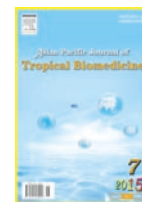




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## Treatment of patients with acromioclavicular joint injuries (Rockwood II-VI) with modeled Kirschner wire and cortical screw

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## ABSTRACT

**Objective:** To propose an original method of surgical treatment for the acromial extremity of the clavicle rupture (Rockwood II-VI) with modeled Kirschner wire and cortical screw.**Methods:** Anatomical study and a test method were applied to 43 cadavers of both sexes. During the period between 2000 and 2013, 34 patients of both sexes were operated upon using the new method. In the comparison group ( $n = 120$ ), the fixation of the acromial extremity of the clavicle rupture was performed with hamate plate, Lee hook and Kirschner wires.**Results:** Its application allows, according to the evaluation scale of Constant and Murley (1987), 10% more preservation of the function of the shoulder compared with traditional methods of surgical treatment, and shortens the required hospital treatment and temporary disability periods.**Conclusions:** It is shown that the proposed author's method combines low invasiveness, minimum dimensions of the construction and low-cost treatment.

## 1. Introduction

Dislocation of the acromial extremity of the clavicle is a fairly common injury to the locomotor system, constituting from 3%-15% to 19% of the total number of dislocations and being the third most common dislocation after the shoulder and forearm[1-4]. Those most frequently affected by these injuries are young, able-bodied people, who lead an active lifestyle and engage in sport[5-7].

The complex biomechanical relationships in the acromioclavicular joints of humans, when the biasing force is caused by the action of muscles, provoke clavicle dislocation, and ruptured capsule-ligamentous apparatus is uncondusive to the maintenance of stability. All of this leads to difficulties in treatment that are naturally accompanied by a high rate of complications and relapse[8].

To determine the optimal method of treatment, the correct biomechanical assessment of the injury to the ligamentous apparatus of the clavicle is vital, which is impossible to determine without the

particular role of one or other ligament in retaining the clavicle in the correct anatomical position.

At the same time, in the available scientific literature we analyzed, there is no consensus on the degree of importance of the elements of the ligament apparatus of the acromioclavicular joint when dislocation occurs. Thus, some authors have noted the occurrence of dislocation following damage to the acromioclavicular ligament alone[9]. Others believe that, for the occurrence of a complete dislocation, damage to both the acromioclavicular and the clavicular-coracoid ligament is necessary[10]. However, all authors agree that damage to the acromioclavicular ligament leads to a particular violation of the relationship of the articular surfaces in the acromioclavicular joint[11,12].

Thus, understanding the role of the ligamentous apparatus during rupture to the acromioclavicular joint expressed contradictions are traced.

This provides a basis for the further biomechanical study of the acromioclavicular joint through the determination of the optimal location for the application and construction of the retainer for its stabilization. For the treatment of injury to the acromioclavicular joint both conservative and operational methods are used[8,11]. Different types of splints, bandages and casts came into widespread use throughout the last century. However, the imperfection of their

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construction, awkwardness, discomfort and high recurrence rate significantly reduced the frequency of their use. Surgical methods are more convenient for patients in terms of post-operative treatment and social adaptation.

Nowadays, there exist more than 300 techniques of surgical treatment for rupture of the acromioclavicular joint, including plastic acromial extremity of the clavicle (AEC) ligaments, splinting, and perosseous osteosynthesis[13-16].

The most high-tech AEC treatment methods involve restoring the clavicular-coracoid ligament through the construction of rigid threads, for example Endobutton, including the use of endoscopic techniques[4,17-19]. The minimally invasive acromioclavicular reconstruction method is also widespread[20,21].

However, despite the use of these expensive metal and surgical approaches, the number of postoperative complications remains high, so Lin *et al.* performed a study that found that hamate plates use for the recovery of AEC lead to impingement syndrome in 37.5% and to damage to the rotator cuff shoulder in 15% of patients following hamate plate removal, which resulted in significantly limited motion in the shoulder joint[22].

Thus, the development of new methods of surgical treatment for dislocation of the acromial extremity of the clavicle is topical as well as socially and economically justified[23].

The aim of this work was to improve the results of treatment for patients with traumatic damage to the acromioclavicular joint and dislocation of the acromial extremity of the clavicle.

## 2. Materials and methods

Biomechanical testing was performed on 43 human cadavers of both sexes (31 men, 12 women) who had died from somatic pathology. It was performed in three stages. All manipulations of cadavers were carried out in accordance with permission from the Ethics Committee of the Amur State Medical Academy.

In the first stage, the change in the relationship between the articular surfaces of the clavicle and the acromial process of the blade at the sequential intersection of the elements of musculo-capsular ligament was studied to determine the significance of the elements of the ligamentous apparatus in stabilizing the acromioclavicular joint.

The second stage involved the evaluation of the biomechanical strength parameters for each of the ligaments of the acromioclavicular joint.

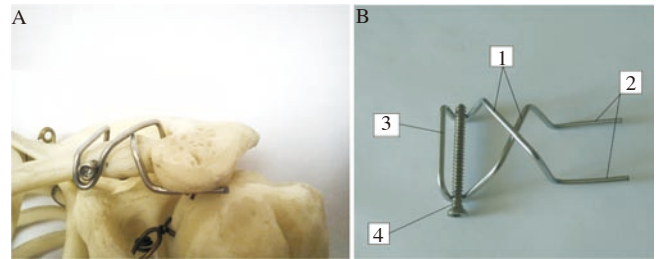
The third stage entailed a study of the stability of the acromioclavicular joint in the condition of osteosynthesis by the proposed device.

The clinical study was performed in accordance with the Declaration of Helsinki (1964), as well as with permission from the Ethics Committee of the Amur State Medical Academy and included an analysis of the results of the treatment of 154 patients with closed injuries to the acromioclavicular joint, who were hospitalized at Amur Regional Hospital (Blagoveshchensk) during the period between 2000 and 2013. All patients were divided into a study group (34 patients) and a clinical comparison group (120 patients).

Treatment was carried out with the informed agreement of the patients in a drawn-up protocol for each person ( $n = 154$ ).

The absence of significant differences between patients by sex, age and circumstances of injury in the test groups indicated that they were uniformly formed.

The main group (the prospective study) included patients operated by our methodology with the use of a modeled 1.8 mm Kirschner wire and 3.5 mm screws (Russian Federation Priority Reference No. 201110773) (Figures 1A and 1B).



**Figure 1.** General view of the device (A) and device after fixation on the layout (B).

1: Body consisting of crossing ends of Kirschner wire; 2: Two bayonet shaped ends; 3: Distal part presented by semicircle with two loops; 4: Cortical screw with 3.5 mm diameter, lead through 2 loops of devices and clavicle.

Kirschner wire (DEOST, Pushchino, Russian Federation), thickness 1.8 mm, length 370 mm. The wire is made of steel 17X-18-H9 (steel corrosion-resistant vulgaris). Steel composition (%): Cr (17-19); Ni (8-10); Si (up to 0.8); Ti (0.5); Cu (0.3); Mn (up to 0.2); C (0.13-0.21); S (up to 0.02); P (up to 0.035).

Cortical screw (DEOST, Pushchino, Russian Federation) head diameter 6 mm, thread diameter 3.5 mm, hex size 2.5 mm, the length varies (from 28 to 38 mm).

The screw is made of titanium alloy BT-6 (wrought titanium alloy). Alloy composition (%): Ti (86.45-90.9); Al (5.3-6.8); V (3.5-5.3); Fe (up to 0.6); C (0.1); Si (up to 0.1); N (up to 0.05); Zr (up to 0.3); O (up to 0.2); H (up to 0.015); impurities (up to 0.3).

The clinical comparison group (retrospective study) consisted of patients who received treatment in the form of different types of submersible constructions: Lee hook ( $n = 76$ ), Kirschner wire ( $n = 25$ ), hamate plate ( $n = 19$ ).

The conventional preoperative preparation was followed. The operation was performed at 2-3 days of receipt. As the anesthetic technique, endotracheal anesthetic was used. Operational line access of 4 cm in length was performed directly above the acromioclavicular joint. Damaged meniscus was removed. Usually, the construction was produced during the operation, based on the individual patient's anatomy, for which a Kirschner wire was bent with the help of pliers. After installing the construction and the removal of the dislocation, in the clavicle using a drill of diameter 2.8 mm was formed a channel in the sagittal plane, in the front-to-back direction to enable the introduction of a 3.5 mm screw. Carving was cut in the channel. After the introduction of the screw and control for hemostasis, the wound was sutured in layers. In the early postoperative period, debridement was performed with antiseptic solutions, and the sutures were removed 11-12 days post-surgery.

The fixation of the shoulder was carried out using a soft bandage.

Then the patient was discharged to outpatient treatment with a recommendation to limit physical activity within 1 month after surgery. In this period, physiotherapy exercises were performed to develop motion in the shoulder joint. After this time, the patient was discharged to work. Removal of construction was carried out 4 months after the primary surgery.

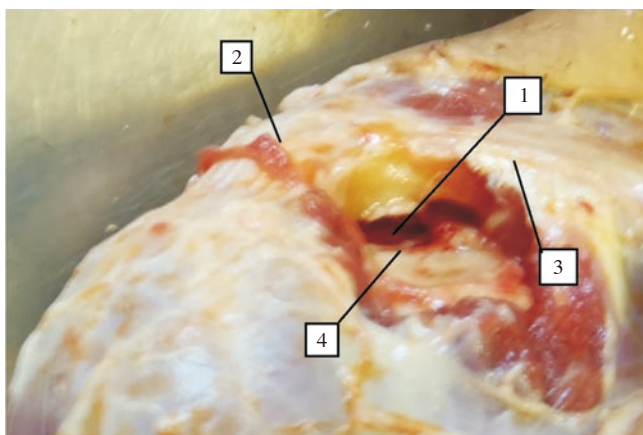
The result of the treatment was monitored in dynamics and measured in points. The immediate results were assessed using the scale of Constant and Murley (1987)[24] 4 months post-surgery (prior to removal of the construction).

A statistical analysis of the results was performed via standard methods of mathematical statistics using the software packages Excel and Statistica v.8.0. To assess the sample, the average (M) and the error of the mean (m) were calculated, and the significance of the differences between the mean values were assessed using a parametric student's *t*-test. Differences were considered significant at  $P < 0.05$ .

### 3. Results

Over the sequential intersection of the musculo-capsular ligament apparatus of the acromioclavicular joint (Stage I of the biomechanical study), the following data were obtained: over the clipping from the clavicle M. deltoideus and M. trapezius, discongruence in the acromioclavicular joint did not occur, however, it appeared at a bias instability of the clavicle anteriorly and posteriorly. Additional crossing of the acromioclavicular ligament led to the expansion of the joint gap to  $(0.73 \pm 0.02)$  cm, with the displacement of the clavicle appearing up to  $(1.01 \pm 0.02)$  cm. Subsequent crossing of the clavicular-coracoid ligament led to the increased displacement of the clavicle up to  $(1.57 \pm 0.03)$  cm and posteriorly to  $(2.12 \pm 0.04)$  cm.

The isolated intersection of the clavicular-coracoid ligament (Figure 2) caused a downward shift in the coracoid process of the blade, while irregularities in the relationships between the acromioclavicular joint were not mentioned.

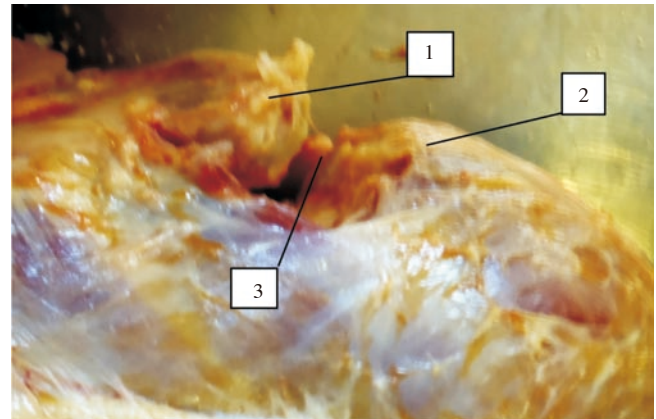


**Figure 2.** Isolated crossing of clavicular-coracoid ligament.

1: Rough clavicular-coracoid ligament; 2: Acromioclavicular joint; 3: The clavicle; 4: Coracoid process of the blade.

At the same time, isolated intersection of the acromioclavicular ligament and joint capsule (Figure 3) led to the expansion of the joint gap to  $(0.69 \pm 0.03)$  cm, with the occurrence of a clavicle upward shift at  $(0.97 \pm 0.07)$  cm.

Investigation of the strength characteristics of the acromioclavicular ligament (II stage) was carried out using the original biomechanical stand.

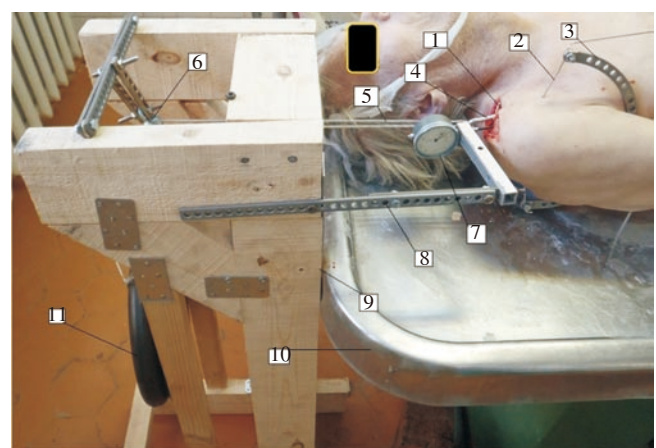


**Figure 3.** Isolated intersection of acromioclavicular ligament and joint capsule.

1: Acromial extremity of the clavicle; 2: Acromial process of the blade joint capsule; 3: Point of intersection of the joint capsule and the acromioclavicular ligament.

We found that the amount of force that led to the rupture of the ligament was  $[(893.00 \pm 1.45) (H)]$ , with the maximum amount of displacement of the acromial extremity of the clavicle before the rupture being  $(4.00 \pm 0.18)$  mm.

During the III experimental phase, studies have found that the critical strain of the proposed construction occurs with the  $[(116.00 \pm 1.15) (H)]$  load, with the maximum amount of displacement of the acromial extremity of the clavicle before the rupture being  $[(4.50 \pm 0.02) (mm)]$  (Figure 4).



**Figure 4.** Study of the hardness level of the rupture of modeled wire and screws with full crossing ligaments of the acromioclavicular joint.

1: Simulated wire and screw; 2: Kirschner wire; 3: A semicircle of Elizarov unit 180 mm in diameter; 4: Carbine; 5: Wire rope with diameter of 2.5 mm; 6: Roller; 7: Indicator of linear measurements; 8: A prefix to the indicator of linear measurements; 9: Bed; 10: Section table; 11: Load.

While comparing the results of the treatment in a group of clinical

**Table 1**

Comparison of anatomical and functional results of treatment using the scale of Constant and Murley (1987).

Index (maximum balls)	Main group				Clinical comparison group			
	Modeled wire and 3.5 mm cortical screw (n = 34)		Lee hook (n = 76)		Percutaneous fixation by Kirschner wires (n = 25)		Hamate plate (n = 19)	
	Before surgery	4 month after surgery	Before surgery	4 month after surgery	Before surgery	4 month after surgery	Before surgery	4 month after surgery
Pain (15)	1.03	14.90	1.25	14.50	1.20	14.80	1.05	14.70
Daily activities (20)	5.47	19.80	4.95	19.00	4.32	19.20	4.32	19.70
Range of motion in the shoulder joint (40)	10.80	39.50	10.30	36.60	8.16	37.60	8.00	38.50
Power load (25)	0.00	21.90	0.03	19.60	0.08	19.50	0.00	20.70
Overall rating (100)	17.30	95.90	16.53	89.70	13.76	91.10	13.37	93.60

**Table 2**

Comparison of the period of treatment in the study group and the comparison group.

Index	Main group		Clinical comparison group	
	1 Modeled wire and 3.5 mm cortical screw (n = 34)	2 Lee hook (n = 76)	3 Percutaneous fixation by Kirschner wires (n = 25)	4 Hamate plate (n = 19)
Overall hospital stay	13.00 ± 0.71	15.10 ± 0.46 ( $P_{1,2} < 0.05$ )	11.70 ± 0.84 ( $P_{1,3} > 0.05$ )	12.20 ± 0.97 ( $P_{1,4} > 0.05$ )
After surgery hospital stay	8.94 ± 0.48	11.10 ± 0.39 ( $P_{1,2} < 0.001$ )	8.56 ± 0.91 ( $P_{1,3} > 0.05$ )	8.32 ± 0.89 ( $P_{1,4} > 0.05$ )
Period of temporary disability	40.40 ± 0.71	55.20 ± 0.57 ( $P_{1,2} < 0.001$ )	51.70 ± 0.96 ( $P_{1,3} < 0.001$ )	42.10 ± 0.67 ( $P_{1,4} > 0.05$ )

comparisons and basic group using the scale of Constant and Murley (1987)[24], the following parameters were evaluated (Table 1). These data confirmed the effectiveness of the developed technique. So, at the end of treatment (4 months after the initial surgery), the average was 95.90 points, which corresponded to an excellent result. In the comparison group, the index was: over osteosynthesis with Lee hook-89.70 points, intradermal fixation-91.10 points, osteosynthesis with hamate plate-93.60 points.

To fix the hands of the main group of patients after the operation, a Dezo soft bandage was used. In the clinical comparison group, for external fixation was used a Smirnov-Weinstein cast-103 (85.9%) cases, a Dezo cast-15 (12.5%) and a Turner cast-2 cases (1.6%) (Table 1).

Comparisons of the treatment times for the main group and the clinical group are shown in Table 2. The overall hospital stay for the study group was (13.00 ± 0.71), while the postoperative hospital stay was (8.94 ± 0.48). The same indexes were received for the comparison group: osteosynthesis with Lee hook (15.10 ± 0.46) and (11.10 ± 0.39) ( $P < 0.001$ ), intradermal fixation (11.70 ± 0.84) and (8.56 ± 0.91) ( $P > 0.05$ ), and osteosynthesis with hamate plate (12.20 ± 0.97) and (8.32 ± 0.89) ( $P > 0.05$ ) (Table 2).

The duration of temporary disability among the study group (40.40 ± 0.71) was 15, 11 and 2 days less than when using the Lee hook (55.20 ± 0.57,  $P_1 < 0.001$ ), fixing with the wires (51.70 ± 0.96,  $P < 0.001$ ) and using the hamate plate (42.10 ± 0.67,  $P > 0.05$ ), which indicated the effectiveness of the proposed method.

The greatest number of complications in patients in the clinical comparison group was observed after the application of the Lee hook [26 (33.9%)]. Percutaneous fixation by Kirschner wires was accompanied by complications in 12 (48%) cases, osteosynthesis by hamate plate in 4 (21%) cases.

The complication rate in the study group was 3 cases (8.7%). In one case, it was a superficial inflammation in the surgical wound, broken by the introduction of antibiotics that, in the end, did not affect the duration of treatment.

Deforming arthrosis of the acromioclavicular joint in the same occurred in one patient.

Even though in one case there was a fracture of construction, in our opinion, that was incidental with nonobservance by the patient, who began to perform full physical stress on the shoulder joint in the early postoperative period.

#### 4. Discussion

In terms of biomechanical experiment, it was revealed that the main role in stabilizing the acromioclavicular joint belongs to the acromioclavicular ligament and joint capsule, in which an over isolated intersection is marked by the complete dissociation (dislocation) of the articular surfaces. The displacement of the clavicle is up [(1.01 ± 0.02) cm], and the expansion of joint gap [(0.73 ± 0.02) cm]. Rupture of the acromioclavicular ligaments and joint capsule occurs at a force [(893.00 ± 1.45) (H)].

Therefore, the most rational option for surgical treatment is the method of the temporary splinting of the acromioclavicular joint by submerged metallic construction that creates stability compared with this indicator.

An original construction for the osteosynthesis of the acromioclavicular joint (priority reference No. 201110773), with the following qualities: simplicity of manufacture, availability, personality (made in the operating room, depending on the patient's anatomy) is proposed.

Through its use, unlike other metal constructions, used less invasive access 4 cm length, micromotion in the acromioclavicular joint persists and there is no interponing implant between articular surfaces.

In the context of biomechanical experiment, the proposed construction demonstrated the ability to withstand the biasing force of [(116.00 ± 1.15) (H)], which corresponds to the strength parameters of the acromioclavicular-clavicular ligament.

These estimates are the results of treatment of 34 patients in the

main group using the scale of Constant and Murley (1987)[24] to confirm the effectiveness of the developed method. At the end of treatment (4 months after surgery), the average score was 95.90 balls, that corresponds to an excellent result, and is no worse than those of the comparison group, which carried out osteosynthesis with a hook plate (93.60 points), fixing with Lee hook (89.70 points), and percutaneous fixation with Kirschner wires (91.10 points).

The application of the proposed method of treatment leads to an increase of the quantity of complications by 12.3% compared with the hamate plate ( $P > 0.05$ ), 25.2%-Lee hook fixation ( $P < 0.01$ ) and 39.3%-Kirschner wires ( $P < 0.001$ ).

The overall hospital stay in the study group was ( $13.00 \pm 0.71$ ) days, that corresponds to indexes over the osteosynthesis with hamate plate ( $12.20 \pm 0.97$ ) days, Lee hook ( $15.10 \pm 0.46$ ) days, and percutaneous fixation with wires ( $11.70 \pm 0.84$ ) days.

Thus, the proposed method constitutes an available, less invasive, effective technology that can be recommended for wider use for the surgical treatment of patients with rupture to the AEC and dislocation of the acromial extremity of the clavicle.

### Conflict of interest statement

We declare that we have no conflict of interest.

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### References

- [1] Macdonald PB, Lapointe P. Acromioclavicular and sternoclavicular joint injuries. *Orthop Clin North Am* 2008; **39**: 535-45.
- [2] Ponomarenko NS, Tishkov NV, Alekperov AA. Experience of surgical treatment of dislocations of the acromial extremity of the clavicle. Abstracts of the IX Congress Orthopaedic Traumatologist of the Russia. Saratov, Russia. 2010, p. 235-6.
- [3] Donnelly TD, Macfarlane RJ, Nagy MT, Ralte P, Waseem M. Fractures of the clavicle: an overview. *Open Orthop J* 2013; **7**: 329-33.
- [4] Li H, Wang C, Wang J, Wu K, Hang D. Restoration of horizontal stability in complete acromioclavicular joint separations: surgical technique and preliminary results. *Eur J Med Res* 2013; **18**: 42.
- [5] Bateman JE. Athletic injuries about the shoulder in throwing and body-contacts sports. *Clin Orthop* 1962; **23**: 75-83.
- [6] Willimon SC, Gaskill TR, Millett PJ. Acromioclavicular joint injuries: anatomy, diagnosis, and treatment. *Phys Sportsmed* 2011; **39**(1): 116-22.
- [7] Babhulkar A, Pawaskar A. Acromioclavicular joint dislocations. *Curr Rev Musculoskelet Med* 2014; **7**(1): 33-9.
- [8] Mazzocca AD, Arciero RA, Bicos J. Evaluation and treatment of acromioclavicular joint injuries. *Am J Sports Med* 2007; **35**(2): 316-29.
- [9] Kayupov SK. Surgical treatment of dislocations of the acromial extremity with the creation of the U-shaped submersible acromioclavicular ligament [dissertation]. Astana: Astana Medical University; 1998, p. 16.
- [10] Sokolovsky AM. Surgical treatment of dislocations of the acromial end of a clavicle. In: *Topical issues of biology and medicine*. Minsk: Minsk State Medical Institute; 1996, p. 323-4.
- [11] Simovitch R, Sanders B, Ozbaydar M, Lavery K, Warner JJ. Acromioclavicular joint injuries: diagnosis and management. *J Am Acad Orthop Surg* 2009; **17**(4): 207-19.
- [12] Modi CS, Beazley J, Zywiell MG, Lawrence TM, Veillette CJ. Controversies relating to the management of acromioclavicular joint dislocations. *Bone Joint J* 2013; **95-B**(12): 1595-602.
- [13] Horst K, Dienstknecht T, Pishnamaz M, Sellei RM, Kobbe P, Pape HC. Operative treatment of acute acromioclavicular joint injuries graded Rockwood III and IV: risks and benefits in tight rope technique vs. k-wire fixation. *Patient Saf Surg* 2013; **7**: 18.
- [14] Kraus N, Haas NP, Scheibel M, Gerhardt C. Arthroscopically assisted stabilization of acute high-grade acromioclavicular joint separations in a coracoclavicular Double-TightRope technique: V-shaped versus parallel drill hole orientation. *Arch Orthop Trauma Surg* 2013; **133**(10): 1431-40.
- [15] Virtanen KJ, Remes VM, Tulikoura IT, Pajarinen JT, Savolainen VT, Björkenheim JM, et al. Surgical treatment of Rockwood grade-V acromioclavicular joint dislocations: 50 patients followed for 15-22 years. *Acta Orthop* 2013; **84**(2): 191-5.
- [16] Zhu YY, Cui HY, Jiang PQ, Wang JL. [Complications of treatment of acromioclavicular joint dislocation and unstable distal clavicular fracture with clavicular hook plate]. *Zhongguo Gu Shang* 2013; **26**(11): 927-31. Chinese.
- [17] Struhl S. Double endobutton technique for repair of complete acromioclavicular joint dislocations. *Techniques in Shoulder Elbow Surgery* 2007; **8**(4): 175-9.
- [18] Horst K, Dienstknecht T, Andruszkow H, Gradl G, Kobbe P, Pape HC. Radiographic changes in the operative treatment of acute acromioclavicular joint dislocation-tight rope technique vs. K-wire fixation. *Pol J Radiol* 2013; **78**(4): 15-20.
- [19] Yin JH. [Triple-Endobutton plates for the treatment of Rockwood type III to V acromioclavicular joint dislocation]. *Zhongguo Gu Shang* 2014; **27**(1): 61-3. Chinese.
- [20] Rockwood CA, Green DP, Bucholz RW, Heckman JD. *Rockwood and Green's fractures in adults*. Philadelphia: Lippincott-Raven Publishers; 1996, p. 223.
- [21] Petersen W, Wellmann M, Rosslenbroich S, Zantop T. [Minimally invasive acromioclavicular joint reconstruction (MINAR)]. *Oper Orthop Traumatol* 2010; **22**(1): 52-61. German.
- [22] Lin HY, Wong PK, Ho WP, Chuang TY, Liao YS, Wong CC. Clavicular hook plate may induce subacromial shoulder impingement and rotator cuff lesion-dynamic sonographic evaluation. *J Orthop Surg Res* 2014; **9**: 6.
- [23] Andreani L, Bonicoli E, Parchi P, Piolanti N, Michele L. Acromioclavicular repair using two different techniques. *Eur J Orthop Surg Traumatol* 2014; **24**(2): 237-42.
- [24] Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. *Clin Orthop Relat Res* 1987; (214): 160-4.