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A Retrospective Study in the Treatment of a 2-Part Greater Tuberosity Fracture Using the F3 Biomet Plate

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The purpose of this study was to evaluate the clinical efficacy of the F3 Biomet plate in the treatment of 2-part displaced humeral greater tuberosity fractures. We compared the clinical outcomes of patients with displaced greater tuberosity fractures who underwent surgical treatment using an F3 plate with those of patients who were treated nonsurgically. Eleven patients with 2-part displaced humeral greater tuberosity fractures were surgically treated with use of an F3 Biomet plate, whereas 12 patients with equal injuries were treated nonsurgically. Each patient underwent follow-up for at least 1 year. We retrospectively collected data and analyzed the clinical outcomes. The Constant score and DASH score were used to assess the shoulder function, and X-rays were taken to evaluate the fracture healing. X-rays of the patients in both groups showed that the fractures achieved union after the 1-year follow-up. Patients treated surgically with an F3 plate and open reduction internal fixation had better Constant score and DASH score results for shoulder function than those treated nonsurgically. In the present study, surgical treatment of displaced humeral greater tuberosity fractures with the use of an F3 plate led to a 100% union rate and good clinical outcomes. The F3 Biomet plate can be considered an effective implant for the treatment of displaced humeral greater tuberosity fractures. The level of evidence is therapeutic III.

Key words: 2-part greater tuberosity fracture – F3 Biomet plate – Impingement

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Proximal humeral fractures are clinically common, and 13% to 33% of such fractures involve greater tuberosity fractures, which are frequently caused by high-energy trauma.[1] A humeral greater tuberosity fracture is a periarticular fracture. A displaced tuberosity lying under the acromion provides a bony block to abduction. In addition, a fragment may extend into the bicipital groove or bicipital sulcus of the humerus, affecting the biceps tendon indirectly, whereas superior displacement leads to malfunction of the rotator cuff and impingement.[2] Inappropriate treatment cannot prevent further displacement and secondary decrease of shoulder function, and may result in shoulder dysfunction.[3] When the displacement of the greater tuberosity is more than 5 mm or the angular displacement is greater than 45°, surgical reduction and internal fixation are considered for treatment.[4] In recent years, a variety of surgical devices and techniques for this type of fracture have been reported. Flatow *et al*[5] reported a series of 12 patients with displaced isolated greater tuberosity fractures who were treated with open reduction and internal fixation (ORIF) using nonabsorbable sutures. Park *et al*[6] retrospectively reviewed 13 displaced isolated greater tuberosity fractures treated with suture fixation. All patients obtained satisfactory results. Other authors have reported similarly promising results using closed reduction and percutaneous fixation techniques.[7,8] With further development of arthroscopy techniques, some displaced isolated greater tuberosity fractures can be treated by the arthroscopic fixation, with good results reported in several small series.[9–12] However, the selection of the implant remains controversial, and no method has been proven as the ideal choice.

Materials and Methods

Study population

This was a retrospective study approved by our Institutional Review Board. Between September 2010 and January 2014, a total of 27 patients with 2-part displaced humeral greater tuberosity fractures were treated in the hospital. All of the included patients provided consent to participate in any reviews in the future. Our exclusion criteria include: (1) pathologic fracture or refracture; (2) old fracture or open fracture; (3) multiple fracture, concomitant plexus, and/or nerve injuries; (4) patients with existing systemic disease that has a relevant effect on the fracture healing, such as paraplegia, multiple sclerosis, and relevant neurologic disorders; and (5) patients who were lost to follow-up. After the selection based on the exclusion criteria, a total of 23 patients were selected in this study and divided into 2 groups according to the therapeutic method. Eleven patients were surgically treated by ORIF with use of an F3 Biomet plate, and 12 patients underwent nonsurgical treatment because they refused to undergo the surgery—with consideration given to such factors as bad state of health, lack of compliance, personal economic reasons, etc—despite fragment displacement greater than 5 mm. All of the patients had fresh closed fractures (time between injury and treatment was less than 7 days), and were confirmed to have isolated greater tuberosity fractures on X-ray. All fractures were classified according to the morphology. The patient demographics and fracture characteristics are summarized in Table 1.

Table 1 Patient demographics

Characteristic	Surgical (n = 11)	Nonsurgical (n = 12)	*P* value
Age, y, mean (SD) (n = 11)	54 (8)	12 (9)	0.620
Gender, n (%)			0.684
Male	5 (45)	5 (42)	
Female	6 (55)	7 (58)	
Smoking, n (%)			0.635
Yes	3 (27)	3 (25)	
No	8 (73)	9 (75)	
Employment, n (%)			0.827
Desk work	4 (36)	5 (42)	
Manual work	5 (46)	4 (33)	
Retirement	2 (18)	3 (25)	
Trauma history, n (%)			0.673
Falling from a height (<1 m)	6 (55)	6 (50)	
Falling from a height (1–2 m)	3 (27)	5 (42)	
Other	2 (18)	1 (8)	
Morphologic classification, n (%)			0.799
Avulsion	4 (36)	6 (50)	
Split	6 (55)	5 (42)	
Depression	1 (9)	1 (9)	

Surgical technique

Eleven patients underwent ORIF with the use of an F3 plate under general anesthesia. The patients were placed in the supine position on a radiolucent operating table. A rubber cushion was placed under the affected shoulder, and the injured arm was abducted by a surgical assistant. A longitudinal deltoid-splitting approach was used, and the

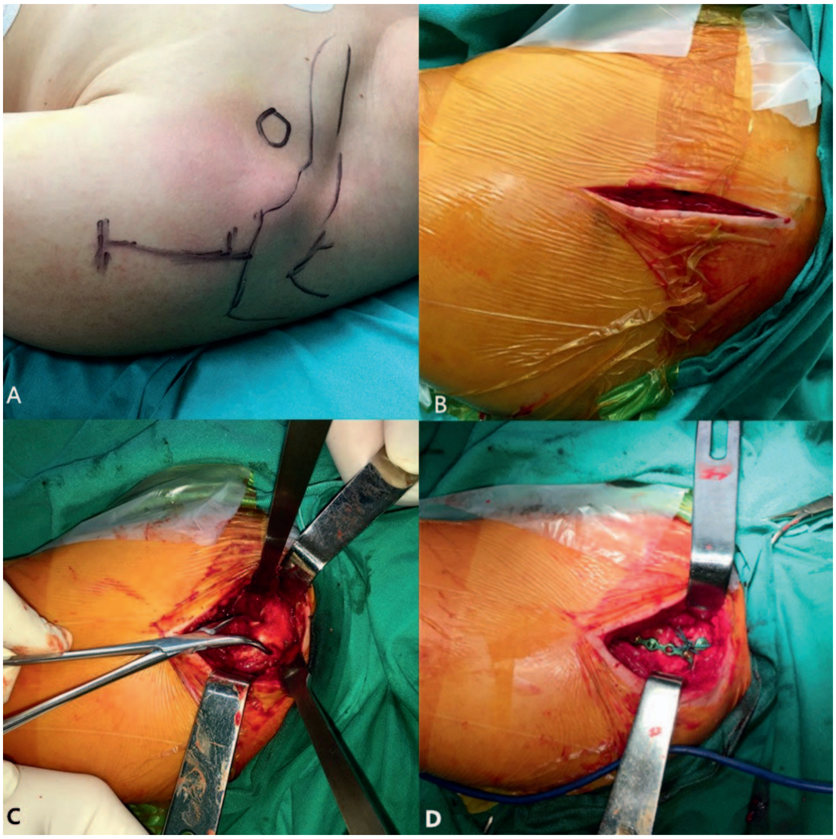

Fig. 1 (A) The mark of the surgical incision. (B) The deltoid-split approach. (C) Performing the reduction under the direct observation. (D) Fixing the F3 plate around the greater tuberosity fragment.

incision was 4 to 5 cm long (Fig. 1B). The space between the anterior part and intermediate part of the deltoid was located by identifying the adipose and fiber texture. There were fewer blood vessels in this area. A blunt dissection was used to separate the muscle at 4 to 5 cm from the apex to the distal point of the acromion, and the bursa subdeltoidea was split to expose the fracture. To protect the axillary nerve, the nerve was identified by placing an index finger in the bursa subdeltoidea, and its course was marked on the skin (Fig. 1A). The reduction was performed through traction and manipulation under direct observation (Fig. 1C). If necessary, Kirschner wires were used to temporarily fix the fracture fragments. During the operation, a Y-type F3 (Biomet, Warsaw, Indiana) high-flexible mini-locking plate was shaped and bent according to the specific fracture condition. The plate was placed tightly around the greater tuberosity fragment, ensuring that the proximal fragment was fixed with at least 3 screws. In addition, the distal side of the F3 plate was fixed by 3 screws on the metaphysis. Subsequently, we examined by visual inspection whether the rotator cuff was torn or injured, and if necessary, the rotator cuff injury was sutured and repaired (Fig. 1D). The shoulder was moved in all directions to confirm reliable fixation of the greater tuberosity. The incision was closed after a radiographic examination by C-arms showing a satisfactory reduction. The chief operator was the same for all 11 patients' surgeries.

Rehabilitation

Postoperative rehabilitation was initiated on the first day after surgery. The ipsilateral elbow and wrist joints were allowed to perform a passive range of motion. At 2 weeks after surgery, the operated shoulder was allowed to perform passive outward and inward rotation. At 3 weeks after surgery, the shoulder was allowed to perform passive flexion and extension. At 6 weeks after surgery, an active shoulder movement range was allowed, and the strength limit was increased daily. At 12 weeks after surgery, normal weight-bearing loads were allowed, and the patients were allowed to return to work or sporting activities.

Twelve patients who were treated nonoperatively had a standardized rehabilitation program. Patients

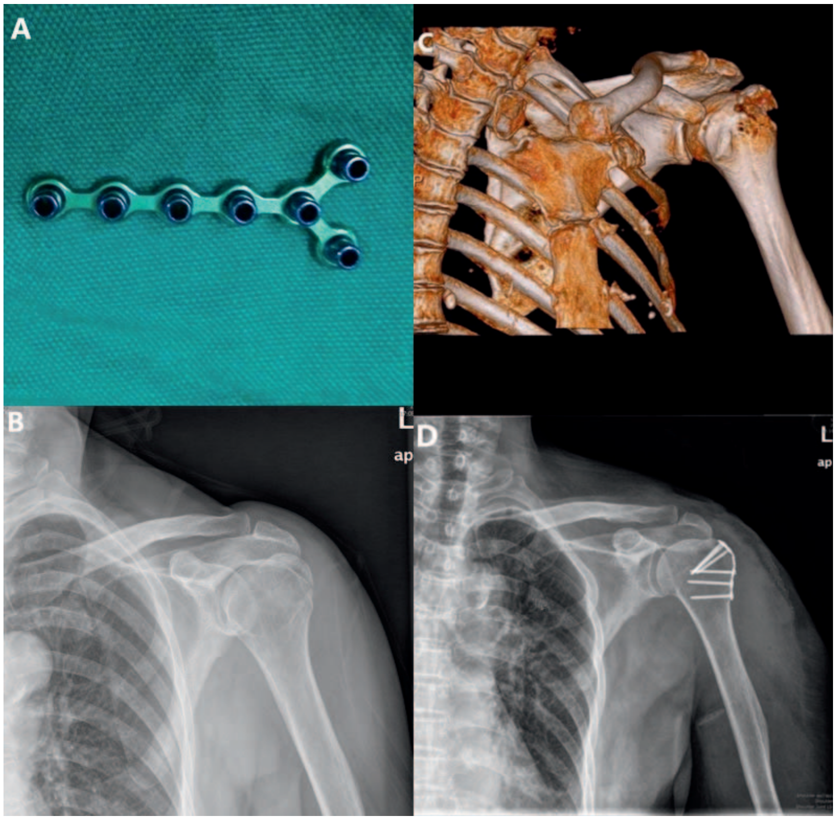

Fig. 2 (A) An F3 Biomet plate. (B) An anteroposterior X-ray of a displaced greater tuberosity fracture of the left shoulder in a 61-year-old woman who sustained a fall injury. (C) Preoperative computed tomography 3-dimensional reconstruction. (D) An anteroposterior X-ray taken after the implantation of F3 Biomet plates 1 year after the surgery.

were immobilized in a sling for 3 weeks. Active assisted exercises were started 3 to 6 weeks after the injury. The patients were allowed to bear weights on their arms after 6 to 8 weeks.

Follow-up and clinical evaluations

All patients underwent follow-up for at least 1 year. Follow-up evaluations of the clinical outcomes and associated complications were performed from 12 months after the injury. The general shoulder function and rotator cuff function were determined clinically by standard tests, with measurements of the motion using a goniometer. Impingement syndrome was diagnosed by patient history and a physical examination using Neer clinical sign. We used the DASH score[13] and the Constant score[14] (Constant and Murley 1987) for objective assessment. Shoulder strength was assessed according to the recommended methodology for the Constant score. X-rays in the anteroposterior and lateral views were used to evaluate the fracture healing, plate and screw placement, and reduction. We retrospectively reviewed all X-rays and medical records to evaluate the clinical outcomes, shoulder function, and associated complications (*e.g.*, wound infection, loss of reduction, subacromial impingement).

Statistical analysis

The data were collected independently by two examiners who were not involved in the initial treatment. Statistical analyses were performed with the Statistical Package for Social Sciences (SPSS, Chicago, Illinois) for Windows. Fisher exact test was used for categoric variables (*e.g.*, sex, smoking, fracture classification). We checked whether continuous variables (*e.g.*, age, Constant score, DASH score) were in accordance with a normal distribution, and we used an independent-sample *t*-test for normally distributed continuous variables. A P value of less than 0.05 was regarded as statistically significant.

Results

X-rays of the patients in both groups showed that the fractures achieved union after the 1-year follow-up. All 11 patients in the F3 group (Fig. 2B and 2C) successfully completed the operation. The mean operation time was 57 minutes (range, 40–75 minutes), and the mean intraoperative blood loss

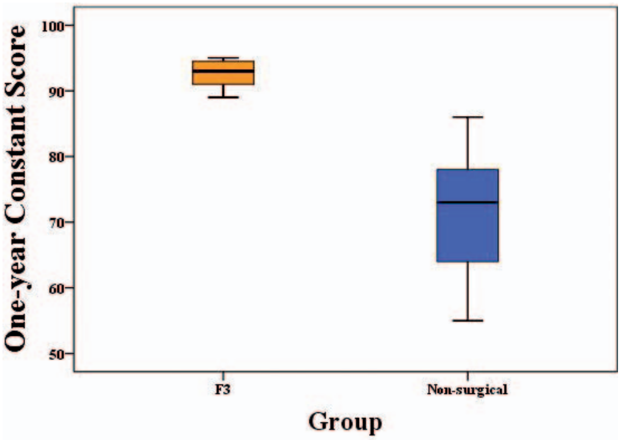

Fig. 3 The 1-year Constant score for the F3 and nonsurgical groups.

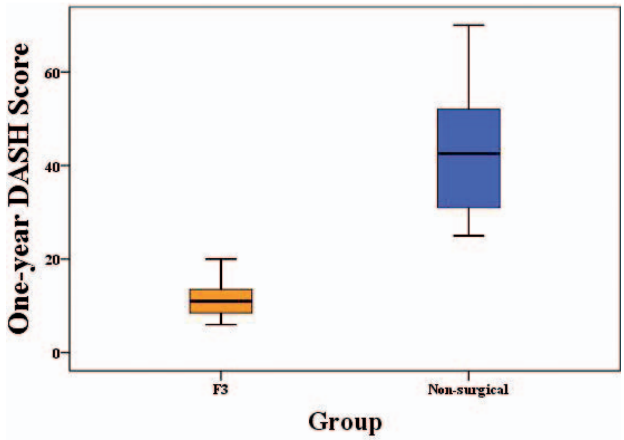

Fig. 4 The 1-year DASH score for the F3 and nonsurgical groups.

was 86 mL (range, 60–110 mL). Only 1 patient underwent a rotator cuff tendon repair. All of the operative incisions achieved primary healing, and there were no infections, internal fixation breaks or loosening, fracture fragment displacements, shoulder impingement syndromes, or other complications (Fig. 2D). The 12 patients who underwent nonsurgical treatment of displaced greater tuberosity fractures were evaluated as the control group. The X-rays revealed that fractures healed without any signs of nonunion. But the fragments of 8 patients still stayed at the original displacements. Although 1 patient had small heterotopic bone fragments beneath the acromion, he chose not to undergo the surgery because the relevant influence on the shoulder function was acceptable to him. Another patient showed further superior displacement of the greater tuberosity. He elected not to undergo further revision surgery because he had little pain.

During the 1-year follow up, the mean Constant score in the F3 group was 92.73 (SD, 2.05), whereas that in the nonsurgical group was 71.42 (SD, 9.45; Fig. 3). The mean DASH score was 11.45 (SD, 4.06) in the F3 group and 43.75 (SD, 14.17) in the nonsurgical group (Fig. 4). The operative details and clinical evaluations of the patients in the F3 group are summarized in Table 2. Statistical analyses revealed that the patients in the surgical group had significantly better functional outcomes than those in the nonsurgical group (Table 3).

Discussion

The results of our study revealed good functional and radiographic outcomes after ORIF of displaced greater tuberosity fractures using an F3 plate. Platzer *et al*[7] retrospectively analyzed the functional and radiographic results of 52 patients with operative treatment of displaced greater tuberosity fractures at a mean time of 5.5 years after injury. Those results were compared with the functional and radiographic outcomes of 9 patients with equal injuries who were treated nonsurgically. They found that the patients with nonsurgical treatment showed significantly worse results. As the end point of the supraspinatus muscle, infraspinatus muscle, and teres minor muscle, the humeral greater tuberosity plays a significant role in maintaining shoulder function and activity. Because the different muscles have uneven traction effects after a fracture, the humeral greater tuberosity is prone to displacement. This separation may cause nonunion of the greater tuberosity, affecting the rotator cuff and brachial glenoid articular activity. Surgical treatment should be undertaken for fractures with a displacement larger than 1 cm.[4] Meanwhile, fractures displaced between 0.5 and 1 cm fall into a gray zone for treatment. Some authors agree that posterosuperior displacement leads to significant symptoms of subacromial impingement, which should be treated with surgery.[3,15] Park *et al*[16] believed that fractures with a displacement of only 3 mm should be corrected in heavy laborers and athletes who need to engage in overhead activities.

Clinically, the most common surgical methods for this type of fracture are open reduction locking-plate internal fixation, cannulated screw fixation, and bone-anchored suturing. These methods have some disadvantages. Lill *et al*[17] stated that a traditional proximal humerus plate has a high degree of contact

Table 2 Synopsis of operation and clinical evaluation of patients in the F3 group

Patient no.	Age, y/sex	Ipsilateral side	Morphologic classification	Operation time, min	Intraoperative blood loss, mL	Follow-up time, mo	Shoulder range of motion (forward elevation), °	Shoulder range of motion (abduction), °	Time to return of sporting activities, wk	Shoulder strength (assessed according to the recommended methodology for the Constant score)	DASH score	Constant score
1	63/M	Lt	Split	50	60	13	165	145	25	10	95	8
2	59/F	Rt	Avulsion	57	80	21	145	155	25	14	91	13
3	63/F	Rt	Avulsion	40	75	14	160	150	25	11	93	11
4	50/M	Lt	Split	72	100	24	170	170	25	9	92	14
5	51/M	Lt	Split	75	110	12	175	170	20	12	89	20
6	56/F	Rt	Split	70	95	24	140	145	25	12	94	9
7	46/M	Rt	Depression	45	80	16	160	150	25	11	94	10
8	38/F	Rt	Avulsion	55	85	19	155	145	25	10	95	6
9	61/F	Lt	Split	68	95	26	165	155	25	13	91	11
10	55/M	Lt	Split	50	90	14	150	135	25	11	91	16
11	49/F	Rt	Avulsion	48	80	18	165	150	25	10	95	8

Lt, left; Rt, right.

Table 3 Surgical and nonsurgical clinical scores

	Surgical, mean (SD)	Nonsurgical, mean (SD)	*P* value
Constant score	92.72 (2.05)	71.42 (9.45)	0.002
DASH score	11.45 (4.06)	43.75 (14.17)	0.002

with the bone, which affects the periosteal blood supply and is not conducive to fracture healing. The larger the implanted plate, the higher the chances are of secondary impingement syndrome.[18,19] The plate may also affect the biceps tendon, because the continuous friction can cause biceps injury and even rupture. Braunstein *et al*[20] reported that the fixation strength and compression strength of cannulated screws are limited, such that the screws can easily become loose. Platzer *et al*[3] stated that a secondary loss of reduction, which could be found in 17% of patients, also increases the risk of subacromial impingement. In addition, the greater tuberosity of the humerus is mainly cancellous bone, and for elderly patients with osteoporosis, fracture fragments are prone to displacement, again because of the traction on the muscles after the operation. Hollow lag screws are thick, and the drilling and tightening of the screws tend to cause a secondary injury to the fractured bone, whereas the washers for the screws can result in secondary impingement syndrome.[21] Bone-anchored suturing is also widely used in clinical practice. This technique fixes the tendon and bone interface, allows patients to avoid allergies to the implant, and does not require implant removal. Dimakopoulos *et al*[15] evaluated the long-term functional and radiographic results of transosseous suture fixation in 188 patients, of whom 56 had 2-part fractures of the greater tuberosity. All of these patients showed bony union within 4 months. At the time of the final evaluation, the mean Constant score was 91 points. However, suturing would further diminish the stability of the fragments; in addition, if a greater tuberosity fracture has multiple fragments, it is not conductive to fixation of the fractured bone fragments.[4]

The F3 Biomet plate (Fig. 2A) was initially used for fixation of fractures of the phalanx and other small long bones. We applied these mini-plates to the treatment of isolated humeral greater tuberosity fractures. Gruson *et al*[4] stated that the choice of method was dependent not only on the fracture type and characteristics (displacement, location, comminution), but also on a multitude of patient-related factors (age, comorbidities, preinjury level of function, local bone quality). We believe that the F3 plate is appropriate for displaced greater tuberosity fractures if the patient can tolerate the operation.

The mini-locking plate can sufficiently cover fracture fragments, and the locking screws can be fixed at angles even in osteoporotic fracture fragments, yielding good tensile strength and anchor force to ensure the fixation strength of the fractured fragments, such that displacement cannot easily occur. Gaudelli *et al*[22] reported that locking plate fixation provided stronger and stiffer biomechanical fixation than tension bands and double-row suture bridges for split-type greater tuberosity fractures. Compared with nonsurgical management, patients can perform shoulder function exercises earlier. For treatment of a comminuted fracture, we use locking screws to fix the relatively large displacement fragments if possible, and bundle or suture small fragments along with the fence structure of the implant. If the fragments are too small to be fixed by a locking screw, we cover these small fragments with the plate. The frictional force extruded between the fragments and the steel plate can also contribute to the stability of the fracture fragments. In addition, the fence structure can facilitate the repair of the rotator cuff if necessary and provide more reliable stability. The plate can be shaped inside of the body during the operation, which facilitates maximal fixation of the plate to the complicated bone surface. The plate has multiple drilled holes, which allow the pressure to be distributed to each screw hole.

In the present study, the F3 Biomet plate provided reliable stability, and satisfactory functional results were obtained. All fractures healed within 9 to 14 weeks. There were no infections, internal fixation breaks or loosening, fracture fragment displacements, shoulder impingement syndromes, or other complications. Recently, Schöffl *et al*[23] used a small Bamberg plate cut from a calcaneus plate to treat greater tuberosity fractures. Although a small number of cases were presented, the results were better than those in the studies by Szyszkowitz *et al*[24] and Dimakopoulos *et al*.[15] Chen *et al*[25] treated greater tuberosity fractures using an AO X-shaped midfoot locking plate that was originally designed for midfoot fractures. Nineteen patients with displaced fractures of the greater tuberosity were treated surgically by ORIF using the AO X-shaped midfoot locking plate. All fractures healed without associated complications. At the last follow-up, the mean Constant score was 90.6 (SD, 4.0) points. These plates performed functions similar to those of the F3 Biomet plate. However, the F3 plate can be shaped and cut inside of the body, thereby facilitating maximal fixation of the complicated bone surface. Nevertheless, the present study also has some limitations, such as having few cases, short follow-up time, etc. Further studies are therefore required to fully evaluate the role of the F3 Biomet plate for displaced humeral greater tuberosity fractures.

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References

1. Kim E, Shin HK, Kim CH. Characteristics of an isolated greater tuberosity fracture of the humerus. *J Orthop Sci* 2005; **10**(5):441–444
2. De Palma AF, Cautilli RA. Fractures of the upper end of the humerus. *Clin Orthop* 1961;**20**:73–93
3. Platzer P, Kutscha-Lissberg F, Lehr S, Vecsei V, Gaebler C. The influence of displacement on shoulder function in patients with minimally displaced fractures of the greater tuberosity. *Injury* 2005;**36**(10):1185–1189
4. Gruson KI, Ruchelsman DE, Tejwani NC. Isolated tuberosity fractures of the proximal humeral: current concepts. *Injury* 2008;**39**(3):284–298
5. Flatow EL, Cuomo F, Maday MG, Miller SR, McIlveen SJ, Bigliani LU. Open reduction and internal fixation of two-part displaced fractures of the greater tuberosity of the proximal part of the humerus. *J Bone Joint Surg Am* 1991;**73**:1213–1218
6. Park MC, Murthi AM, Roth NS, Blaine TA, Levine WN, Bigliani LU. Two-part and three-part fractures of the proximal humerus treated with suture fixation. *J Orthop Trauma* 2003;**17**(5):319–325
7. Platzer P, Thalhammer G, Oberleitner G, Kutscha-Lissberg F, Wieland T, Vecsei V *et al*. Displaced fractures of the greater tuberosity: a comparison of operative and nonoperative treatment. *J Trauma* 2008;**65**(4):843–848
8. Resch H, Hubner C, Schwaiger R. Minimally invasive reduction and osteosynthesis of articular fractures of the humeral head. *Injury* 2001;**32**(suppl 1):SA25–SA32
9. Kim KC, Rhee KJ, Shin HD, Kim YM. Arthroscopic fixation for displaced greater tuberosity fracture using the suture-bridge technique. *Arthroscopy* 2008;**24**(1):120–123
10. Ji JH, Shafi M, Song IS, Kim YY, McFarland EG, Moon CY. Arthroscopic fixation technique for comminuted, displaced greater tuberosity fracture. *Arthroscopy* 2010;**26**(5):600–609

11. Taverna E, Sansone V, Battistella F. Arthroscopic treatment for greater tuberosity fractures: rationale and surgical technique. *Arthroscopy* 2004;**20**(6):53–57
12. Carrera EF, Matsumoto MH, Netto NA, Faloppa F. Fixation of greater tuberosity fractures. *Arthroscopy* 2004;**20**(8):109–111
13. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand). *Am J Ind Med* 1996;**29**(6):602–608
14. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987; **214**(214):667–667
15. Dimakopoulos P, Panagopoulos A, Kasimatis G. Transosseous suture fixation of proximal humeral fractures. *J Bone Jt Surg Am* 2007;**89**(8):1700–1709
16. Park TS, Choi IY, Kim YH, Park MR, Shon JH, Kim SI. A new suggestion for the treatment of minimally displaced fractures of the greater tuberosity of the proximal humerus. *Bull Hosp Joint Dis* 1997;**56**(3):171–176
17. Lill H, Lange K, Prasse-Badde J, Schmidt A, Verheyden P, Echtermeyer V. T-plate osteosynthesis in dislocated proximal humerus fractures. *Unfallchirurgie* 1997;**23**(5):183–192
18. Clavert P, Adam P, Bevort A, Bonnomet F, Kempf JF. Pitfalls and complications with locking plate for proximal humerus fracture. *J Shoulder Elbow Surg* 2010;**19**(4):489–494
19. Niall DM, O'Mahony J, McElwain JP. Plating of humeral shaft fractures has the pendulum swung back? *Injury* 2004;**35**(6): 580–586
20. Braunstein V, Wiedemann E, Plitz W, Muensterer OJ, Mutschler W, Hinterwimmer S. Operative treatment of greater tuberosity fractures of the humerus a biomechanical analysis. *Clin Biomech (Bristol, Avon)* 2007;**22**(6):652–657
21. Scheibel M, Lichtenberg S, Habermeyer P. Reversed arthroscopic subacromial decompression for massive rotator cuff tears. *J Shoulder Elbow Surg* 2004;**13**(3):272–278
22. Gaudelli C, Ménard J, Mutch J, Laflamme GY, Petit Y, Rouleau DM. Locking plate fixation provides superior fixation of humerus split type greater tuberosity fractures than tension bands and double row suture bridges. *Clin Biomech (Bristol, Avon)* 2014;**29**(9):1003–1008
23. Schöffl V, Popp D, Strecker W. A simple and effective implant for displaced fractures of the greater tuberosity: the "Bamberg" plate. *Arch Orthop Trauma Surg* 2011;**131**(4):509–512
24. Szyszkowitz R, Seggl W, Schleifer P, Cundy PJ. Proximal humeral fractures: management techniques and expected results. *Clin Orthop Relat Res* 1993;**292**:13–25
25. Chen YF, Zhang CQ. AO X-shaped midfoot locking plate to treat displaced isolated greater tuberosity fractures. *Orthopedics* 2013;**36**(8):995–999