Tzu Chi Medical Journal 2023; 35 (2): 171-175

Original Article

Nail-stem construct method for periprosthetic humeral fractures with recalcitrant nonunion after total elbow arthroplasty: A surgical technique

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Submission : 11-Jul-2022
Revision : 30-Aug-2022
Acceptance : 28-Nov-2022
Web Publication : 21-Feb-2023

Abstract

Objectives: The objective of this study was to describe the surgical technique using an innovative nail-stem construct in treatment of periprosthetic humeral fractures with recalcitrant nonunion after total elbow arthroplasty (TEA). **Materials and Methods:** Patients diagnosed with humeral recalcitrant nonunion in periprosthetic fractures and stem loosening after TEA were retrospectively recruited between 2018 and 2019. The demographic data and related clinical outcomes were recorded. We use a cutting length of the nail pushing into the humeral canal and then pull back distally to dock the tip of the humeral stem. The cement was packed into the humeral canal, and the periprosthetic bone defect was impacting with harvested allograft chip. **Results:** Patient age, gender, lesion site, number of previous surgeries, and the time period from the primary TEA to the nail-stem reconstruction were allocated. Moreover, the range of motion, degree of elbow stability, and level of pain were evaluated for each patient following this procedure. All the four patients achieved an optimal range of motion and secure stability with painless elbow at final follow-up. **Conclusion:** Our proposed nail-stem construct with double allogenous bone plate is a feasible alternative for revisional TEA in patients with implant loosening, periprosthetic humeral fractures, and recalcitrant nonunion.

Keywords: *Implant loosening, Nail-stem construct, Recalcitrant nonunion, Revision surgery, Total elbow arthroplasty*

Introduction

The number of total elbow arthroplasty (TEA) procedures performed has increased in recent years; however, TEA involves a higher percentage of complications and revisions compared with arthroplasty procedures performed at other sites [1]. The survival rates of TEA are reported to be 92%, 81%, 71%, and 61%, at 5, 10, 15, and 20 years, respectively [2]. Infection, aseptic loosening, and periprosthetic fractures are the most common complications requiring revision surgery; whereas, a periprosthetic fracture with recalcitrant nonunion in an aseptic loosened implant is the most complex complication following TEA [3,4]. This may be related to several factors, including patient age, prosthetic design, and multiple prior surgical procedures [5,6].

Ligament deficiency caused by nonanatomic force transmission in a semi-constrained implant is the primary cause of substantial bone resorption [7]. In a study of 92 TEAs with a mean follow-up of 6.5 years, the rate of mechanical implant failure was 25%, and more than half of the study population showed aseptic loosening [5]. The overall complication and revision rates have been reported as approximately 24% and 13%, respectively [8,9]. Furthermore, fractures around the loose prosthesis associated with massive bone loss are technically challenging and represent complex scenarios in revision TEA [10]. Although revision of the loose prosthesis and reduction of the fracture with allograft reconstruction have been the gold standard of treatment [10], recalcitrant nonunion can still be a big issue, in all kinds of different osteosynthesis methods [Table 1]. To overcome this, we developed an innovative and inexpensive procedure using a nail-stem construct for salvaging this kind of periprosthetic humeral fracture following TEA. Similar approaches in cases of periprosthetic femoral fractures with nonunion after total hip arthroplasty had previously been described, which involved treatment with nails overlapping the femoral stem tip [15-18]. These hip procedures inspired the concept of our nail-stem construct used in the elbow. To the best of our

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Access this article online

Quick Response Code:

Website: www.tcmjmed.com

DOI: 10.4103/tcmj.tcmj_193_22

How to cite this article: Chiang YS, Chen SH, Liu KC, Yang CC, Chien JT. Nail-stem construct method for periprosthetic humeral fractures with recalcitrant nonunion after total elbow arthroplasty: A surgical technique. Tzu Chi Med J 2023;35(2):171-5.

knowledge, no previous reports on the use of this technique on the elbow have been published. Herein, we describe our procedure using the nail-stem construct in detail and report the encouraging early results in four patients.

Materials and Methods

Between 2018 and 2019, we included four patients diagnosed with implant loosening and periprosthetic humeral fractures subsequent to previous TEA (Coonrad-Morrey Total Elbow; Zimmer, Warsaw, IN). The demographic characteristics recorded were patient age, sex, lesion site, number of previous surgeries, and the time from the primary TEA to the nail-stem reconstruction [Table 2]. A total of one right and three left elbow nail-stem reconstruction procedures were performed at our hospital. All four patients were women with a mean age of 79.3 years who had previously undergone TEA for rheumatoid arthritis (two cases) and traumatic osteoarthritis (two cases). Pyogenic nonunion was excluded in the above cases with clinical symptom, preoperative laboratory test, and intraoperative wound culture. Ethical approval for this study was provided by the Institutional Review Board Committee of the Buddhist Dalin Tzu Chi Hospital, Taiwan (IRB no. B10902002). Verbal consent for publication was obtained from all patients.

Case 1

A 73-year-old woman had undergone left primary TEA, 13 years prior to presentation to our center, due to rheumatoid arthritis. A periprosthetic humeral fracture around the loosened stem occurred after a fall 5 years postoperatively. In the following 7 years, a total of five surgeries were performed at two medical centers, resulting in persistent loosening and nonunion. Triceps insufficiency and fibrosis were noted due to repetitive trauma after multiple surgeries. Previous revision procedures included a conventional plate and wire with auto-bone grafts, exchange with a long stem, and onlay allo-bone grafts. We used the nail-stem construct to treat the recalcitrant nonunion, and double allogenous bone plates were fixed with cerclage wires [Figure 1].

Case 2

A 76-year-old woman with rheumatoid arthritis was referred to our hospital due to failed osteosynthesis for a periprosthetic humeral fracture. Recalcitrant nonunion persisted despite three previous revision surgeries. The last surgical procedure involved locking plate fixation and autogenous bone chip grafting. Triceps insufficiency was also noted after previous surgeries. We solved this problem after adopting the nail-stem construct and double allogenous bone plate fixation.

Table 1: Advantages and disadvantages of different surgical methods for periprosthetic humeral shaft fractures with severe bone loss

Surgical methods	Representative origin	Disadvantage	Advantage
Allograft-prosthetic composites	Morrey *et al.* [11]	Limit functional outcome/unavailable in hospitals with allograft shortage	Recreate a bone stock
Onlay allogenous bone plating	Sanchez-Sotelo *et al*. [12]	Technically demanding procedure/ substantial complication rate	Satisfactory result
Endoprosthetic arthroplasty	Torbert *et al*. [13]	Poor outcome/high complication rate	Easy procedure/low technique demanding
Vascular graft + plating	Gathen *et al*. [14]	Difficulty with vessel end-to-end anastomosis due to fibrosis and scarring	Vascularity leading to bone regeneration ability
Nail-stem construct	This study	Need longer follow-up time/technically demanding procedure	Inexpensive/innovative/durable alternative procedure

Table 2: Patient data and the results of the four cases

	Age (years old)	Sex	Number of previous surgeries (exclude nail-stem construct)	Time period from primary TEA to ail-stem construction (years)	Lesion site based on *Mayo classification	Blood loss (cc)	Operation time	Mean hospital stay (days)	Preoperative/ postoperative VAS	Elbow motion arch (°)	Union	Union time (months)	Follow-up time (months)
Case 1	73	Female	5	12	H-II3	500	2 h 15 min	12	6/1	45–120	Solid union	14	36
Case 2	76	Female	4	10	H-II3	400	2 h 9 min	7	7/1	30–120	Solid union	13	24
Case 3	87	Female	1	10	H-II3	300	2 h 8 min	7	7/1	0–130	Solid union	12	16
Case 4	81	Female	4	10	H-II3	350	4 h 9 min	6	6/1	40–120	Solid union	12	12
Mean	79.3	-	3.5	10.5	-	387.5	2 h 40 min	8.5	6.5/1	28.75–122.5	-	12.75	-

*Mayo classification: Humeral fractures. H-I: Fracture of the column or the condyles, H-II: Fracture around the stem (II1: Implant well fixed, II2: Implant loose with acceptable bone stock, II3: Implant loose with severe bone loss), H-III: Fracture proximal to the stem, TEA: Total elbow arthroplasty, VAS: Visual Analog Scale

Figure 1: Case 1. Preoperative AP (a) and lateral (b) radiographs showing nonunion after multiple surgeries. AP (c) and lateral (d) radiographs obtained 36 months postoperatively showing solid union with stable fixation of the stem–nail construct. AP: anteroposterior

Case 3

An 87-year-old woman sustained an acute periprosthetic fracture of the distal humerus after a fall. She had undergone primary TEA for traumatic osteoarthritis 11 years earlier, and aseptic loosening of the humeral stem was found postoperatively. We treated the loosened implant and fracture with a nail-stem construct.

Case 4

An 81-year-old woman underwent left primary TEA 10 years ago due to traumatic osteoarthritis. A periprosthetic humeral fracture around the loosened stem occurred after a fall. Persistent implant loosening and recalcitrant nonunion occurred despite four surgeries being performed at two medical centers. The last surgical procedure involved conventional plate and wire fixation with double allogenous bone plating. Physical examination showed triceps insufficiency and fibrosis before our surgery. We solved this problem after adopting the nail-stem construct and double allogenous bone plates with cerclage wire fixation.

Surgical technique

The affected arm was placed on an elbow support in the lateral decubitus or prone position. A posterior incision was made with the triceps muscle split at the midline to expose the distal humerus. After identifying the radial nerve, extensive debridement was performed to remove all the previously implanted cement, K-wires, and screws/plates. Adequate decortication of the nonunion was performed until the 'paprika sign' (punctate bleeding) was seen. Without disassembling the prosthetic ulnohumeral hinge (Coonrad-Morrey Total Elbow; Zimmer), the humeral stem was pulled out from the intramedullary (IM) canal. The proximal humeral IM canal was then over-reamed at least 2 mm to facilitate smooth nail (Nailing System; Stryker, Mahwah, NJ) insertion. The smooth nail needs to be cut with a diamond tip of the drill for an appropriate length. An appropriate cutting length of the nail was easily docked distally to the tip of the humeral stem with 3–5 cm of overlap into the stem and was long enough proximally to reach the humeral head and achieve construct stability [Figure 2]. Hence, the upper tip of the nail-stem construct needs to be long enough to the humeral head and should not be below the surgical neck of the humerus. Hence, the minimal length of the cutting nail would be measured by the surgical neck of the humerus, and it is difficult to measure from the site of the fracture because the nonunionized zone is very large. The selected IM nail was pushed into the humeral canal and then pulled back distally several times to achieve the final nail-stem construct. Then, the cement was packed into the humeral canal, and the IM nail was inserted to lead the stem into the nail, with the interface being cemented to augment fixation. Prevention of cement into the nonunion site should be necessary. We filled the cement only in the proximal portion of the humeral segment and the nail-to-stem interface. At the final setting of the cemented nail-stem composite, elbow flexion-extension should be checked several times to achieve a maximal range of motion before the 5 min of cement hardened. Moreover, the anatomical alignment was assured via fluoroscopy after totally hardens. For the periprosthetic bone defect, the harvested allograft chip was impacted, and double bone plates were subsequently fixed with cerclage wires. The wound was closed, and a sling protection was worn for 6–8 weeks. A rehabilitation program was initiated on the 1st postoperative day.

Results

In our four patients, the mean duration from the primary TEA to the final revision with a nail-stem construct was 10.5 years, and the mean number of previous surgeries was

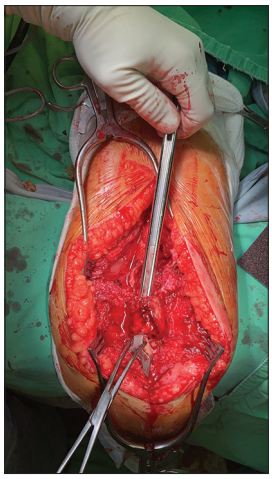

Figure 2: Checking the distal fit and adequate overlapping up to 5 cm between the nail and stem

3.5. All the fractures were Mayo classification type II [3]. For the nail-stem construct procedure, the mean surgical time was 2 h 40 min, the mean blood loss volume was 387.5 mL, and the mean hospital stay was 8.5 days [Table 2].

Preoperatively, all patients showed painful disability with deformity and instability. The mean preoperative Visual Analog Scale (VAS) score was 6.5. Triceps insufficiency with fibrotic and moderate atrophy was noted in Cases 1, 2, and 4 prior to surgery; however, adequate range of motion with a painless and stable elbow could be achieved 1 year postsurgery [Figure 3]. The postoperative VAS score was 1. There were no complications, such as radial nerve injury, infection, or instability. Radiographically, solid unions were achieved in all cases without implant loosening or refracture at the final follow-up [Figure 1].

Discussion

Periprosthetic fracture nonunion associated with humeral stem loosening remains the most technically demanding condition on which to operate due to extensive bone loss, poor bone quality, and soft tissue contracture. Recalcitrant nonunion with persistent loosening of the humeral component continues to occur despite various osteosynthesis techniques, such as plate/screw/wire fixation, locking plate fixation, onlay allogenous bone plating, or revision with a longer stem. Therefore, we developed an innovative elongation technique to provide a "serviceable elbow" for patients with humeral bone loss following TEA. This technical procedure was successfully adopted in older patients who had failed multiple surgeries. The longevity of such a functional elbow can be maintained under protected weightlifting for over 3 years, as demonstrated in our four cases. Although loosening may be a concern in the future due to the semi-constrained hinge design, the current longer and larger nail-stem reconstruction can be expected to decrease the incidence of loosening to a minimal rate.

Morrey *et al*. [11] performed allograft-prosthetic composite reconstruction for massive bone loss with a less desirable outcome involving limited functional restoration. Sanchez-Sotelo *et al*. [12] treated periprosthetic humeral

Figure 3: Case 1. Painless elbow with a nearly full range of motion 12 months postoperatively

fractures associated with a loose component, and subsequent implant revision using strut allograft augmentation resulted in a substantial complication rate.

Endoprosthetic arthroplasty has been associated with poor outcomes and high complication rates in up to 50% of cases [4,13,19]. In our study, in relation to Cases 1, 2, and 4, multiple attempts at osteosynthesis had failed in other hospitals even with the locking plate fixation procedure or revision with a longer stem. Gathen *et al.* [14] used a vascularized fibula graft with double-plate fixation for a patient with extensive segmental loss of the humerus. The free fibular graft brings vascularity to the region of humeral nonunion with a background of a previous pathological fracture following radiotherapy. In our cases, unions were achieved even in the presence of a suboptimal soft tissue environment because adequate construct stability and a massive amount of bone grafting around the fracture site were achieved [Table 1].

There are multiple benefits of the nail-stem construct. Disconnecting the hinge is not required, and the original humeral and ulnar components can be retained without exchange. Therefore, it is an inexpensive procedure compared to the revision with a long stem or conversion to an endoprosthesis. The IM nail can accomplish an excellent fit with its larger diameter compared to the very thin humeral stem. Furthermore, the nail length can be customized to reach the humeral head. This kind of IM construct can provide enough stability and realign the humeral stem to a functional position, unlike extramedullary plate fixation which tends to fail in the osteoporotic humerus.

Some technical specifications of this procedure need to be emphasized. First, multiple fit trials prior to final cementation

are essential to achieve a smooth and trouble-free insertion of the whole construct into the humeral canal. Second, suboptimal length of the nail can cause a compromise in the range of motion and difficulty in implantation. Third, overlapping between the nail and the stem should be more than 3 cm to avoid rotational instability or dislodgement. In a biomechanical model, Melvin *et al.* [20] reported that to obtain a stable stem–nail connection, 2.9–3.5 cm of overlap should be achieved. Finally, full cementation helped maintain the whole construct among the interfaces of the humeral canal, the nail, and the stem. The additional allografts can impact the periprosthetic bone defect to provide further bone stock. In our study, there was no sign of construct loosening within 3 years of follow-up despite mobilization from the 1st postoperative day. All our patients obtained painless elbows and returned to normal activity.

The current large and long nail-stem construct can eliminate the development of stress risers commonly seen in thin and short stems, which are the major problems causing instability and progressive loosening. With the positive results that were observed in the revision scenarios, we applied this nail-stem construct method in Case 3 patient who had severe rheumatoid arthritis in the primary setting to prevent further failure of periprosthetic fracture nonunion.

This study had some limitations, such as a short follow-up time and a small number of cases. Moreover, because this is a technically demanding procedure, a favorable outcome may not be achieved by inexperienced surgeons.

Conclusion

Recalcitrant nonunion of humeral components following TEA represents a significant challenge. The loosened humeral stem can be salvaged by IM fixation using a nail-stem construct and onlay allogenous bone plating. The outcomes of fracture union, implant survival, and satisfactory clinical results with the use of this technique require further investigation with a larger sample size and long-term follow-up.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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