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TRAUMA SURGERY

# Internal fixation of proximal humerus fractures using the T2-proximal humeral nail

**Dragos Popescu · Jenaro A. Fernandez-Valencia · Moisés Rios · Jordi Cuñé · Anna Domingo · Salvi Prat**

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**Abstract**
*Introduction* Surgical management of proximal humerus fractures remains controversial and there is an increasing interest in intramedullary nailing. Created to improve previous designs, the T2-proximal humeral nail (PHN) (Stryker®) has been recently released, and the English literature lacks a series evaluating its results. We present a clinical prospective study evaluating this implant for proximal humeral fractures.
*Method* We evaluated the functional and radiological results and possible complications. Twenty-nine patients with displaced fractures of the proximal humerus were treated with this nail. One patient was lost right after surgery and excluded from the assessment. Eighteen patients were older than 70 years.
*Results* There were 21 fractures of the proximal part of the humerus and 7 fractures that also involved the shaft; 15 of the fractures were two-part fractures (surgical neck), 5 were three-part fractures, and 1 was a four-part fracture. All fractures healed in a mean period of 2.7 months. There was one delayed union that healed in 4 months. One case of avascular necrosis of the humeral head was observed (a four-part fracture), but remained asymptomatic and did not require further treatment. In one case a back-out of one proximal screw was observed. A final evaluation with a minimum 1 year follow-up was performed by an independent observer; in 18 patients, the mean Constant score was 65.7 or 76.1% with the adjustment of age and gender; in 19 patients, the mean Oxford Shoulder Score was 21.7. The results obtained with the T2-PHN nail indicate that it represents a safe and reliable method in the treatment of two- and three-part fractures of the proximal humerus. The proximal fixation mechanism diminishes the rate of back-out of the screws, a frequent complication described in the literature. Better functional results were obtained from the patients younger than 70 years, but these were not statistically significant.

**Keywords** Humerus · Nail · Proximal · Fracture · PHN · T2

D. Popescu (✉) · J. A. Fernandez-Valencia · M. Rios · A. Domingo · S. Prat
Department of Orthopedics and Trauma Surgery (Trauma Unit) Hospital Clínic, University of Barcelona, Villarroel, 170, 08036 Barcelona, Spain
e-mail: drag_popescu@yahoo.es

J. A. Fernandez-Valencia
e-mail: jenarovalencia@hotmail.com

M. Rios
e-mail: mrios@clinic.ub.es

A. Domingo
e-mail: adomingo@clinic.ub.es

S. Prat
e-mail: sprat@clinic.ub.es

J. Cuñé
Department of Orthopedics and Trauma Surgery Hospital Clínic, University of Barcelona, Barcelona, Spain
e-mail: yurinka00@hotmail.com

## Introduction

Fractures of the proximal part of the humerus account for 4–5% of all fractures [5, 9]. Approximately 15% of these fractures require surgical management [11], this being the case of displaced or unstable fractures. A variety of surgical options are available, including Kirschner wires, tension bands, plate fixation, intramedullary nails and hemiarthroplasty. However, no single technique has been demonstrated to be superior.

Historically, one of the most common methods employed was percutaneous pinning, although a biomechanical study conducted by Wheeler et al. [19] found that insertion of an intramedullary nail was superior to percutaneous pinning. Tension-band wiring with Ender nails requires open reduction. A randomized controlled trial comparing tension-band wiring with non-operative treatment found no significant difference in outcome at 1, 3 and 5 years [21]. However, the authors did find that surgery improved the position of the fracture fragments, although not necessarily the function. Open reduction and internal fixation with plates can achieve effective reduction of the fracture and provides good biomechanical fixation [11, 17], but it can also cause devascularization, scarring and stiffness. A biomechanical study by Hessmann et al. [8] found no differences in axial, torsional stiffness or failure between a locked-plate fixation and intramedullary nailing. Hemiarthroplasty has also become a common method of treatment for displaced three- or four-part fractures in the elderly and offers good pain relief; however, most series report it to be less successful in terms of function and range of motion [3, 7].

The use of a locked antegrade humeral nail preserves the periosteal blood supply and retains surrounding soft-tissue attachments. Moreover, its guided locking technique is supposed to considerably shorten the operating time. The T2-proximal humeral nail (PHN) (Stryker®) is a fixed-angle intramedullary device designed for proximal humeral fixation. It provides proximal screws for stabilization of the humeral head and tuberosities. We report the clinical and radiological results from a 1 year follow-up for a consecutive series of patients treated for two- and three-part proximal humerus fractures using the T2-PHN system.

## Materials and methods

### Nail description

The T2-proximal humeral nail (PHN) (Stryker®) is a standard 150 mm (Fig. 1) cannulated and tapered device with a 6° curvature. It has four 5-mm proximal locking and two distal holes. Each of the proximal holes is placed at a different level of the humeral head according to the anatomical position of the main fragments. The two distal oblong holes allow dynamization with the aim of reducing the risk of nail protrusion. The long PHN (Fig. 2) is designed for fractures that also involve the shaft and is available in lengths of 220, 240 and 260 mm. We chose this specific nail for its ability to provide angular stable fixation, this being achieved via the threaded locking proximal holes and nylon bushings that are thought to improve the holding strength and prevent screw migration or back-out, especially in osteoporotic bone. Finally, the proximal length can be adjusted with different size end caps to enhance stability and prevent bony ingrowths into the driving end.

### Group of patients

A total of 29 patients admitted to the Orthopaedic Trauma Unit between May 2005 and June 2006 with displaced fractures of the proximal humerus were treated with the

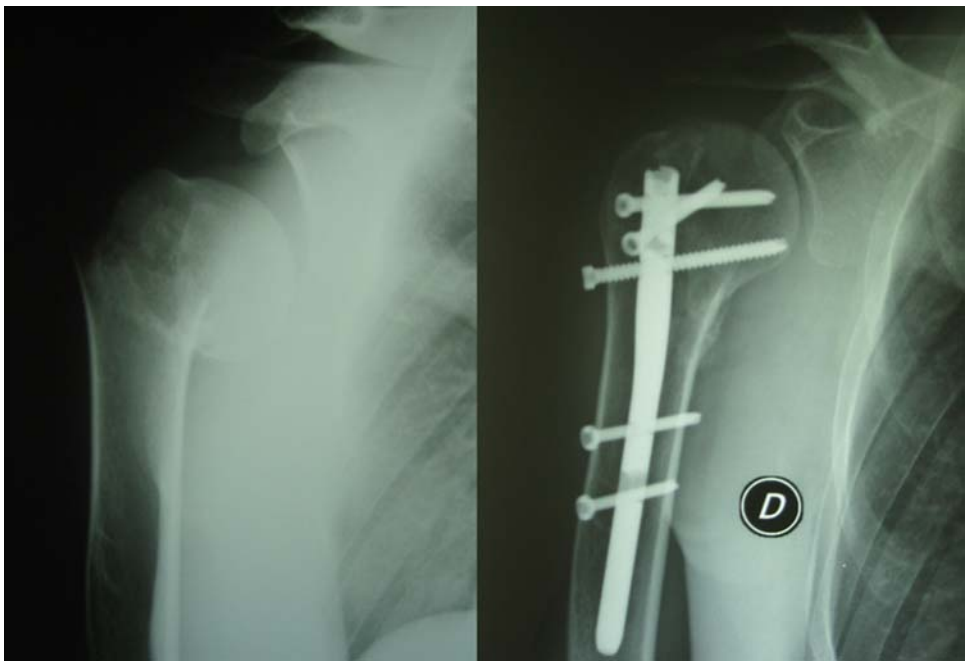


**Fig. 1** Case example of a three-part fracture of the proximal right humerus in a 73-year-old woman treated with the standard T2-PHN. The fracture united in 3 months with a correct neck-shaft angle. The Constant score was 74 and the Oxford score 16

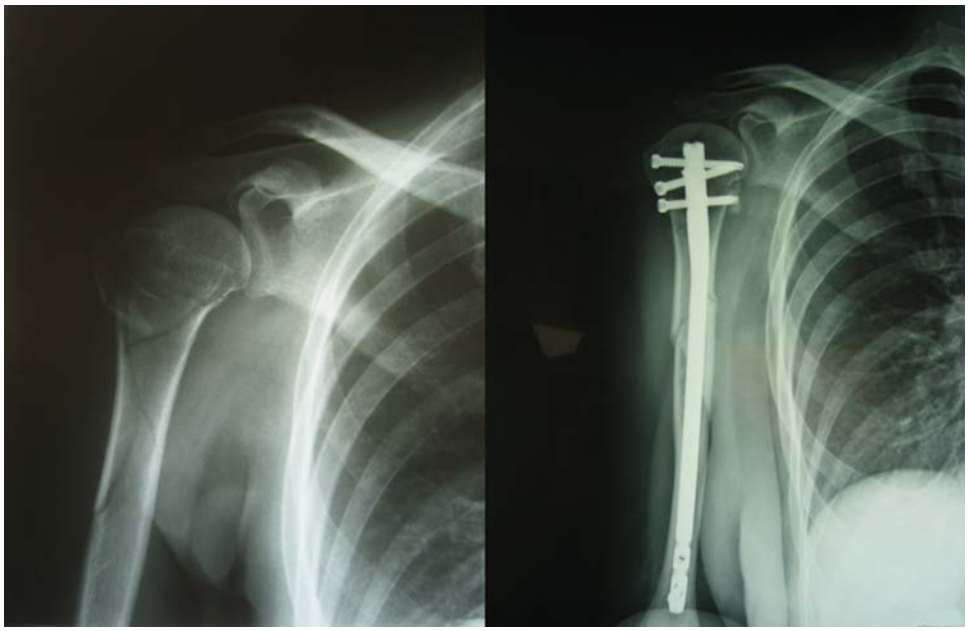

**Fig. 2** Case example of a combined neck and shaft fracture of the right humerus in a 49-year-old woman. She was treated with a 220 mm T2-PHN. The final Constant score was 75 and the Oxford score 16

T2-PHN device. One patient was lost to follow-up immediately after surgery, leaving a total of 28 patients for this series.

The general criterion was that patients were followed up at 1, 3, and 6 months until there was evidence of clinical and radiological union; however, the reviews were done according to medical faculty criteria, and in some cases the follow-up did not follow this schedule. Three patients were lost at the 6 month follow-up visit, and a further six did not attend the final 1 year follow-up appointment. This left a total of 19 patients for the final assessment.

The mean age was 66.5 years (range: 27–88), with a higher prevalence (18/28) of patients older than 70 years. There were 17 women and 11 men. The mechanism of injury was predominantly a casual fall (24 patients), followed by three vehicle crashes and one sporting event. In five cases, six ipsilateral fractures were associated; four distal radius fractures, one radial head fracture and one scaphoid fracture. Two of the cases corresponded to young patients (both 27 years old) involved in a high-energy trauma. The remaining cases corresponded to elderly patients (70, 79, and 82 years old). In two other cases a fracture was present in another extremity, one contralateral Monteggia fracture, and one periprosthetic fracture around knee prosthesis (Rorabeck type 2).

## Fracture types

There were 21 fractures of the proximal part of the humerus alone and 7 fractures that also involved the shaft. The proximal fractures were classified according to the Neer [14] and AO [13] classifications by one of the authors (M. R.) in order to exclude inter-observer error. CT scan was used only in selected cases in order to estimate the extent of articular surface involvement and the amount of tuberosity displacement in comminuted fractures.

We used the strict definition of fragments according to the Neer classification system, which considers a displaced fracture as one with fragments of "greater than 1 cm displacement or greater than 45 degrees of angulation." Two-part fractures according to the Neer classification (subgroup 3) were predominant in 15 patients, followed by three-part fractures in 5 patients (subgroups 8, 9 and 10) and 1 patient with a four-part fracture (subgroup 12). These corresponded to the following types in the AO classification: 1.1-A31 (1 patient), 1.1-A32 (8 patients), 1.1-A33 (6 patients), 1.1-B13 (3 patients), 1.1-B31 (1 patient), 1.1-B32 (1 patient), and 1.1-C23 (1 patient). Two fracture-dislocations (AO 1.1-B3 group) were observed. There were no anatomical neck fractures or isolated tuberosity fractures.

The study includes seven patients with combined contiguous proximal and shaft fractures (AO 1.1 and AO 1.2 fractures). In all these cases we used the T2-PHN long nail of 220 mm length.

## Surgical technique

A total of five different surgeons performed the surgery of the present series. All patients were placed in a beach-chair position. We used the deltoid-splitting approach in all but two patients (a fracture dislocation and a four-part fracture required a deltoid-pectoral approach), and here the skin incision ranged from 3 to 5 cm. We paid careful attention in performing an accurate longitudinal split of the supraspinatus tendon in the direction of its fibers, and a standard entry point was used for both types of nail. This was situated

medial to the greater tuberosity and posterior to the bicipital groove. In five cases we used a joystick technique to reduce the proximal fragment with a Steinmann pin or a Kirschner wire. Between two and four proximal screws were inserted depending on the type of fracture, degree of instability and bone quality. We used three screws in 18 cases, two screws in 9 (mainly fractures that extended to the shaft), and four screws in 1 case.

The distal locking screws for standard nails were inserted via targeting sleeves into the humeral shaft. If longer nails (220 mm) were used, then a free-hand method under fluoroscopic control was employed to insert the distal screws. Occasionally (two cases), the nailing was supplemented with additional osteosutures using a number 5 non-absorbable filament (Etibond®). In none of the cases was bone graft employed.

The rotator cuff was carefully closed with non-absorbable sutures (Etibond® 2).

### After-care

The patients started pendulum exercises 24–48 h after surgery. A sling was worn for 3 weeks, and after this period active and assisted shoulder motion was allowed.

### Assessment

As a general basis, radiological assessment was performed immediately after surgery, and at 1, 3, 6, and 12 months. It consisted of an AP view of the glenohumeral joint and a Neer scapular lateral view. The quality of reduction, healing, formation of ectopic bone, proximal screw migration or backing out, development of glenohumeral osteoarthritis and avascular necrosis of the head were all assessed. The neck-shaft angle was evaluated according to the method described by Agel et al. [2], this being an indicator of a correct surgical reduction of the fragments. Malunion was defined as a neck-shaft angle less than 110° of valgus. Non-union was defined as fixation failure or a non-united fracture. If non-union was detected at 3 months after surgery, the patient was evaluated monthly until union was radiographically documented.

At a minimum follow-up of 12 months the patient was sent an additional appointment by an independent evaluator and the Oxford Shoulder Score [6] and the Constant-Murley Score, adjusted for age and gender [10, 20], for pain, motion and strength were determined.

### Statistics

Data were entered and analyzed with OpenEpi v.2 (available at http://www.openepi.com). To compare the results between patients younger or older than 70 years and between the two types of nails (standard length and 220 mm), the two-sample independent $t$ test was used. The $P$ value was set prior to analysis at 0.05.

## Results

Overall, the fractures healed in a mean period of 2.7 months (1–4 months). There was one delayed union that healed in 4 months. None of the patients required a postoperative blood transfusion and no vascular or nervous lesions were observed. There was no infection in this series. One case of avascular necrosis of the humeral head (a four-part fracture) was observed, but this was asymptomatic and did not require further treatment.

In five cases the proximal insertion of the nail produced a fracture of the larger tuberosity; the patients with this complication were 45, 53, 79, 81 and 83 years old. In two cases the nail was supplemented with additional osteosutures with number five non-absorbable filament, in one case tied around the lateral screw. In the remaining three, the tuberosity was fixed by one of the proximal screws and did not require additional sutures. In all the events, the surgical repair and final reduction was considered satisfactory in all five cases.

The mean neck-shaft angle right after surgery and 1 year after surgery was 123° (90–140) and 120° (90–130), respectively. Four patients had a malunion. The cephalic segment was in varus in all these cases (neck-shaft angle less than 110°), but they did not require further treatment.

Five patients underwent additional operations, four complete implant removals and one proximal screw removal due to back-out of the screw.

At the 1 year follow-up the mean final Constant score for 18 patients was 65.7 (28–88), or 76.1% (31.8–95.4) with the adjustment of age and gender (for one of the patients we did not have the strength measurements so the Constant score was unavailable). The mean Oxford Shoulder Score, available in 19 patients, was 21.7 (12–44).

From the 21 shoulders treated with the standard nail the mean final Constant score was available in 14 of them, the value being 65.3 (28–88) or 75.4% for the adjusted score (31.8–95.4); the corresponding Oxford Shoulder Score was 21.5 (12–44). Eight patients had no pain, four had mild pain and two had moderate or severe pain. The mean range of active anterior elevation was 135° (90–180), of active abduction 121.5° (80–180), and of active external rotation 38.8° (0–80).

From the seven shoulders with the long nail (220 mm), the mean final Constant score was available in four of them, the value being 67.2 (50–75) or 78.5% (61.7–89.1) for the adjusted score. The Oxford Shoulder Score, available in five patients, was 22.4 (16–44). The mean range of active

**Table 1** Functional results at 1-year-follow-up in patients grouped by the nail length

| Type of nail | Constant score | Adjusted constant score (%) | Oxford score |
|---|---|---|---|
| Standard | 65.35 | 75.42 | 21.5 |
| 220 mm | 67.25 | 78.5 | 22.4 |
| Total | 65.7 | 76.1 | 21.7 |

No differences were found between them ($P > 0.05$)

**Table 2** Functional results at 1-year-follow-up in patients divided in age groups

| Age | Constant score | Adjusted constant score (%) | Oxford score |
|---|---|---|---|
| <70 years | 79.33 | 86.10 | 16.14 |
| >70 years | 59.00 | 71.11 | 25.00 |
| *P* | 0.009 | 0.09 | 0.07 |

Better results in patients younger than 70 years old are not statistically significant

anterior elevation was 127.5° (80–180), of active abduction 105° (80–180), and of active external rotation 55° (20–80).

We found no functional differences between the standard and the long nails (Table 1). Although the mean Constant score was significantly better in patients younger than 70 years old ($P = 0.009$), the adjusted score and the Oxford Score were not significantly better in this group of patients ($P = 0.09$, $P = 0.07$, respectively) (Table 2). As a conclusion, elderly patients in the present study did not show differences when the scoring was weighted according to the age group.

## Discussion

The present series shows satisfactory results using the T2-PHN for the treatment of two-part and three-part proximal humerus fractures, with a mean Constant score of 65.7 (28–88), or 76.1% (31.8–95.4) with the adjustment of age and gender, and an Oxford Shoulder Score of 21.7 (13–44) at the 1 year follow-up.

The only published series reporting results with the T2-PHN nail appeared in a non-indexed Medline journal [18]. The authors reviewed their results in 15 patients with an average age of 64.6 years. Most of the cases were four-fragment fractures (60%). The mean Constant score at the 1 year follow-up was 68.3, while the age- and gender-adapted score was 79%. One patient developed partial avascular necrosis, but did not require further treatment. To our knowledge, the present series is the first report in the English-language literature to examine the results on the use of this specific nail.

Most of the published series report satisfactory results with other nails such as the Polarus® (Accumed, Beaverton, UK) [1, 16], the Targon® (Aesculap, Tuttlingen, Germany) [11], or the Telegraph® (FH Orthopedics SAS, Heimsbrunn, France) [4].

A common problem related to the proximal humerus nails is the backing-out of the proximal screws [1, 2, 16]. Mittlemeier et al. [12] reported 59 backed-out screws in 115 patients treated with a sliding stable nail (Targon® PH); these were removed under local anesthesia and no special treatment was necessary. The authors suggested that a modification of the fixation screws was required in order to reduce this minor but frequent complication. The T2-PHN was designed to prevent precisely this complication, and in the present series only one case of back-out was observed.

The iatrogenic risk of producing an additional fracture through the entry point of the nail has been assessed previously. Agel et al. [2] reported two cases from 20 patients in their series. The Targon® nail uses a more internal entry point in order to avoid this complication [12]. In the present series the five patients with a two-part fracture presented an additional fracture of the larger tuberosity through the entry point. Unlike the Targon® nail which is a straight nail, the 6° curvature of the T2-nail might determine a too-lateral entry point and be a reason for this complication. However, the surgical outcome after reduction was satisfactory, in two cases the larger tuberosity was stabilized with a suture and in the remaining cases with a screw that fixed the fragment to the nail. Thus, for two-part fractures we recommend gentle work during proximal insertion and selection of a more medial entry point than that reported in the technique, namely at 2–3 mm medial from the larger tuberosity. Although this observation needs further investigation, we recommend performing a gentle manual drilling.

Another important issue is possible damage to the rotator cuff due to the entry point of the nail. None of the patients in our series developed signs of rotator cuff pathology. The entry point should be created through an accurate longitudinal split of the supraspinatus tendon in the direction of its fibers. This will ensure a good suture after stabilization of the fracture and avoid late complications. A possible lesion of the axillary nerve during guided locking has been related to the proximal humerus nailing [15]. However, none of the patients in this series presented axillary nerve damage.

There were four cases of malunion in the present series, with the cephalic segment in varus in all cases. Agel et al. [2], in a retrospective review of 20 patients treated with the Polarus® nail, found that lateral insertion points associated with metaphyseal comminution were likely to displace to a varus neck-shaft angle. In our series, the neck-shaft angle was practically the same at 1 year after surgery: 102° initially to 99.5° in the four malunion cases, and 123° initially to 120° in the whole series. Non-union and avascular

necrosis in the present series showed similar results as reported previously with other proximal humerus nails [1, 2, 4, 12, 16, 18].

This research has several limitations. The follow-up time was relatively short and it was not a randomized controlled study. It should also be noted that the results overlap with the learning curve of our unit's surgeons in terms of using this implant. However, the use of the T2-PHN has provided satisfactory results in 79% of cases for the treatment of two- and three-part fractures.

In most cases the surgical approach is short and the fracture is treated biologically, in the sense that the blood circulation to the humeral head is not compromised and the periosteum is preserved. Moreover, this implant only presented one case of proximal screw back-out, this being the main complication related to proximal humerus nailing in previous series with other nails. The functional outcome was comparable with other studies, but it is not clear whether the use of proximal humerus nailing should provide better results than the new fixed-angle proximal humerus plates.

Further randomized studies are required to validate the possible advantages of endomedullary nailing of the proximal humerus for each type of fracture, especially in elderly patients with osteoporotic bone.

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