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Medial cortical positive support

A key factor for the postoperative stability of proximal humerus fractures

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Abstract

Treatments for proximal humerus fractures (PHFs) often fail to achieve anatomical reduction. The purpose of this study was to evaluate the role of positive medial cortical support (PMCS) in the nonanatomical reduction of PHFs.

A retrospective analysis was performed of 78 patients with PHFs who underwent surgery from August 2014 to September 2017 and whose treatments did not achieve anatomical reduction. Based on the results of standard AP radiographs of the shoulders 3, 6, and 12 months after surgery, the patients were divided into PMCS or negative medial cortical support (NMCS) groups. The postsurgical change in head-shaft angle (HSA) between the 2 groups was compared. Shoulder joint function and visual analog scale (VAS) scores of the 2 groups were also compared at the same time.

Of the 78 patients analyzed, 37 were in the PMCS group and, 41 in the NMCS group. There was no statistically significant difference in any of the characteristics of the 2 groups ($P > .05$), or in postsurgical HSA. However, the HSA of the 2 groups had become significantly different ($P < .05$) 3, 6, and 12 months following surgery. The changes in HSA of the 2 groups were different at various time points ($P < .05$). One year after surgery, the shoulder function score of the PMCS group was significantly better than that of the NMCS group, as was the VAS score (both $P < .05$).

Patients whose surgery for PHF does not achieve anatomical reduction during surgery can undergo PMCS to achieve improved results, postoperatively. NMCS should be avoided as far as possible.

Abbreviations: AP =anteroposterior, HSA = head-shaft angle, NMCS = negative medial cortical support, PHFs = proximal humerus fractures, PMCS = positive medial cortical support, PHILOS = proximal humeral internal locking system, VAS = visual analog scale.

Keywords: positive medial cortical support, proximal humerus fracture, malunion

1. Introduction

Proximal humeral fractures (PHFs) account for approximately 5% of all fractures,[1] the incidence of which increases with age.[2] It is usual in such cases to use a proximal humeral internal locking system (PHILOS).[3–10] Although PHILOS has a mechanical advantage[5] which leads to great improvements in postoperative shoulder function,[11–13] there are also many complications with the technique, especially in elderly patients with osteoporosis, the principal complication being varus malunion, avascular necrosis, or screw penetration into the surface of the humeral head, usually the reason for re-hospitalization for secondary surgery.[14,15] The usual cause of varus malunion healing is the lack of medial support.[16,17] In PHILOS, the medial support screw is a factor preventing varus malunion, especially in patients with comminuted fracture of the medial cortex or poor reduction of the medial side. Anatomical reduction of the medial cortex is an additional factor that can prevent varus malunion.[18,19] While the medial cortex may not be fully coincident for various reasons during surgery, the medial cortex of the fractured fragments of the humeral head displaced medially to the medial cortex of the humeral shaft in the anteroposterior (AP) view is defined as positive medial cortical support (PMCS). This causes the humeral head to impact the humeral shaft when inverted, providing secondary stability.

No studies have so far been published that evaluate the effect of PMCS in PHFs. Thus, the purpose of this study was to determine the role of PMCS when the medial cortex of a proximal fracture of the humerus is not able to achieve anatomical reduction.

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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2. Methods

2.1. Study design

The study was a retrospective case series. Patients diagnosed with PHF from August 2014 to September 2017 who had undergone surgery at the Department of Orthopedics, Beilun People's

Hospital were evaluated. This study was approved by the Ethics Committee of Beilun People's Hospital (reference number 201802211, February 21, 2018) and was conducted in strict accordance with the Declaration of Helsinki. All participants provided written informed consent.

2.2. Patient selection

A total of 115 PHF patients underwent surgery. According to the Neer classification,[20] 39 patients had 2 partial fractures, 57 had 3 partial fractures and 19 had 4 partial fractures. Of these, 25 patients were excluded: 2 due to having an open fracture, 7 with nerve damage, and 16 that were lost to follow-up. Therefore, 90 patients were selected for this study. However, 12 patients had an anatomical reset, and so were excluded. Finally, 78 patients were selected for this study. The inclusion criteria for the patients were:

1. Acute closed fracture treated by PHILOS within 2 weeks of injury;
2. Age ≥18 years;
3. No neurological or vascular injury;
4. No history of upper limb fracture.

Exclusion criteria were:

1. No medial cortical injury in the PHF;
2. More than 2 weeks between fracture and surgery;
3. Pathological fracture;
4. Open fracture;
5. Combined shoulder dislocation, scapular fracture, or neurovascular injury.

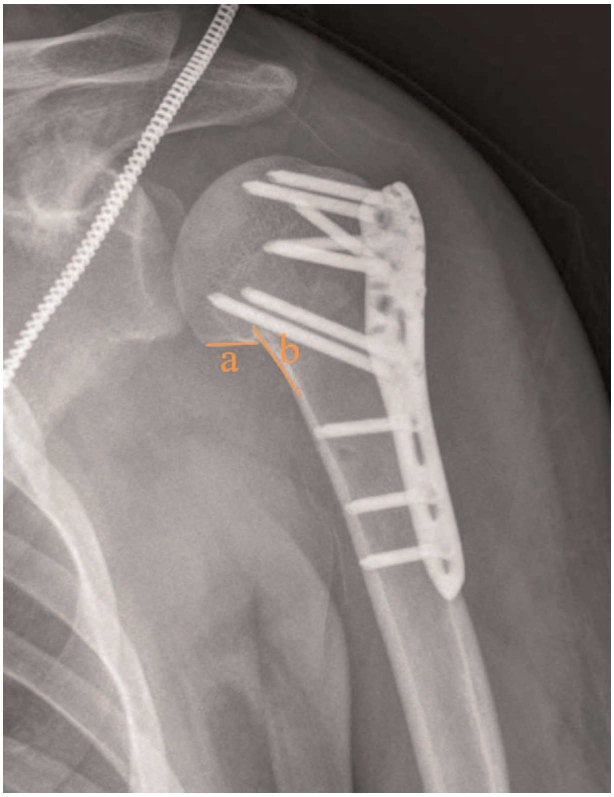

Figure 1. Proximal humeral head fragment (A) which had been displaced medially to the upper medial edge of the distal humeral fracture (B).

2.3. Surgical technique and postoperative rehabilitation

All shoulder operations were performed by 2 senior surgeons (DB, HMY), with patients arranged in a beach chair position. Standard surgery was performed through the deltoid approach. An incision was created under the acromion then the PHF was exposed by blunt dissection of the deltoid bundle along the deltoid muscle, taking care to minimize surgical trauma to the adjacent soft tissue. The damaged soft tissue around the end of the fracture was cleaned, and the fracture end reduced and temporarily fixed with Kirshner wires. PHILOS of an appropriate length was inserted into the fracture site and placed in an appropriate position. The humeral head and the distal end of the plate were fixed using a 3.5 mm diameter cortical nail and at least 5 locking screws placed in the proximal segment. For patients with bone defects, artificial or autologous bone was used for bone grafting. The rotator cuff and joint capsule were repaired. An indwelling drainage tube was inserted and the incision closed layer-by-layer.

All patients underwent similar postoperative rehabilitation. All patients were provided with external shoulder joint support after surgery. Pendulum movement or internal and external rotation was performed 1 week after surgery. According to the type of fracture and postoperative fracture healing, active rehabilitation exercise was performed 4 to 6 weeks after surgery. Gradual stretching and resistance were performed to strengthen movement until the fracture had healed.

2.4. Patient assessment

The condition of the medial cortex after reduction of each PHF was evaluated. Based on the results of standard AP radiographs of the shoulder of the patient, PMCS was defined as a proximal humeral head fragment (a) that had been displaced medially to the upper medial edge of the distal humeral fracture (b) (Fig. 1). Negative medial cortical support (NMCS) was defined as having humeral head fragments (a) being laterally displaced to the lateral edge of the shaft fragment (b), thereby losing medial cortical support of the humeral shaft (Fig. 2).

Shoulder radiographs in the standard AP position were conducted immediately and 3, 6, and 12 months after surgery. The head-shaft angle (HSA) was measured in each patient, as described by Agudelo et al.[21] The angle between a line perpendicular to 1 connecting the superior and inferior borders of the humeral head joint surface (a) running through the center of the humeral head (b) and 1 parallel to the long axis of the humeral shaft (c) was defined as HSA ($\alpha+\beta$) (Fig. 3). The HSA of each shoulder joint was independently measured from AP radiographs by 2 clinicians (SXC, DB), and the order in which they were measured by the 2 physicians randomized. The final HSA value was the mean of the 2 measurements. Greiner et al,[22] defined postoperative has <120° as the standard for varus malunion of PHFs.

A functional assessment of the shoulder joint was performed 1 year postoperatively, using the Constant-Murley score, the American Shoulder and Elbow Surgeon Shoulder Assessment Form and the University of California in Los Angeles score. We used a visual analog scale (VAS) score to assess postoperative shoulder pain, 0 indicating no pain at all and 10 indicating the most severe pain in history.

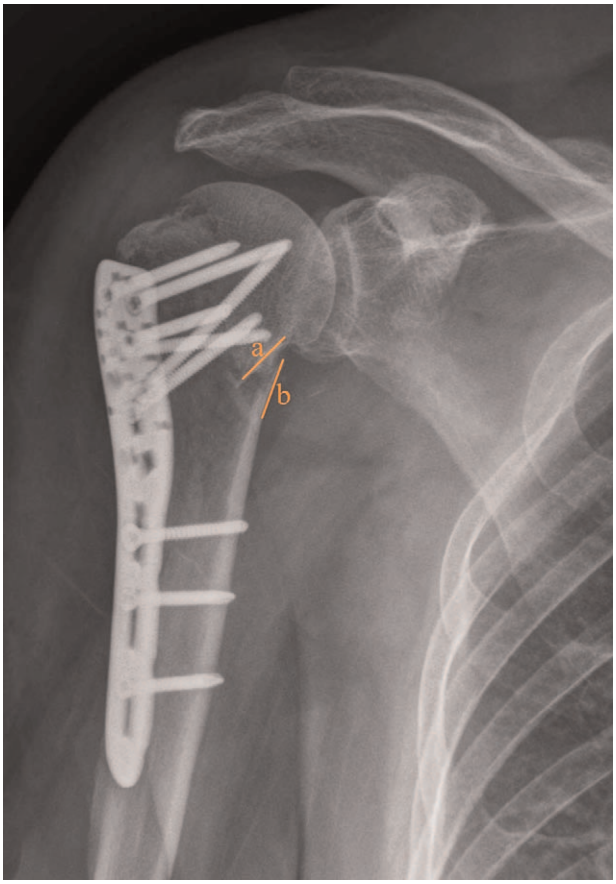

Figure 2. Negative medial cortical support (NMCS) occurs when humeral head fragments (A) are laterally displaced to the lateral edge of the shaft fragment (B).

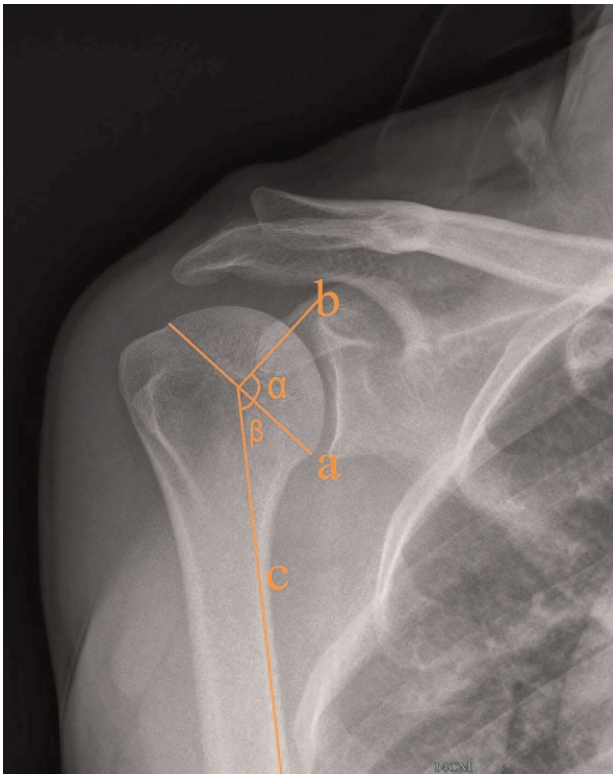

Figure 3. Head-shaft angle (HSA) (α+β) is the angle between a line perpendicular to 1 connecting the superior and inferior borders of the humeral head joint surface (A) running through the center of the humeral head (B) and 1 parallel to the long axis of the humeral shaft (C).

The trend in decline of HSA between the 2 groups was considered the main outcome variable, and shoulder joint function and VAS scores of patients between the 2 groups as the secondary outcome variable.

2.5. Statistical analysis

Statistical analysis was performed using SPSS v22.0 software (IBM Corporation, Armonk, NY) with all count data recorded as means and SD. All count data were compared using an independent-samples t test and all measurements compared using a Chi-Squared test. $P<.05$ was considered statistically significant.

3. Results

Table 1 summarizes the descriptive characteristics of the study population. In all 78 patients with PHFs, 37 had varying degrees of PMCS and 41 patients had varying degrees of NMCS, as shown in postoperative X-rays. There was no statistical difference in the characteristics of patients with PHFs in the PMCS group compared with those in the NMCS group ($P>.05$).

As can be observed in Table 2, the HSA in both PMCS and NMCS groups decreased continuously over time. No significant difference was observed in the HSA in the PMCS group compared with that in the NMCS group after surgery ($P<.05$). Three months after surgery, the HSA of the PMCS group had decreased 3.92°±1.50°, compared with as much as 8.22°±3.09° in the NMCS group, a statistically significant difference between the 2 groups ($P<.05$). There were also significant differences in HSA

Table 1

Different characteristics between PMCS and NMCS.

	PMCS (n=37)	NMCS (n=41)	P
Age	48.27±7.21	46.72±5.90	.461
BMI	23.87±3.81	22.58±3.47	.637
Sex			
Male	17	24	
Female	20	17	.364
Side			
Left	14	20	
Right	23	21	.368
Diabetes			
Yes	4	8	.356
No	33	33	
Hypertension			
Yes	7	6	
No	30	35	.763
Smoking			
Yes	10	17	
No	27	24	.235

PMCS = positive medial cortical support, NMCS = negative medial cortical support, BMI = body mass index.

Table 2

Postoperative follow up data.

	PMCS (n=37)	NMCS (n=41)	*P*
HSA			
postsurgical	136.32±4.68	136.29±5.32	.910
3 months	132.41±5.08	127.98±6.45	.035
6 months	131.03±5.27	125.88±6.57	.000
1 year	129.92±5.47	125.04±6.54	.001
Change of HSA			
3 months	3.92±1.50	8.22±3.09	.000
6 months	5.30±2.07	10.32±3.25	.000
1 year	6.41±2.49	11.15±3.31	.000
CSS	76.43±5.97	73.21±5.74	.018
ASES	88.62±4.60	85.78±6.32	.024
UCLA	31.82±2.21	29.73±2.98	.001
VAS	1.14±1.00	1.76±1.26	.018
Varus malunion (HSA <120°)	3	11	.081

PMCS = positive medial cortical support, NMCS = negative medial cortical support, HSA = head-shaft angle, CSS = Constant Shoulder Score, ASES = American Shoulder and Elbow Surgeon, UCLA = University of California at Los Angeles, VAS = visual analog scale.

between the 2 groups at 6 months and 1 year postoperatively ($P<.05$). Similarly, as can be seen from Table 2, shoulder function and VAS scores of the PMCS group were better than those of the NMCS group 1 year after surgery, differences that were statistically significant ($P<.05$).

As shown in Table 2, 3 patients had HSA <120° in the PMCS group 1 year after surgery, compared with 11 in the NMCS group, although the difference between the 2 groups was not significant ($P>.05$).

4. Discussion

In this retrospective study, we found that the HSA in the PMCS and NMCS groups continued to decline over time after surgery, and the trend in decline of HSA in the NMCS group was significantly greater than that in the PMCS group. Shoulder joint function and VAS scores of the patients were also superior in the NMCS group 1 year after surgery. To the best of our knowledge, this is the first study that has demonstrated that PMCS is better than NMCS in PHF patients after surgery.

Patients with a PHF who underwent surgery with PHILOS face many complications after surgery, in particular suffering medial cortical destruction and varus of the humeral head, a problem that every orthopedic surgeon must face. Medial support of the humeral head is key to restoring HSA.[23–25] There are many ways to achieve medial cortical support of the humeral head. Gardner et al[23] first described the effects of medial support and PHILOS fixation to prevent varus in patients' humeral heads. Their results demonstrated that mechanical support in the medial region of the humeral head is critical for maintaining reduction in patients with PHFs treated with PHILOS. Pan yang et al[25] demonstrated in a biomechanical study that cortical support in anatomical reduction of the medial cortex can prevent humeral head varus. Similarly, medial support from the screws in PHILOS can also increase support of the humeral head. Therefore, in order to prevent malunion caused by humeral head varus, in the present study, all patients were fixed with PHILOS and were supported with medial support screws to prevent varus of the humeral head.

Anatomical reduction of the medial cortex can also effectively prevent varus of the humeral head. A study by Pan Yang et al[25] indicated that medial cortical contact can provide greater medial support to prevent varus. However, at present, anatomical reduction of the medial cortex is not universal. A greater number of patients exhibit different degrees of malposition in standard postoperative AP X-rays. In the present study, only 13% of patients achieved anatomical reset in imaging. There may be even fewer patients who actually achieve anatomical reduction. There are 2 possibilities regarding the so-called "anatomical reset" from the surgical perspective: some will have exact anatomical cortex-to-cortex positioning and others may have slight positive or negative malposition, although is difficult to determine which for each patient due to limited image resolution.[26]

It is precisely because true anatomical reduction is difficult to achieve that many patients with PHF have PMCS or NMCS after surgery. In the present study, there was a significantly smaller changer in HSA in patients in the PMCS group during follow-up compared with those in the NMCS group, especially within the first 3 months. We found that the medial cortex of the humeral head and that of the shaft of the humerus collided in the PMCS group, preventing postoperative varus of the humeral head, the medial cortex of the shaft of the humerus exerting an opposing force on the humerus head. The reverse force against varus eventually reached dynamic equilibrium. In the NMCS group, the humeral head lacked obstruction from the humeral shaft when undergoing varus, so the change in HSA in the NMCA group was significantly larger than that in the PMCS group. Six and 12 months after surgery, the change in HSA was significantly reduced, possibly related to fracture healing. A study by Zhang et al[24] demonstrated that the mean healing time of patients with PHF was 4.4 months, providing a good explanation for the small change in HSA 6 and 12 months after surgery.

We evaluated shoulder function 1 year after surgery. Constant Shoulder Score, American Shoulder and Elbow Surgeon, and University of California at Los Angeles scores indicated that shoulder function in the PMCS group was better than that of the NMCS group, results that were statistically different. This suggests that humeral head varus affects shoulder joint function. VAS results of patients 1 year after surgery demonstrated that the PMCS group was functionally better than the NMCS group, possibly related to the malunion caused by humeral head varus. As displayed in Table 2, there are 14 patients with HSA <120° 1 year after surgery, including 11 in the NMCS group and 3 in the PMCS group. Although there was no significant difference between the 2 groups, it is likely that NMCS is more prone to suffering humeral head varus, leading to malformation.

This research, however, has some limitations. Firstly, the sample size is small. A larger sample size would be required to confirm the results. Secondly, imaging and the respective measurements were subjective and there may have been a degree of bias. Additionally, this is a retrospective study of fractures of different types in patients of various ages, and so a larger, longer-term, multicenter, prospective study would support the conclusions. In the future, more detailed research on the biomechanics and finite element analysis based on these fractures would assist in verifying the research results.

5. Conclusions

In conclusion, this study found that in patients with PHF, postoperative PMCS was more able to prevent malunion caused by varus of the humerus head, providing better shoulder function after surgery. Therefore, when anatomical reduction in PHF surgery cannot be achieved, the orthopedic surgeon should avoid NMCS.

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Formal analysis: Xuchao Shi.
Visualization: Mingyuan Han, Bo Dai.
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Writing – review & editing: Mingyuan Han, Bo Dai.

References

[1] Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury 2006;37:691–7.
[2] Vachtsevanos L, Hayden L, Desai AS, et al. Management of proximal humerus fractures in adults. World J Orthop 2014;5:685–93.
[3] Launonen AP, Lepola V, Saranko A, et al. Epidemiology of proximal humerus fractures. Arch Osteoporos 2015;10:209.
[4] Bufquin T, Hersan A, Hubert L, et al. Reverse shoulder arthroplasty for the treatment of three- and four-part fractures of the proximal humerus in the elderly: a prospective review of 43 cases with a short-term follow-up. J Bone Joint Surg Br 2007;89:516–20.
[5] Hatzidakis AM, Shevlin MJ, Fenton DL, et al. Angular-stable locked intramedullary nailing of two-part surgical neck fractures of the proximal part of the humerus. A multicenter retrospective observational study. J Bone Joint Surg Am 2011;93:2172–9.
[6] Koukakis A, Apostolou CD, Taneja T, et al. Fixation of proximal humerus fractures using the PHILOS plate: early experience. Clin Orthop Relat Res 2006;442:115–20.
[7] Nolan BM, Kippe MA, Wiater JM, et al. Surgical treatment of displaced proximal humerus fractures with a short intramedullary nail. J Shoulder Elbow Surg 2011;20:1241–7.
[8] Olerud P, Ahrengart L, Ponzer S, et al. Hemiarthroplasty versus nonoperative treatment of displaced 4-part proximal humeral fractures in elderly patients: a randomized controlled trial. J Shoulder Elbow Surg 2011;20:1025–33.
[9] Papadopoulos P, Karataglis D, Stavridis SI, et al. Mid-term results of internal fixation of proximal humeral fractures with the Philos plate. Injury 2009;40:1292–6.
[10] Solberg BD, Moon CN, Franco DP, et al. Surgical treatment of three and four-part proximal humeral fractures. J Bone Joint Surg Am 2009;91:1689–97.
[11] Chudik SC, Weinhold P, Dahners LE. Fixed-angle plate fixation in simulated fractures of the proximal humerus: a biomechanical study of a new device. J Shoulder Elbow Surg 2003;12:578–88.
[12] Fankhauser F, Boldin C, Schippinger G, et al. A new locking plate for unstable fractures of the proximal humerus. Clin Orthop Relat Res 2005;176–81.
[13] Rouleau DM, Laflamme GY, Berry GK, et al. Proximal humerus fractures treated by percutaneous locking plate internal fixation. Orthop Traumatol Surg Res 2009;95:56–62.
[14] Sproul RC, Iyengar JJ, Devcic Z, et al. A systematic review of locking plate fixation of proximal humerus fractures. Injury 2011;42:408–13.
[15] Carbone S, Papalia M. The amount of impaction and loss of reduction in osteoporotic proximal humeral fractures after surgical fixation. Osteoporos Int 2016;27:627–33.
[16] Pak P, Eng K, Page RS. Fixed-angle locking proximal humerus plate: an evaluation of functional results and implant-related outcomes. ANZ J Surg 2013;83:878–82.
[17] Thanasas C, Kontakis G, Angoules A, et al. Treatment of proximal humerus fractures with locking plates: a systematic review. J Shoulder Elbow Surg 2009;18:837–44.
[18] Cofield RH. Comminuted fractures of the proximal humerus. Clin Orthop Relat Res 1988;49–57.
[19] Lescheid J, Zdero R, Shah S, et al. The biomechanics of locked plating for repairing proximal humerus fractures with or without medial cortical support. J Trauma 2010;69:1235–42.
[20] Neer CS. Displaced proximal humeral fractures. I. Classification and evaluation. J Bone Joint Surg Am 1970;52:1077–89.
[21] Agudelo J, Schürmann M, Stahel P, et al. Analysis of efficacy and failure in proximal humerus fractures treated with locking plates. J Orthop Trauma 2007;21:676–81.
[22] Greiner S, Kääb MJ, Haas NP, et al. Humeral head necrosis rate at mid-term follow-up after open reduction and angular stable plate fixation for proximal humeral fractures. Injury 2009;40:186–91.
[23] Gardner MJ, Weil Y, Barker JU, et al. The importance of medial support in locked plating of proximal humerus fractures. J Orthop Trauma 2007;21:185–91.
[24] Zhang L, Zheng J, Wang W, et al. The clinical benefit of medial support screws in locking plating of proximal humerus fractures: a prospective randomized study. Int Orthop 2011;35:1655–61.
[25] Yang P, Zhang Y, Liu J, et al. Biomechanical effect of medial cortical support and medial screw support on locking plate fixation in proximal humeral fractures with a medial gap: a finite element analysis. Acta Orthop Traumatol Turc 2015;49:203–9.
[26] Chang SM, Zhang YQ, Ma Z, et al. Fracture reduction with positive medial cortical support: a key element in stability reconstruction for the unstable pertrochanteric hip fractures. Arch Orthop Trauma Surg 2015;135:811–8.