

## The Surgical Treatments of Complex Proximal Humeral Fractures

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### Abstract

This study aims to analyze the surgical treatments and efficacy of complex proximal humeral fractures in clinical condition. Fifty-three patients were included in this study from January to December 2010 for Neer, three or four part proximal humeral fractures or dislocations. Operation is conducted by deltoid and pectoralis major approach. Surgical necks were fixed with screwed Kirschgner wire or modified Ender nail plus tension band, while greater and lesser tuberosity fractures were fixed by tension band fixation with 8 non-absorbable suture or strands. The rehabilitation condition of living and working abilities of these patients were investigated by questionnaire surveys. The postoperative functions were evaluated using Constant-Murley absolute value score. The results indicated that mean Constant-Murley score obtained was 83.6 (62~94). The mean active forward elevation was 135° (60°-180°). The mean pain VAH score was 14 (10-17). Muscle strength was measured by common muscle testing method. The results showed that, 11 cases were in grade 5 (23.91%), 31 cases in grade 4 (67.39%), and 4 cases in grade 3 (8.70%). In conclusion, complex proximal humeral fractures were conducted by tuberosity fractures anatomical reduction and non-absorbable suture or strand plus tension band fixation on surgical necks. After operation, patients were encouraged to do proper functional exercises at early stage. By this way, better treatment results could be achieved. The incidence of humeral head necrosis is closely associated with the severity of fractures.

**Keywords:** Humeral fractures; Proxima; Fractures fixation; Constant-Murley score

### Introduction

Proximal humeral fractures are more common. Approximately 70%~80% of proximal humeral fractures are accompanied with no or mild displaced fractures, while only 20%~30% need surgical treatments. In proximal humeral fractures, pure surgical neck fracture is one of the most common one [10]. Surgical neck fractures can also be called as shaft displaced fractures, with fracture displacement greater than 1 cm or angular deformity bigger than 45° [9]. In single shaft displacement, the upper end of humerus is divided into two separate parts. Therefore, single shaft displacement belongs to "two part" fractures [20]. If single shaft displacement is accompanied with a tuberosity fracture and the displacement is larger than 1 cm, the upper end of humerus is divided into three separate parts, and the shaft displacement here can be included into "three part" fractures [1]. Moreover, if single shaft displacement is combined with fractures of two tuberosity and the displacements are all greater than 1 cm, the upper end of humeral is divided into four separate bone blocks, namely, humeral head, greater tuberosity, lesser tuberosity and the upper end of humeral shaft [21]. Thus the bone fractures here belong to "four part" fractures. When "three parts" displaced fractures occur, humeral head may still have certain blood circulation [16]. But when "four parts" displaced fractures happen, humeral head avascular necrosis is prone to be developed due to the impairment to the blood circulation of humeral head [4]. When surgical neck fractures are accompanied with greater and lesser tuberosity fractures and shoulder dislocation, i.e., Neer three or four part fractures, satisfactory effects cannot be achieved by conservative treatments generally due to the complexity in bone fracture types and difficulty in treatments. At

present, the main surgical treatments for complex proximal humeral fractures mainly include open reduction plus internal fixation and artificial humeral head replacement.

This study retrospectively analyzed the patients with Neer three and four part proximal humeral fractures or dislocations undergoing open reduction plus internal fixation in our hospital in January, 2010 to December, 2010.

### Materials and Methods

#### General data

A total of 53 patients of Neer three or four part proximal humeral fractures or dislocation received surgical treatments in January, 2010 to December, 2010. In these cases, 46 cases provided complete medical records. These cases contained 25 males and 21 females with mean age of 42.5 ± 12.6 years old; left side fractures 24 cases and right side fractures 22 cases; traffic accident injury 21 cases, walking or ride falling injury 17 cases, and crushing injury 8 cases. Before operation, the scapula anteroposterior films and tangential X-ray films of all patients were taken. For the patients who could tolerate pains, axillary films were taken. All patients underwent preoperative CT examination (shoulder plain scanning, with space of 3 mm) to determine the displacement status of tuberosity fractures.

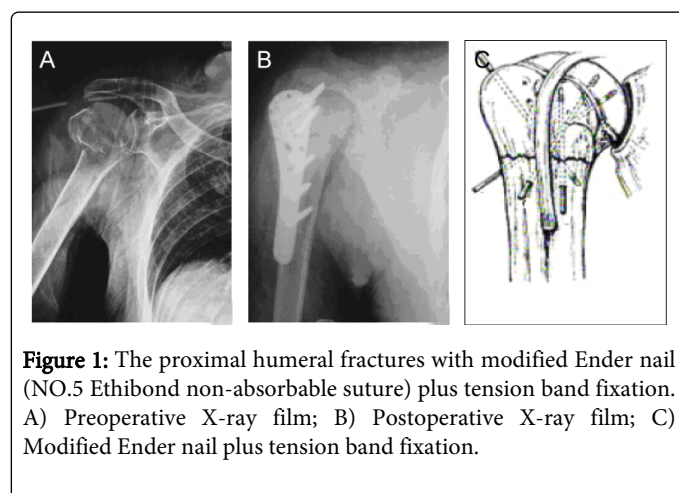
Neer bone fractures classification method was employed in this study. Radiological examination and intraoperation both indicated that the cases were all belong to Neer three or four part proximal humeral fractures or fractures dislocation. The cases of abduction inserted Neer four part fractures were exclusive. The considered cases involve 16 cases pure Neer three part fractures, 7 cases Neer three part fractures plus anterior dislocation of the shoulder, 2 cases Neer three

part fractures plus posterior dislocation of the shoulder, 7 cases pure Neer four part fractures, 9 cases Neer four part fractures plus anterior dislocation of the shoulder, and 5 cases Neer four part fractures plus posterior dislocation of the shoulder.

### Operation methods

Neck interscalene block anesthesia or general anesthesia was adopted. During the operation, the patients were placed in beacher-position. The operation applies deltoid and pectoralis major approach. With cephalic vein as a symbol, the deltoid muscle and cephalic vein were pulled outside. It should be paid attention to protect the anterior fiber of deltoid and cephalic vein. Surgical neck was mainly treated with screwed Kirschner wires or modified Ender nail plus tension band fixation, while greater and lesser tuberosity fractures were fixed on shaft by tension band fixation with non-absorbable suture (Ethibond 5) or steel wire of shape "8".

When surgical neck fractures were too comminuted to be fixed with screwed Kirschner wire, we used modified Ender nail plus tension band fixation. The process indicated that a hole in diameter of 3 mm was processed on one end of Ender nail allowing suture or wire going through. The end of Ender nail can be embedded under supraspinatus tendon to avoid subacromial impingement and the influences of postoperative functional exercise were led by over high nail tail. Three cases in this study were conducted with this operation (Figure 1). It should be noticed that the soft tissues connected with humeral head, such as the greater or lesser tuberosity, joint capsule etc., should be protected, remaining completely free during the reduction of the dislocated humeral head. For the severe comminuted surgical neck fractures, autogenous bone or artificial bone implant is required as a support. By this way, normal neck-shaft angle and humeral head height can be maintained, and the normal position of greater tuberosity can be recovered. But the implanted bones should not exceed humeral head to avoid postoperative subacromial impingement.



**Figure 1:** The proximal humeral fractures with modified Ender nail (NO.5 Ethibond non-absorbable suture) plus tension band fixation. A) Preoperative X-ray film; B) Postoperative X-ray film; C) Modified Ender nail plus tension band fixation.

### Postoperative functional exercise

Passive functional exercise was initiated on the second day after operation. Patients can do some pendular motions, passive flexion,

and passive external rotation. Two weeks later, passive adduction and passive internal rotation can be added. After 8 weeks, X-ray films showed the bone callus. And the patients can do some active functional exercises after bone fractures healing. Meanwhile, the flexion, adduction, internal rotation and external rotation exercises can be strengthened. Three months later, patients can start strength exercise and enhance the passive and active exercises in all directions.

### Follow-up and function evaluation

Follow-up was processed by taking X-ray films, clinical examination, and questionnaire survey to patients through appointment. The mean follow-up duration was 19.7 months (15~24 months). The result evaluation employs Constant-Murley absolute value score method. Constant-Murley absolute value score was 100 in total, in which 15 comprises scores of pain, 20 daily life ability, 40 activity degree, and 25 deltoid muscle strength. In this study, score of 90~100 was judged as excellent, 80~89 as good, 70~79 as moderate, and 70 below as poor [12].

### Results

#### Clinical results

The mean Constant-Murley score of the patients in this study was 83.6 (62~94), with excellent and good rate of 67.39% (31/46), moderate rate of 21.74% (10/46), poor rate of 10.87% (5/46). In these patients, the mean Constant-Murley score of the Neer three part fractures or dislocation (25 cases) was 86.1, with excellent and good rate of 68% (17/25), moderate rate of 32% (8/25). Besides, the mean Constant-Murley score of the Neer four part fractures or dislocation (21 cases) was 79.6, with excellent and good rate of 66.67% (14/21), moderate rate of 9.52% (2/21), and poor rate of 23.81% (5/21).

The Constant-Murley score standard for daily life and work abilities evaluation is indicated as: 4 for complete working ability recovery, 4 for complete recovery in recreation and sports, 2 for injured shoulder showing no effect on sleep, and 10 for hand being able to lift above head. At the same time, several motions closely associated with daily life were therein added. These motions were required from patients to give judgments, but their scores were not included in Constant-Murley score (Table 1).

The mean active forward elevation was 135° (60°-180°). In these cases, the forward elevation in 150°~180° 21 cases, 120°~150° 13 cases, 90°~120° 9 cases, and 60°~90° 3 cases. The mean lateral external rotation was 30° (0°-60°), and mean internal rotation reaches a L1 level. Pain was subjectively evaluated on patients using VAH method. Mean pain score was 14 (10~17). The pains of most of the patients were just indicated as patient's discomfort, which was defined as mild pain. In these cases, 14 cases showed no pain, 28 cases mild pain, 4 cases of moderate pain, and no severe pain. The determination of muscle strength uses muscle testing method. The result suggested that grade 5 contains 11 cases (23.91%), grade 4 31 cases (67.39%), and grade 3 of 4 cases (8.70%).

Daily function	Cannot complete	Very difficult	Slightly difficult	No problem
Get dressing	0	2	14	30
Sleep on the injured shoulder	2	2	17	25
Wash back and tie back buttons	5	7	13	21
Comb hair	0	6	11	29
Use pants back pocket	0	1	7	36
Fetch things from the shelves higher than head	3	3	16	24
Lift 10 kg things	1	3	11	31
Wash the armpit of contralateral shoulder	0	3	16	25
Whether or not restore to original life and work level	0	0	17	29
Whether or not being able to participate in recreational activities as before	0	0	11	35

Table 1: Investigation on daily life and working abilities (examples).

### Postoperative X-ray evaluation

All fractures were healed in 4 to 6 weeks after operation, without delayed healing and non-healing. During the follow-up, greater and lesser tuberosity did not generate secondary displacements. Two cases were observed with postoperative superficial infections, which were cured by simple debridement dressing.

In clinical works, we found that humeral head necrosis after trauma was mainly manifested as complete or partial humeral head absorption. Parts of humeral head necrosis were illustrated as the injured humeral head, which is significantly smaller than the uninjured side by scapula anteroposterior X-ray films. This phenomenon is not completely consistent with that of femoral head necrosis. In the early stage, the weight-bearing area of humeral head necrosis was observed with typical sclerosis, cystic degeneration, and resulting collapse. The phenomenon above may be the manifestation of humeral head necrosis process. Therefore, the humeral head shortening and absorption presented by X-ray film can be diagnosed as early humeral head necrosis. Humeral head shortening and absorption refers to that humeral head articular surface was integrated in the appearance and without collapse, only the injured humeral head was significantly smaller than the uninjured side by scapula anteroposterior X-ray films (Figure 2). Partial absorption refers to the collapse of partial humeral head articular surface (Figure 3). Complete absorption refers to the disappearance of humeral head. The Neer three part fractures in this study exhibit 1 cases of partial absorption and 2 cases of humeral head shortening, accounting for 12% of Neer three part fractures (Table 2); Neer four part fractures show 1 cases of complete absorption, 3 cases of partial absorption, and 5 cases of humeral head shortening, accounting for 42.86% of Neer four part fractures (Table 3).

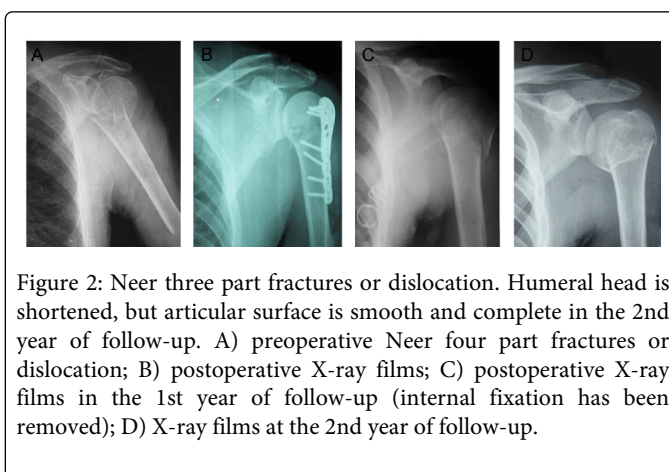


Figure 2: Neer three part fractures or dislocation. Humeral head is shortened, but articular surface is smooth and complete in the 2nd year of follow-up. A) preoperative Neer four part fractures or dislocation; B) postoperative X-ray films; C) postoperative X-ray films in the 1st year of follow-up (internal fixation has been removed); D) X-ray films at the 2nd year of follow-up.

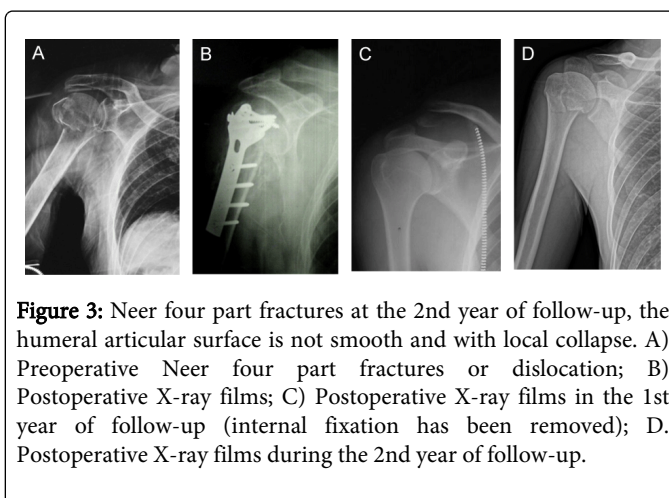


Figure 3: Neer four part fractures at the 2nd year of follow-up, the humeral articular surface is not smooth and with local collapse. A) Preoperative Neer four part fractures or dislocation; B) Postoperative X-ray films; C) Postoperative X-ray films in the 1st year of follow-up (internal fixation has been removed); D. Postoperative X-ray films during the 2nd year of follow-up.

Cases	Necrosis degree	Time of follow-up (month)	Forward elevation	Lateral external rotation	Internal rotation	Pain	Muscle strength (level)	Constant Murley score
1	Partial absorption	24	140°	30°	LS	Mild	4	93 Excellent
2	Humeral head shortening	16	100°	20°	L1	No	4	76 Moderate
3	Humeral head shortening	20	160°	50°	L3	no	5	97 Excellent

Table 2: The relationship of the necrosis status of Neer three part fractures or dislocation with result.

Cases	Necrosis degree	Time of follow-up (month)	Forward elevation	Lateral external rotation	Internal rotation	Pain	Muscle strength (level)	Constant-Murley score
1	Complete absorption	19	80°	0°	LS	mild	3	Poor 63
2	Partial absorption	21	70°	20°	LS	mild	3	Poor 67
3	Partial absorption	18	80°	0°	LS	moderate	4	Poor 66
4	Partial absorption	22	160°	50°	T6	moderate	4	Good 84
5	Femoral head shortening	23	170°	40°	T8	moderate	4	Good 86
6	Humeral head shortening	19	140°	30°	T5	no	4	Moderate 77
7	Femoral head shortening	20	170°	60°	L1	mild	5	Excellent 93
8	Humeral head shortening	22	170°	50°	L1	mild	5	Excellent 94
9	Humeral head shortening	22	160°	40°	L2	moderate	5	Good 83

Table 3: The relationship of necrosis status of Neer four part fractures or dislocation with result.

## Discussion

Complex proximal humeral fractures mainly include Neer three or four part fractures or dislocation. Fractures involve the fractures on surgical neck and greater and lesser tuberosity. These fractures can damage the function of the rotator cuff and influence the blood supply of humeral head. The treatments of this kind of fractures are more complex. And conservative treatments cannot achieve an ideal effect. Therefore, most researchers advocate an operation treatment [5]. Operations comprise various methods ranging from various fixation methods to humeral head replacement. They mainly aim the reconstruction of the shoulder's anatomical structure, recovering shoulder function, protecting humeral head blood supply, and avoiding the complications caused by humeral head necrosis [7].

In Neer four part fractures or dislocation, greater and lesser tuberosity and shaft are not contacted with humeral head, but humeral head is always connected with the joint capsule. So it should be paid attention to retain the humeral head and to avoid complete peeling to save part of blood supply [17]. Since proximal humeral fractures are associated with metaphysis and osteoporosis, often bone loss occurs, and the fixation stability is therefore affected. In this situation, we often implant autogenous iliac or artificial bone as a support. During

operation process, the emphasize should be placed on the reduction of the tuberosity, which is the key of the recovering of the rotator cuff function. Meanwhile, it should also be avoided that the greater tuberosity becomes too high and leads to a postoperative subacromial impingement. In our hospital follow-ups have been carried out in 46 cases of proximal humeral fractures to get treatment results. The cases involve fresh Neer part three or four fractures. And they have been treated with different methods. These methods mainly contain Kirschner wire fixation or plate fixation. Tuberosity reduction and fixation are not particularly stressed. In this study, surgical neck fractures were treated with screwed Kirschner wire or modified Ender nail plus tension band fixation, while greater and lesser tuberosity were fixed by non-absorbable suture. The operations above aim at effectively fixing surgical neck fractures and tuberosity fractures and minimizing the impairment to soft tissue meanwhile. At early stage, researchers have used Neer score. Although Neer score and the Constant-Murley score used in this study were slightly different, they were all used mainly in order to evaluate postoperative pain, function and the ability of completing daily work. Thus they can also reflect the effect of treatment [15].

In clinical treatments, it is perceived that the key to obtain excellent treatment result lies in the understanding of the pathological changes

of the proximal humeral fractures, improving operation skills and fixation methods, and correctly guiding postoperative functional exercise. Since the anterior 1/3 fiber of the deltoid muscle is an important muscle for the shoulder flexion, we should pay great attention to protect this fiber in order to avoid postoperative shoulder flexion weakness and to maintain simultaneously a favorable shoulder shape [18]. Moreover, reduction and fixation methods should be determined by fractures types to avoid rough operation. For Neer three part fractures dislocation, it should be noticed that the greater (or lesser) tuberosity and humeral head should not be separated during reduction, since both are connected. By pulling the fractured tuberosity, humeral head reduction can be easily achieved and the tuberosity connected with the humeral head can be maintained. This is very important for the preservation of the humeral head blood supply [2]. In this study, the excellent and good rates of Neer three and four part fractures were significantly enhanced. According to the follow-ups to the surgical treatments of the Neer three and four part fractures in our hospital, we found that there were many deficiencies in the traditional "T" shaped plate fixation of AO. The deficiencies included that "T" shaped plate fixation requires extensively soft tissue incision, which can bring heavy injuries to rotator cuff. The reduction and fixation of the tuberosity fractures were inaccurate and unstable, thus the humeral head blood supply can be easily affected. If the steel plate is placed too high, subacromial impingement can be induced, and shoulder abduction can thereby be influenced. Consequently a smaller inner fixation form is adopted in this study. It mainly comprises multiple screwed Kirschner wires plus tension band fixation. Consequently when surgical neck fractures are too comminuted, modified Ender nail plus tension band fixation is employed. The fractures fixations in all cases of this study were very stable and no internal fixation failure and tuberosity fractures displacement were observed. Fractures healed in an average of 4 to 6 weeks. After the operation, the shoulder is immobilized with a neck wrist sling. During early passive exercise processes, fractures fixation failure did not happen. Hessmann et al. [6] reported that the necrosis rate of Neer three part fractures surgical treatment happened in 20% to 25%. Other literatures pointed out that the necrosis rate of Neer four part fractures surgical treatment turned around 45%~60%. Moreover, the assault and degree of injury and fracture type were major factors influencing humeral head necrosis after trauma [8]. The data in this study showed that necrosis rate of Neer four part fractures or dislocation was significantly higher than that of Neer three part fractures or dislocation. And the necrosis rate of Neer four part fractures in this study was higher than that reported in literatures. This is probably caused by the differences in the diagnostic criteria.

By treating the complex proximal humeral fractures with open reduction and internal fixation, we can obtain better clinical results even if postoperative humeral head necrosis may be developed. It is considered that the key to obtain excellent treatment results lies in the understanding of the pathological changes of the proximal humeral fractures, improving operation skills, applying stable and reliable internal fixation, and correctly guiding postoperative functional exercise. For complex proximal humeral fractures, i.e. humeral head splitting fractures, it is predicted that postoperative complete necrosis absorption is a high possibility [14]. Because of serious comminuted fractures plus osteoporosis, open reduction and internal fixation is difficult to be developed. Thus a stage I artificial joint replacement can be applied to achieve satisfactory effects. In some reports, it is considered that the result of the stage I artificial joint replacement is superior to that of the replacement conducted after the open reduction

and internal fixation which is unsatisfactory. However, artificial joint replacement also faces with tuberosity fractures reconstruction [3]. Although the patients with good tubercle fractures union after open reduction and internal fixation and satisfactory early functional exercise also develop postoperative humeral head necrosis absorption, satisfactory treatment results can also be achieved if the necrosis degree is not serious [13].

Kim et al. [11] analyzed 38 cases developing humeral head necrosis after proximal humeral fractures treatment. The cases were divided into two groups, including anatomic reduction or near anatomic reduction group (20 cases) and the group with a bad union in at least one part (18 cases). The results showed that although the group with good reduction developed humeral head necrosis and collapse, the shoulder function of this group was similar with that of stage I humeral head replacement [19]. Therefore, some researchers stress that it is favorable for younger patients to achieve good reduction in open reduction and internal fixation. Thus even humeral head generates partial necrosis; the young patients also can obtain satisfactory shoulder function. However, if a satisfactory reduction cannot be obtained, they should be treated with artificial humeral head replacement [11].

The 5 cases with Constant-Murley score less than 60 (poor) are all Neer four part fractures or dislocation. According to the X-ray films in the follow-up, they are diagnosed as humeral head necrosis. The degree of humeral head necrosis greatly influences postoperative function. But when the humeral head is shortened or partially absorbed, favorable function can still be acquired. Complete humeral head necrosis and absorption are mainly manifested as the inability or weakness in shoulder active motion. But shoulder can produce passive motion in certain ranges. Meanwhile, the injured shoulder produces different degrees of pain. The results obtained are often very bad.

This study indicated that the cases with complete necrosis and absorption present poor Constant-Murley scores. Moreover, these cases are obviously limited in active motion and show pain and discomfort. The cases with partial necrosis absorption display significantly higher Constant-Murley scores. Besides, the Constant-Murley scores of the cases with apparent humeral head shortening can reach a basically excellent degree. This results probably because the shoulders are non-weight-bearing joints, unlike femoral head avascular necrosis, humeral head avascular necrosis cannot exhibit more significant clinical symptoms and X-ray manifestations. Due to the limitation in sample size, the duration of the follow-up is relatively short in this study. And it lacks a unified image standard for the humeral head necrosis after trauma. Moreover, we also fail to investigate further the CT, the magnetic resonance (MR) and the isotope scanning of humeral head necrosis. Thus the results of this study may present deviations.

## Declaration

We declare that we have no conflict of interest.

## References

1. Ackermann O., Levine M., Eckert K., Rulander C., Stanjek M. & von Schulze Pellengahr C. Uncertainty in the radiological evaluation of deformity in proximal humerus fractures. *Z. Orthop. Unfall.* 2013, 151: 74-79.

2. Berkes M.B., Little M.T., Hepp P., Voigt C., Oestern H., Kaab M., Luo C., Plecko M., Wendt K., Kostler W. & Konrad G. Open reduction internal fixation of proximal humerus fractures. *Curr. Rev. Musculoskelet. Med.* 2013, 6: 47-56.
3. Carofino B.C. & Leopold S.S. Classifications in brief: the Neer classification for proximal humerus fractures. *Clin. Orthop. Relat. Res.* 2013, 471: 39-43.
4. Chambers L. & Dines J.S. Hemiarthroplasty for proximal humerus fractures. *Curr. Rev. Musculoskelet. Med.* 2012, 6: 57-62.
5. Gavaskar A.S., Chowdary N. & Abraham S. Complex proximal humerus fractures treated with locked plating utilizing an extended deltoid split approach with a shoulder strap incision. *J. Orthop. Trauma.* 2012, 27: 73-76.
6. Hessmann M.H., Nijs S., Mittlmeier T., Kloub M., Segers M.M., Winkelbach V. & Blauth M. Internal fixation of fractures of the proximal humerus with the MultiLoc nail. *Oper. Orthop. Traumatol.* 2012, 24: 418-431.
7. Jones K.J., Dines D.M., Gulotta L. & Dines J.S. Management of proximal humerus fractures utilizing reverse total shoulder arthroplasty. *Curr. Rev. Musculoskelet. Med.* 2012, 6: 63-70.
8. Jost B., Spross, C., Grehn H & Gerber C. Locking plate fixation of fractures of the proximal humerus: analysis of complications, revision strategies and outcome. *J. Shoulder. Elbow. Surg.* 2013, 22: 542-549.
9. Jung S.W. Indirect reduction maneuver and minimally invasive approach for displaced proximal humerus fractures in elderly patients. *Clin. Orthop. Surg.* 2013, 5: 66-73.
10. Jung W.B., Moon E.S., Kim S.K., Kovacevic D. & Kin M.S. Does medial support decrease major complications of unstable proximal humerus fractures treated with locking plate? *BMC. Musculoskelet. Disord.* 2013, 14: 102-104.
11. Kim S.H., Lee Y.H., Chung S.W., Shin S.H., Jang W.Y., Gong H.S. & Baek G.H. Outcomes for four-part proximal humerus fractures treated with a locking compression plate and an autologous iliac bone impaction graft. *Injury.* 2012, 43: 1724-1731.
12. Khmel'nitskaya E., Lamont L.E., Taylor S.A., Lorich D.G., Dines D.M. & Dines J.S. Evaluation and management of proximal humerus fractures. *Adv. Orthop.* 2012, 32: 598-560.
13. Matassia F., Angeloni R., Carulli C., Civinini R., Di Bella L., Redl B. & Innocenti M. Locking plate and fibular allograft augmentation in unstable fractures of proximal humerus. *Injury.* 2012, 43: 1939-1942.
14. Misra A., Kapur R. & Maffulli N. Complex proximal humeral fractures in adults, a systematic review of management. *Injury.* 2001, 32: 363-372.
15. Muncibi F., Paez D.C., Matassi F., Carulli C., Nistri L. & Innocenti M. Long term results of percutaneous fixation of proximal humerus fractures. *Indian. J. Orthop.* 2012, 46: 664-667.
16. Ong C.C., Kwon Y.W., Walsh M., Davidovitch R., Zuckerman J.D. & Egol K.A. Outcomes of open reduction and internal fixation of proximal humerus fractures managed with locking plates. *Am. J. Orthop.* 2012, 41: 407-412.
17. Rothberg D. & Higgins T. Fractures of the proximal humerus. *Orthop. Clin. North. Am.* 2013, 44: 9-19.
18. Sankar B. & Nicholson S. Centromedullary manipulation and stabilization of completely displaced proximal humerus fractures in adolescents. *Orthopedics.* 2012, 35: 856-860.
19. Wu, X. & Li, S.H. Modified hemiarthroplasty for four-part fractures of the proximal humerus. *ANZ J. Surg.* 2013, 83: 165-170.
20. Zhu Y., Lu Y., She, J., Zhang J. & Jiang C. Locking intramedullary nails and locking plates in the treatment of two-part proximal humeral surgical neck fractures: a prospective randomized trial with a minimum of three years of follow-up. *J. Bone. Joint. Surg. Am.* 2011, 93: 159-168.
21. Zydek L., Barzdo M., Meissner E. & Berent J. Assessment of bone age based on morphometric study of the upper end of the humerus. *J. Forensic Sci.* 2011, 56: 1416-1423.