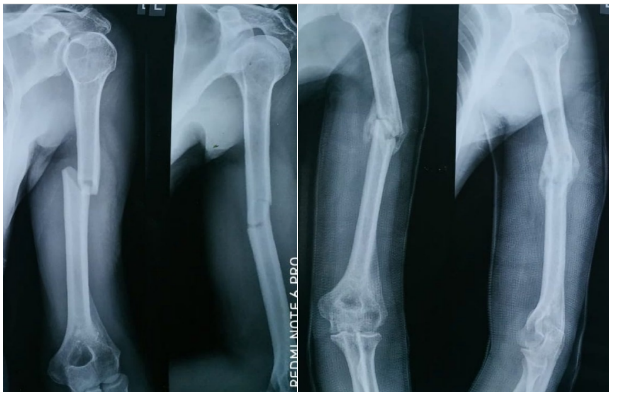

Figure 5. — The progress of union in a transverse humeral fracture in an extension cast.

DISCUSSION

Humerus is one of the long bones which continues to be amenable to conservative management *(12, 13, 14)*. Zhang et al. in 2017 in their study on 252 cases found that the results of non-operative treatment of humeral shaft fractures appeared to give excellent results with lower complications rate compared with that of the operative treatment *(15)*. Mahabier et al. in their study on 186 cases concluded that consolidation time and complication rates were similar after operative and non-operative treatment *(16)*.

Sarmiento et al. in a landmark study of 620 humerus fractures treated with a functional brace reported a non-union of 2.5% with the healing time averaging 9.5 weeks *(5)*. Currently, functional bracing is the most commonly applied method of treatment of humeral fractures with good reproducibility. However, Fjalstead et al revealed that 38% patients treated with this method showed significant external rotation of the shoulder joint

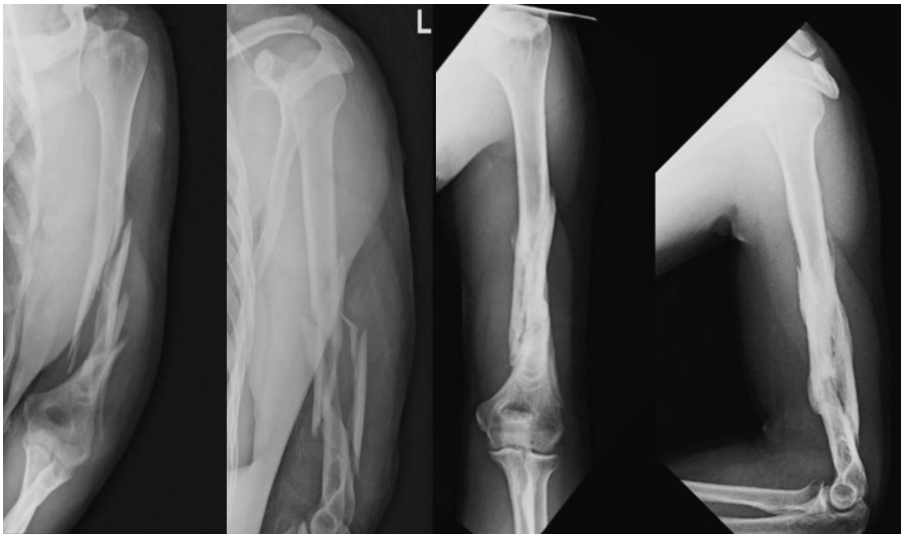

Figure 6. — The progress of union in a comminuted fracture. Extension cast was used.

Table I. — The following chart shows the angulations and composite movements

Topographic or Morphologic type Number of Cases	Mean union time [weeks]	Mean angulation coronal plane	Mean angulation sagittal plane	Composite shoulder movement expressed as a percentage of opposite side	Composite elbow movement expressed as a percentage of opposite side
P [13]	13	12	6	90%	98%
PM [10]	12	13	8	94%	98%
M [25]	8	7	6	94%	97%
MD [9]	9	9	10	92%	94%
D [17]	9	10	12	94%	93%
S [28]	12	7	7	92%	98%
I [17]	11	10	11	93%	93%
C [29]	9	11	9	92%	94%

Table II. — This chart shows the end point pain and function scores of the various types

Topographic or morphographic type	Pain VAS Score, day 1, day 7 at union	ADL Recreational activity at union
P	7 3 1	8-10
PM	8 2 1	6-8
M	6 2 0	8-10
MD	7 3 1	8-10
D	8 3 1	8-10
S	8 3 0	8-10
I	7 2 0	6-8
C	8 3 1	8-10

on CT assessment *(17)*. This has been correlated by Koch et al and Pehlivan et al too *(18, 19)*.

Although overall effectiveness of functional bracing is not disputed, but Toivanen et al reported that proximal shaft fractures have a higher non-union rate *(20)* when treated conservatively. Wallny et al reported that middle third fractures are also at a higher risk of non-union *(21)*.

Sir John Charnley had been rather critical of a sling and termed it as a “deforming force” in his classic work on closed fracture management *(22)*. Chess, who formulated the principle of indexed casts also opined that elbow flexion is disruptive for both humerus and forearm alignment except in

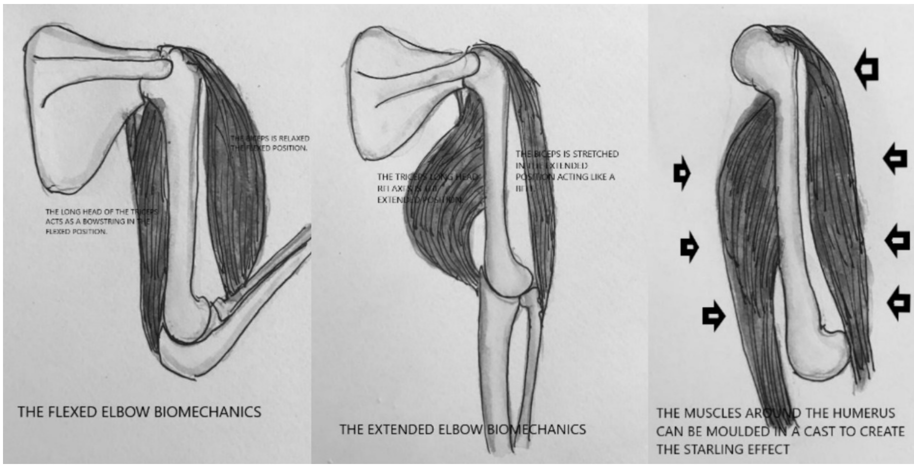

Figure 7. — The biomechanics in flexion and extension.

very specific conditions *(23)*. In an era of resurgent interest in conservative methods, non-union, deformity and shoulder range of motion of the shoulder should be the focus of further research in the conservative management of humeral fractures.

The idea of the elbow extension cast developed when the senior author had to assess, treat and follow up many orthopaedic patients, including those with fractures of the humerus, in a prison over a period of 13 years. Some patients and detainees whose humeral fractures had been treated by extension splinting by a local bone setter reported late to him in the prison and he observed surprisingly good results with low complication rates.

The senior author reassessed the musculoskeletal biomechanics of the humerus to explain this regular finding.

In any fracture immobilisation, active muscle contractions do not occur continuously. Therefore,

Figure 8. — The final range of motion.

Table III. — Depicting the biomechanics of fracture immobilisation

Extension	Flexion
In extension the biceps is stretched passively. It acts like a relatively taut belt against which the humerus can be reduced. The triceps is relaxed passively in extension. However, the medial and lateral heads are directly attached to the humerus and they straddle the fracture area. Despite the fracture, they continue to provide support without producing deforming forces due to their relaxed position. The long head is however relaxed and allows for easier fracture manipulation. This configuration of triceps and biceps in extension causes a **sleeve phenomenon** which allows the cast to recreate Starlings law.	1) In flexion, the biceps muscle is totally relaxed, consequently it does not provide good support to the fractured humerus anteriorly. 2) In flexion the long head and the fascia of triceps is stretched passively across the two joints. It behaves like a bowstring which either causes the humerus to angulate anteriorly or overlap at the fracture site. This can be understood as a **bowstring phenomenon**. This phenomenon is more manifest due to the lack of support of a passively relaxed biceps anteriorly.

musculoskeletal fracture biomechanics have to be understood in terms of passive stretch and relaxation forces.

Two muscles cross both the elbow and the shoulder joint. Triceps and biceps. Both these muscles are central in the understanding of humeral fracture biomechanics. Both muscles have similarities but triceps has an additional biomechanical contribution. (Figure 4 and 7) (Table III).

It is important to understand that the advantage is mainly felt in the sagittal plane. The static medio-lateral forces are not benefited. However, in the extended position the distal fragment can be controlled better due to a longer lever arm provided by the forearm and anatomic position can be better assessed. This is a welcome benefit especially in view of the fact that a prison is a very resource constrained setting and trained assistance is not available.

After being convinced of its benefits, the senior author started application of extension casts on patients in the prison environment with careful personal monitoring and obtaining informed consent from the patients and detainees. This was done with permission of the authorities too. Over a 12-year period 56 patients with closed or open humeral shaft fractures, often sustained due to prison violence, were treated by the first author with an extension cast with reproducible results both in terms of fracture union and function of the elbow and shoulder *(19)*.

This method was also used by the author at his clinic. 18 patients were treated there with X-ray follow up at 1, 3 and 6 weeks. This was followed by x rays 2 weekly. The final x ray was taken at 6 months. This was done with ethical committee clearance and on obtaining informed consent from all the patients.

The application of a longer cast allowed greater immobilization of the fractures resulting in good callus formation initially. This was followed by the application of a shorter cast and institution of movement at the elbow. This helped in consolidation of the callus rather quickly. This could be a good combination of relative and absolute stability at various points of callus formation. One of the features of this type of conservative management is that the healing area can be stressed variably.

An advantage of the conservative treatment is the fact that the humerus is not a load bearing limb and deformity can be tolerated reasonably well. It has been reported that up to 30° varus, 20° procurvatum and shortening of up to 4 cm are tolerated, therefore these fractures do not necessitate an anatomical reduction *(8, 24, 25, 26)*. The conservative treatment can also lead to some loss of motion of the shoulder as well as the elbow *(27, 28, 29)*. Despite the advantages of conservative methods, surgical treatment of humeral shaft fractures in the United States has been increasing over time. The reason for this rise remains unclear. In a scenario where the shift towards operative treatment is inexplicable, more focus should be on improving the conservative methodology *(30)*. This is especially so in the current pandemic *(10, 31)*.

The absence of radial nerve palsy in our study is a definite benefit especially in view of the fact that the special relationship between this fracture and radial nerve palsy is not as strong as the original authors suggested *(32, 33)*.

The study shows that the extension casting is a safe and efficient alternative that provides results that are as good as the functional brace without restriction of shoulder motion. It also provides comparatively lower incidence of proximal shaft malunion and non-union.

CONCLUSION

Extension casting provides the following benefits.

It can be applied easily in resource constrained settings. The ultra light minimally padded casts closely contoured over deltoid, biceps and triceps, applied with a precise cast index is extremely patient compliant.

The flexed forearm is a lever causing rotational motion at the fracture site. An extended forearm causes minimal rotation. This causes rapid union in an average of 10 weeks as opposed to the average of 19 weeks it took for surgically treated humeral diaphyses fractures *(31)*.

The range of the shoulder motion especially external rotation is not disturbed. This is because of the fact that shoulder range of motion can be started immediately.

There is minimal effect on the overall range of motion. In addition, the cast allows excellent patient hygiene and the patient can take bath. In elderly obese women with large frontal protuberances, a flexion cast is extremely irksome and unhygienic. That problem is avoided by this method.

The dependent position of the limb does not result in oedema of the hand. This is because of institution of early range of motion at the shoulder and the action of the unaffected forearm muscles as a pump. We did not encounter any case of swelling of the hand or forearm.

It allows gravity (the principal of the hanging cast) to work all the time which is especially beneficial for comminuted fractures. This could be the reason that we did not encounter any case of shortening.

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