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Surgical treatment of proximal humerus fractures

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Surgical repair of unstable proximal humerus fractures involves accurate reduction of the humerus tubercles, reconstruction of rotator cuff muscles and tendons, stable bone fixation to be performed shortly after injury to ensure functional recovery of the shoulder joint. **Objective** To evaluate the efficacy of surgical treatment with fixation shape memory constructs and through porous titanium nickelide implants used for patients with proximal humerus fractures and a different injury-to-surgery interval. **Material and methods** Surgical treatment with titanium nickelide constructs was performed for 71 patients with proximal humerus fractures. Thirty (42.3 %) patients had comminuted intra- and juxta-articular fractures, 26 (36.6 %) cases were unifocal and metadiaphysial injuries and 15 (21.1 %) had greater tuberosity fractures. 21 (29.6 %) patients had associated rotator cuff tears. An injury-to-surgery interval was 1 to 10 days in 52 (73.2 %) patients and 11 to 30 days in 19 (26.8 %) cases. **Results** Consolidation of realigned bone was achieved in all the patients at 4-to-6-month follow-up. Shoulder joint function recovered in 50 (96.2 %) patients who were surgically treated in the first 10 days of injury and in 14 (73.7 %) out of 19 patients who had procedure performed between 11 and 30 days post injury. There were statistically significant differences in the groups ($\chi^2 = 8.391$, $p = 0.015$). **Conclusions** Accurate bone reduction and shoulder ligament repair performed early after the injury provided restored function to the shoulder joint in 96.2 % of the cases. Preoperative delays showed reduction in favourable outcomes of the surgical intervention by 21.1 %.

Keywords: proximal humerus, fracture, osteosynthesis, shape memory construct, implant, titanium nickelide, injury-to-surgery interval, results

INTRODUCTION

Juxtarticular and intraarticular fractures of the proximal humerus are reported to be displaced with compressed cancellous bone in 36.7 to 45.2 % of the cases [1, 2, 3]. The fractures are accompanied by dislocation in 9.3 to 12.8 % of the cases, injury to supinators in 7.2 % of the patients and injury to pronators in 1.9 % [2, 4, 5, 6]. A variety of constructs available for osteosynthesis and plastic repair of rotator cuff, humerus implants, current medical technologies, rehabilitation programmes allow for an optimal method of treatment to be chosen for a particular type of injury and patient's age [7, 8, 9, 10]. Reconstructive procedures involving open reduction of dislocation, reduction, stable osteosynthesis, plastic repair of bone defects and ligaments performed for patients with damaged soft tissue and bone structures early after an injury can provide functional recovery of the limb in 89.3 to 91.1 % of the cases [4, 6, 11]. The choice of a diagnosis related group considering severity of injury, technique of medical treatment is supposed to be balanced and determined by efficacy of surgical intervention, established standards in length and costs of a complete case [1, 6, 11].

Unreduced bone or secondary displacement, injury to rotator cuff muscles that is not timely diagnosed, ignored procedure to restore ligaments result in degeneration of paraarticular tissues, contractures and impingement syndrome [4, 6, 8, 12].

Objective: to evaluate the efficacy of surgical treatment with fixation shape memory constructs and through porous titanium nickelide implants used for patients with proximal humerus fractures and a different injury-to-surgery interval.

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MATERIAL AND METHODS

Surgical treatment with titanium nickelide constructs was performed for 71 patients (52.2 %) out of 136 cases with proximal humerus fractures between 2012 and 2016.

Of the 71 patients with proximal humerus fractures 33 (46.5 %) were aged from 19 to 45 years. The majority of casualties aged older than 45 years had comminuted intra- and juxtarticular fractures accompanied by compressed cancellous bone (in 21 (70.0 %) of the 30 patients with humerus comminution). Greater tuberosity fractures were typical for patients aged older than 45 years (in 10 (66.7 %) of the 15 patients including an 81-year-old female patient).

Examinations revealed intraarticular fractures in 13 (18.3 %) of 71 patients, juxtarticular injury in 54 (76.1 %) cases and metadiaphyseal fractures in 4 (5.6 %) casualties. 20 (28.2 %) patients had dislocations and associated rotator cuff tears. Supraspinous tear was intraoperatively detected in a female patient with comminuted transtubercle humerus fracture (**Table 1**).

Reconstructive osteosynthesis was performed for 52 (73.2 %) of 71 patients with proximal humerus fractures in the first 1 to 10 days of injury, and 19 (26.8 %) patients underwent surgical treatment at 11 to 30 days of injury (**Table 1**).

Transacromion approach was used in 4 (5.6 %) cases including a neglected intraarticular fracture and associated supraspinatus and infraspinatus tears and in three cases with juxtarticular fractures accompanied by subaxillary dislocation and supinator and pronator tears (**Fig. 1**). Open reduction was produced using anterior deltoid-pectoral approach in 67 (94.4 %) patients.

Open bone reduction was not accurate in 30 (42.3 %) patients of 71 due to the deficit of bone tissue with compressed cancellous bone and removed small bone pieces. V-shaped porous screw (OOO «MITS SPF», Russia, registration certificate № FSR 2009/04558) was used for plastic reconstruction of the proximal humerus in a patient with intraarticular fracture of the split humerus head, subacromion dislocation, supraspinatus tear following regained articular congruency of the head. The screw was introduced in the humerus head through greater tubercle to span the fragments. The torn tendon (diastasis of 5 mm) was sutured and fixed to the superior screw turns and the screw embedded 2 to 3 mm deep. Cannulated through porous titanium nickelide cylindrical nails (OOO «MITS SPF», Russia, registration certificate № FSR 2009/04558) were employed in 29 cases. The porous implant served an auxiliary bar and plastic material to fill in bone defect when realigning the anatomy. Lower end of the bar was placed into the distal bone fragment and partially into medullary canal. The humeral head was mounted on the emerging end of the bar with a preshaped scoop in the core of cancellous bone.

The bone was additionally fixed with thermomechanical memory omega-shaped clamp having intramedullary legs with proximal end shaped as a crook and omega loops. The crook with omega-shaped loops clasped greater tubercle and pressed against porous implant for realignment. S-shaped self-fixation clamps were used for compression and prevention of rotation with superior intraarticular legs of S-shaped clamps introduced into the humerus head over omega-shaped loops of the clamp with intramedullary legs, and inferior legs secured into canals of the humerus shaft (**Fig. 1**).

Reconstructive osteosynthesis was performed without additional fixation only in a 70-year-old patient with inferior subaxillary dislocation of the humerus, supraspinatus and infraspinatus tears and intraarticular humerus fracture (**Fig. 2**).

Omega-shaped clamp with intramedullary legs and S-shaped clamps were used in 22 (31.0 %) patients with unifocal transtubercle fractures and fractures of surgical neck. Repaired supinators were additionally fixed to extramedullary components of the clamps at the attachment sites of injured tendons, and pronator tendons were fixed to lesser tuberosity with intraosseous sutures at the attachment sites.

With the reduction completed a safety leg of S-shaped clamp was introduced into greater tubercle vertical down and obliquely through the supinator fibres in 15 (21.1 %) patients with fractures of greater tubercle. A leg of extramedullary S-shaped component of the clamp was placed in the canal of the humerus shaft formed below the surgical neck. Damaged tendons were sutured to the extramedullary back of the clamp at the attachment level (**Fig. 3**).

Table 1

Types of injuries to the proximal humerus and shoulder joint and injury-to-surgery interval

Proximal humerus fractures MKB code-10 S42.2	Injury-to-surgery interval		Rotator cuff tear(s) MKB code -10 S46.0			Dislocated (subluxated) shoulder joint MKB code -10 S43		
	1 to 10 days	11 to 30 days	M. supraspinatus tendons	M. supraspinatus and M. infraspinatus tendons	Tendons of 1–2 supinators and 1–2 pronators	Anterior subcoracoid	Inferior subaxillary	Posterior sub-acromion
Intraarticular impacted fx of the humeral head	1	–	1	–	–	–	–	1
Intraarticular comminuted fx of the anatomical neck	9	3	–	1	–	–	1	–
Transtubercle bifocal fx	8	1	2	1	1	2	1	–
Bifocal surgical neck fx	6	2	2	–	–	2	–	–
Transtubercle unifocal fx	10	5	1	1	–	–	2	–
Unifocal surgical neck fx	5	2	2	1	2	3	2	–
Bifocal metadiaphyseal fx	4	–	–	–	–	–	–	–
Greater tubercle fx	9	6	3	3	–	3	3	–
Total	52	19	11	7	3	10	9	1

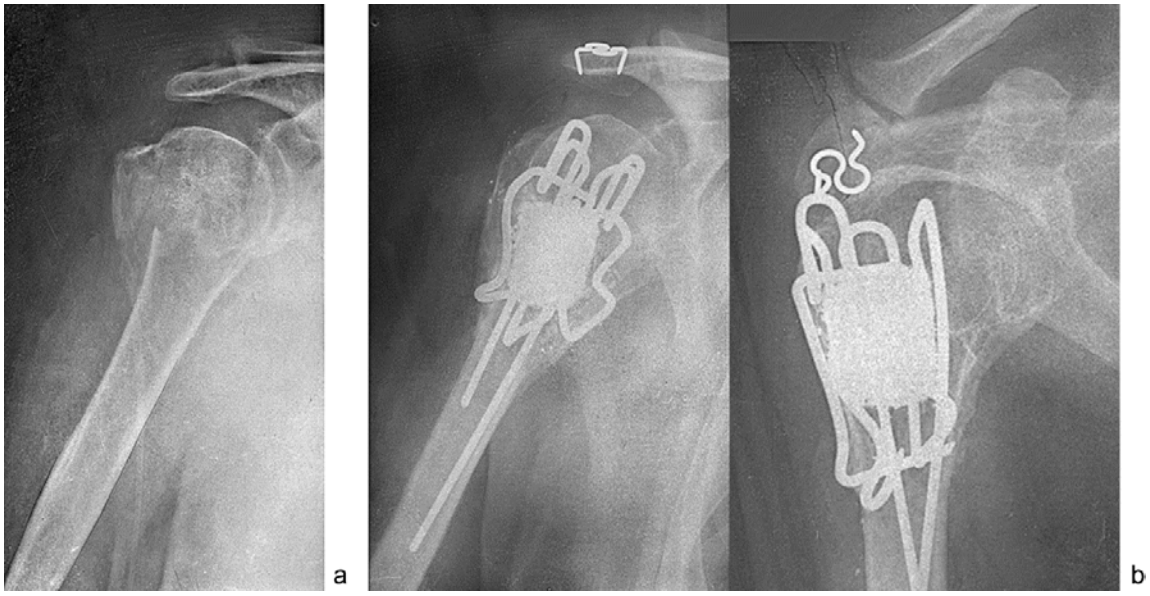

Fig. 1 Radiographs of a 58-year-old patient D. with intraarticular comminuted fracture of the proximal humerus, subcoracoid dislocation, supraspinatus tear: (a) $2^1/_2$ weeks of injury and reduction of dislocation; (b) – $2^1/_2$ years following reconstructive osteosynthesis and repair of the shoulder joint ligaments

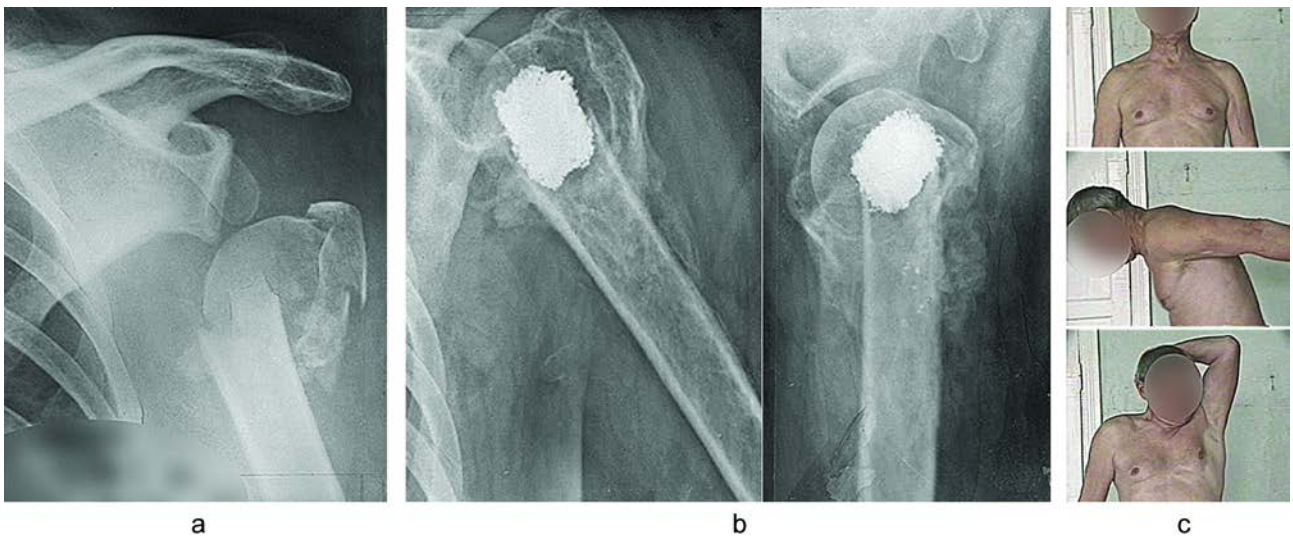

Fig. 2 Radiographs of the humerus and photograph of a 70-year-old patient I. with inferior subaxillary dislocation of the humerus, supraspinatus and infraspinatus tears and intraarticular humerus fracture: (a) preoperatively; (b) 18 months after the surgery; (c) functional result of treatment

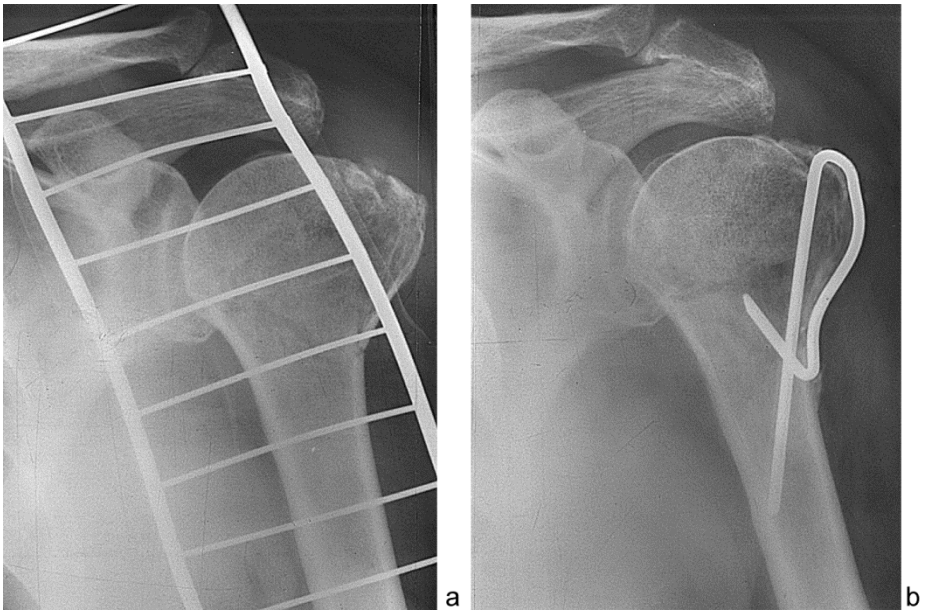

Fig. 3 Radiographs of the humerus of an 81-year-old patients S. with fracture of greater tubercle and surgical neck and supraspinatus tear: (a) preoperatively (28 days of injury); (b) 6-month follow-up

A combination of omega-shaped clamp with intramedullary legs and extramedullary S-shaped clamp was used for two cases with metadiaphyseal fracture to fix intraarticular bone fragments and greater tubercle. Oblique fracture of the humerus shaft was fixed with extramedullary memory shape ring constructs (OOO «MITS SPF», Russia, registration certificate № FSR 2009/04558). Locking intramedullary nail was employed for surgical neck fracture with intact greater tubercle. IM nail was introduced through greater tubercle and ringed clamps were applied to adapt diaphyseal bone fragments.

Drainage was removed 2 to 3 days post surgery. Immobilisation was secured with a sling on cotton gauze pad at abduction of 40° to 45°. Outpatients were recommended to use SA 209 abduction splint with abducted shoulder at 70° to 80°. External immobilisation lasted for 3 weeks in patients with unifocal extraarticular fracture and greater tubercle injury and 4 to $2^1/_2$ weeks in patients with comminuted and metadiaphyseal fractures. Associated rotator cuff injury increased immobilisation with abduction splint by 1 to 2 weeks to be followed by a sling with abducted shoulder at 30° within 2 to 3 weeks.

Comprehensive rehabilitation treatment was aimed at regaining range of motion in the joints of the injured limb, prophylaxis of neurotrophic disorders (Sudeck atrophy) and degeneration of the shoulder joint.

Clinical, radiological and statistical methods were used to review outcomes of surgical treatment performed for groups of patients with comminuted intra- and juxtarticular fractures; unifocal juxtarticular and metadiaphyseal fractures, and greater tubercle fractures in the first 1 to days and 11 to 30 days.

Biostatistica 6.0 software package (S.A. Glantz, McGraw Hill, translated into Russian by *Practica*, 1998) was used for statistical analysis. Nonparametric $\chi 2$ test was applied to compare absolute values of quality features in independent samples. Yate's correction for continuity was used with observed frequency less than 10. We set our significance level α at 0.05 conducting the hypothesis test.

No infection complications were observed postoperatively, the sutures were removed after 11 to 14 days, and the wound healed by primary intention in all patients.

RESULTS

Properly realigned bone consolidation occurred within 5 to 6 months in 30 (42.3 %) patients with intra- and extraarticular fractures that underwent surgical treatment in the first 1 to 10 and 11 to 30 days of injury. 26 (36.6 %) patients with unifocal juxtarticular fractures including 4 cases of metadiaphyseal injury showed bone healing in $4^1/_2$ to 5 months, and 15 (21.1 %) patients with greater tubercle fracture, in 3 to 4 months.

30 patients with comminuted intra- and jux-

tarticular fractures repaired within 1 to 10 and 11 to 30 days of injury developed active range of motion in frontal plane measuring 80° ± 10° with an arm elevated forward and upward, and 15° ± 5° with an arm elevated backward and upward. ROM in sagittal plane measured 150° ± 10° with an arm elevated aside and upward, rotation around vertical axis 35° ± 6°. With the hand placed behind the back the fingers could reach a level of 6 to 8 thoracic vertebrae. The patients could hold the affected limb in abduction of 90° at least 3 minutes.

An 18-to-36-month follow-up showed full and pain free circumduction in 23 (95.8 %) patients. The fingers could reach the spine of the opposing scapula with a hand place behind the back. The patient could hold a load of 1 kg in the affected hand with the abducted arm for more than 3 minutes. The outcomes were assessed as good (**Table 2**).

A 70-year-old patient with comminuted intraarticular fracture and associated dislocation complained of dull pains in the affected shoulder joint. Clinical assessment showed limited ROM with the hand placed behind the back (the fingers could reach spinous processes of 8 to 9 thoracic vertebrae. Radiographs demonstrated to a narrow articular space in the clavicle-acromion articulation and marginal osseous enlargement in the scapular and clavicle articular surfaces. Inferior medial quadrant of the humeral head was above the lower pole of glenoid cavity which was normal. Cortical bone at the superior surface of greater tubercle appeared to be rough and sclerotic of 1.0×1.5 cm in area with sclerosis transferred to supraspinatus. Marginal osseous enlargement was seen at the transition area of medial head to the surgical neck. A course of treatment was administered for grade I–II deforming arthritis of shoulder joint. The outcome was assessed as fair (**Fig. 2**). Range of motion restored completely in the affected shoulder joint in 4 (66.6 %) of 6 patients with comminuted intra- and juxtarticular fractures of the proximal humerus repaired within 11 to 30 days of injury corresponding to functional standards. Muscle tone and strength were symmetrical to those of uninvolved limb with the difference of at least 0.5 to 1.0 kgf. A poor outcome (16.7 %) of a 48-year-old patient with comminuted transtubercle fracture, supinator and pronator tears was caused by limited extension of 25°, lateral rotation of 40°, position of abducted arm with a load of 1.0 kg in the hand persisting for at least 2 minutes. Control radiographs showed osteoporotic bone and thin cortical bone of greater and lesser tuberosity, bursitis of subacromial bursa, calcified areas at coraco-acromial ligament.

One (16.7 %) patient had pains elevating the arm from abduction. Radiographs showed sclerosis of 2.0 cm at the apex of greater tuberosity. The outcome was evaluated as fair (**Table 2**).

Range of motion in the affected shoulder joint was functionally normal in 18 (94.7 %) patients with juxtarticular unifocal fracture including 5 cases with associated rotator cuff tear at 5 months post surgery performed during the first 1 to 10 days of injury. The patients could hold a load of 1 kg in the affected limb abducted at 90° for at least 1 to 2 minutes. A patient with transtuberosity fracture, supraspinatus and infraspinatus could reach spinous processes of 8 to 9 thoracic vertebrae with the hand placed behind the back. Abduction of 90° could be maintained for 1 minute. An 18-to-24-month follow-up showed full, pain free circumduction corresponding to functional standards in 18 (94.7 %) patients. Muscle tone and strength of involved limb were equal to those of uninvolved side (**Table 2**).

Table 2

Outcomes of surgical treatment of 71 patients with proximal humerus fractures

Type of fracture	Injury-to-surgery interval, days	Results of treatment						Total	
		good		fair		poor			
		abs.	%	abs.	%	abs.	%	abs.	%
Intra- and juxtarticular bifocal fx	1–10	23	95.8	1	4.2	–	–	24	80.0
	11–30	4	66.6	1	16.7	1	16.7	6	20.0
Subtotal		27	90.0	2	6.7	1	3.3	30	42.3
Unifocal juxtarticular metadiaphyseal fx	1–10	18	94.7	1	5.3	–	–	19	73.1
	11–30	5	71.4	2	28.6	–	–	7	26.9
Subtotal		23	88.5	3	11.5	–	–	26	36.6
Greater tubercle fx	1–10	9	100.0	–	–	–	–	9	60.0
	11–30	5	83.3	1	16.7	–	–	6	40.0
Subtotal		14	93.3	1	6.7	–	–	15	21.1
Proximal humerus fx	1–10	50	96.2	2	3.8	–	–	52	73.2
	11–30	14	73.7	4	21.1	1	5.3	19	26.8
Total		64	90.1	6	8.5	1	1.4	71	100.0

Range of motion in the affected shoulder joint completely restored within 4 to 5 months in 5 (71.4 %) of 7 patients with unifocal juxtarticular fracture repaired during 11 to 30 days of injury. Limited external (30°) and internal (50°) rotation, abduction of the involved limb that could be maintained for at least 1 to 2 minutes were observed in 2 (28.6 %) cases with rotator cuff tear. One of the patients reported low muscle strength and dull pain in the involved limb after physical activity at two-year follow-up. Range of active motion in the shoulder joint persisted within functional standards. The outcome was assessed as fair.

Comparison of the outcomes with regard to injury-to-surgery interval in the group of comminuted fractures showed statistically insignificant differences ($\chi^2 = 5.579$, $p = 0.061$) (**Table 2**). Range of motion in the affected shoulder joint completely restored in 27 (90.0 %) of 30 patients. Range of motion restored within physiological standards was observed in 23 (88.5 %) of 26 patients with unifocal juxtarticular and metadiaphyseal fractures and in 14 (93.3 %) cases of greater tuberosity fractures. Statistically insignificant differences were detected in the groups depending on injury-to-surgery interval in the groups ($\chi^2 = 0.918$, $p = 0.336$ and $\chi^2 = 0.045$, $p = 0.833$, correspondingly).

Review of the outcomes of surgical interventions performed during the first 1 to 10 days of injury showed statistically significant differences in 52 (73.2 %) patients and in 19 (26.8 %) of 71 patients with an injury-to-surgery interval of 11 to 30 days ($\chi^2 = 8.391$, $p = 0.015$) (**Table 2**). Fair and poor results were mostly observed in patients with associated rotator cuff tear.

DISCUSSION

The recent literature focuses on emergent surgical treatment to be performed for patients with injury to bone and stabilising structures of the shoulder joint applying optimal approach, methods of reconstructive procedures aimed at recovery of shoulder anatomy and adequate bone fixation [1, 2, 4, 12]. Reconstructive procedures produced early after trauma can provide recovery to limb function in 89.3 to 91.1 % of the patients [4, 6, 11]. Poor outcomes of reconstructive osteosynthesis with LCP, LPHP plating can be caused by subacromial impingement, screws migrated from osteoporotic bone [3, 5, 8, 10].

Bone fixation with locking intramedullary nails (HLN, stedtfeldt, UHN) makes rotation impossible and allows for additional attachment of rotator cuff tendon to a proximal nail foramen [4]. Efficacy of intramedullary nailing of intraarticular comminuted fractures with associated bone loss is questionable [4]. In opinion of several researchers, outcomes of joint replacement in patients with comminuted intra- and juxtarticular fractures of the proximal humerus appeared to be worse as compared to patients who underwent no surgery [7, 9].

Bone stabilisation with self-fixation memory shape constructs makes the migration from osteoporotic bone supporting good relationship between humerus tubercles and the shaft and reducing a risk of subacromial impingement syndrome. Application of through porous implants is practical in restoration of anatomo-topographical relationship in patients with bone tissue defects due to compression of cancellous bone or removal of small bone pieces. Bone healing and complete recovery of shoulder function following reconstructive osteosynthesis with a 1-to-10-day injury-to-surgery interval have been shown to achieve in 95.8 % of the patients with intra- and juxtarticular bifocal fractures, in 94.7 % of the cases with juxtarticular fractures and in 100 % of the patients with fractures of greater tubercle.

Unreduced bone or secondary displacement, injury to rotator cuff muscles that is not timely diagnosed, ignored procedure to restore ligaments result in degeneration of paraarticular tissues, contractures and impingement syndrome. Interventions performed for secondary changes of the humerus structures were shown to be effective in 60.8 to 90.2 % of the patients only [6, 8, 12]. Closed reduction of dislocation were performed for 19 (26.8 %) patients of our observations at inpatient trauma unit. The patients were referred to inpatient department 11 to 30 days later to receive surgical treatment due to secondary bone displacement, suspected rotator cuff musculature tear or subluxation. Bone healing and completely restored shoulder function were achieved in 66.6 %

of patients with intra- and juxtarticular fractures, in 71.4 % of unifocal injury and in 83.3 % of greater tubercle fractures.

Fair and poor results were mostly observed in patients with associated rotator cuff tear.

Review of outcomes of surgical treatment performed for 52 (73.2 %) patients in the first 1 to 10 days of injury, and 19 (26.8 %) of 71 patients showed statistically significant differences (χ^2 = 8,391, p = 0,015).

Therefore, an injury-to-surgery interval is an important factor in obtaining functional result irrespective of a surgical technique used to repair proximal humerus fractures [7, 8, 9, 10].

CONCLUSIONS

1. Accurate bone reduction and shoulder ligament repair performed early after the injury provided restored function to the shoulder joint in 96.2 % of the cases.

2. Preoperative delays showed reduction in favourable outcomes of the surgical intervention by 21.1 %.

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