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Original Article

Treatment of proximal humeral fractures using anatomical locking plate: correlation of functional and radiographic results☆

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ABSTRACT

Objective: To correlate the functional outcomes and radiographic indices of proximal humerus fractures treated using an anatomical locking plate for the proximal humerus.
Methods: Thirty-nine patients with fractures of the proximal humerus who had been treated using an anatomical locking plate were assessed after a mean follow-up of 27 months. These patients were assessed using the University of California Los Angeles (UCLA) score and their range of motion was evaluated using the method of the American Academy of Orthopedic Surgeons on the operated shoulder and comparative radiographs on both shoulders. The correlation between radiographic measurements and functional outcomes was established.
Results: We found that 64% of the results were good or excellent, according to the UCLA score, with the following means: elevation of 124°; lateral rotation of 44°; and medial rotation of thumb to T9. The type of fracture according to Neer's classification and the patient's age had significant correlations with the range of motion, such that the greater the number of parts in the fracture and the greater the patient's age were, the worse the results also were. Elevation and UCLA score were found to present associations with the anatomical neck-shaft angle in anteroposterior view; fractures fixed with varus deviations greater than 15° showed the worst results ($p < 0.001$).
Conclusion: The variation in the neck-shaft angle measurements in anteroposterior view showed a significant correlation with the range of motion; varus deviations greater than 15° were not well tolerated. This parameter may be one of the predictors of functional results from proximal humerus fractures treated using a locking plate.

☆ Study conducted at the Group of Shoulder and Elbow, Service of Orthopedic and Traumatology, Hospital do Servidor Público Estadual de São Paulo (SOT/HSPE), São Paulo, SP, Brazil.

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Tratamento das fraturas do úmero proximal com placa anatômica bloqueada: correlação dos resultados funcionais e radiográficos

Palavras-chave:
Fraturas do ombro/cirurgia
Fixação interna de fraturas
Avaliação de resultados

RESUMO

Objetivo: Correlacionar os resultados funcionais e os índices radiográficos das fraturas do úmero proximal tratadas com placa anatômica bloqueada para úmero proximal.
Métodos: Examinaram-se 39 pacientes com fraturas do úmero proximal tratados com placa anatômica bloqueada, com seguimento médio de 27 meses. Esses pacientes foram submetidos à análise do escore da Universidade da Califórnia de Los Angeles (UCLA) e à avaliação do arco de movimento pelo método da Academia Americana de Cirurgiões Ortopédicos no ombro operado e a exames radiográficos comparativos de ambos os ombros. Estabeleceu-se a correlação entre as medidas radiográficas e os resultados funcionais.
Resultados: Obtivemos 64% de bons e excelentes resultados conforme o escore da UCLA, com médias de 124° de elevação; 44° de rotação lateral; e polegar-T9 de rotação medial. O tipo de fratura, de acordo com a classificação de Neer, e a idade do paciente tiveram significativa correlação com o arco de movimentos; quanto maiores o número de partes das fraturas e a idade dos pacientes, piores os resultados. Encontrou-se associação entre a elevação e o escore da UCLA com o ângulo cervicodiafisário na incidência anteroposterior; as fraturas fixadas com desvios em varo maiores do que 15° apresentaram os piores resultados ($p < 0{,}001$).
Conclusão: A variação da medida do ângulo cervicodiafisário na incidência anteroposterior mostrou significativa correlação com o arco de movimento; desvios em varo maiores do que 15° não foram bem tolerados. Esse parâmetro pode ser um dos preditores dos resultados funcionais nas fraturas do úmero proximal tratadas com placa anatômica bloqueada.

Introduction

Proximal humeral fractures are relatively frequent; they account for 5–10% of all fractures.[1] Their incidence is 6.6 cases for every 1000 people everyyears[2]; 70% in patients above 60 years old.[3] They are the second most common upper limb fracture and the third most common in patients above 75 years old.[4]

The most common mechanism of injury is fall from standing protected by the extended hand[5]; 80% of these fractures have no displacement or are minimally displaced and stable, resulting from low-energy trauma, and can be treated non-surgically[6,7] with good prognosis. Surgical treatment is reserved for patients with fractures that are displaced, unstable, open, associated to vascular injury, or in polytrauma patients.[8]

According to the literature, there is no unique treatment method that is effective for all types of proximal humeral fractures. The most commonly used surgical techniques are: closed reduction and fixation with pins or percutaneous screws, open reduction and internal fixation with plate and screws or with tension band, intramedullary nails, and hemiarthroplasty.[2,9]

Internal fixation of the proximal humerus with locking anatomic plate favors the maintenance of the reduction obtained during surgery, allowing for earlier passive mobilization and thus facilitating post-operative rehabilitation.[10]

However, this technique is not free from complications. The most common among them are: limitation of range of movement, avascular necrosis, loosening of the synthesis material, articular penetration of screws, and/or varus fixation of the humeral head.[1,11]

This study aimed to evaluate the correlation between functional outcomes and radiographic indices of proximal humeral fractures treated with locking anatomical plate.

Methods

This was a retrospective study conducted by the Shoulder and Elbow Group of the Orthopedics and Traumatology Service of the hospital, from January 2012 to March 2013, with 46 patients who suffered fracture of the proximal humerus and underwent surgical treatment (open reduction and internal fixation) with locking anatomic plate (PHILOS – Synthes®).

The following patients were excluded: 1 individual for presenting infection (re-operated for removal of the synthesis material); 1, for developing avascular necrosis of the humeral head; and 5 due to loss of follow-up.

Of the 39 patients available for study, 21 (54%) had a fracture on the left side and 18 (46%) on the right side; 18 (46%) fractured the dominant side, and 21 (54%), the non-dominant; 26 (67%) were female and 13 (33%) male. The mean age was 69 years (range 45–87 years) for the women and 51 years (range 19–71 years) for the men. The mean follow-up was 27 months (range 20–34 months). The most common mechanism of injury was fall from standing in 89% of cases.

Comparing the frequency of age by gender, it is observed that among the women, 25% were between 45 and 61 years;

Fig. 1 – Distribution of patients by age group and gender.

50%, between 61 and 77; and 25%, above 78. Among the men, 25% were between 19 and 46 years; 50%, between 47 and 65; and 25%, above 66 (Fig. 1).

The classification used in this study was described by Neer[12] in 1970, based on displacement of the four main fragments, which were firstly identified by Codman in 1934[13]: humeral head, greater tuberosity, lesser tuberosity, and diaphysis. According to Neer,[12] multiple parts are considered when there are deviations greater than 1 cm or 45° between fragments. For the greater tuberosity, a distance greater than 5 mm makes it a displaced part.

For diagnosis and preoperative classification, X-rays in the true shoulder anteroposterior, scapular Y, and Velpeau views were used, as well as CT scan when there was doubt regarding articular involvement. Of the 39 studied fractures, 13 (33.3%) were classified as two-part, 12 as three-part (30.8%), and 14 as four-part (35.9%).

To assess the functional results, patients with a minimum of 12 months of follow-up were included. The degree of flexion and rotation (lateral and medial) of both shoulders was measured in accordance to the American Academy of Orthopedic Surgeons[14] method. The University of California in Los Angeles (UCLA) score was applied,[15] which uses objective and subjective criteria and assigns points according to pain, degree of mobility, shoulder function, strength and patient satisfaction. The maximum score is 35 points.

For the age analysis, patients were divided into two groups: 60 years or less (15 patients – 38%) and above 60 (24 patients – 62%), taking into account Law No. 10.741 of the Brazilian Constitution, which declares the Elderly Statute, considering as such individuals aged over 60 years.

Postoperative radiographic evaluation was standardized with a 100 cm distance from the X-ray apparatus to the film in the anteroposterior incidence (AP), with correction of anteversion of the glenoid cavity and limb in neutral rotation; scapular Y made with the patient standing in the posteroanterior position with 45° anteriorly and the X-ray apparatus toward the scapula; and Velpeau view a modification of axillary profile for patients with upper limb immobilization.[16] Radiographs were always made on the same day by the same previously trained staff, at least one year after surgery.

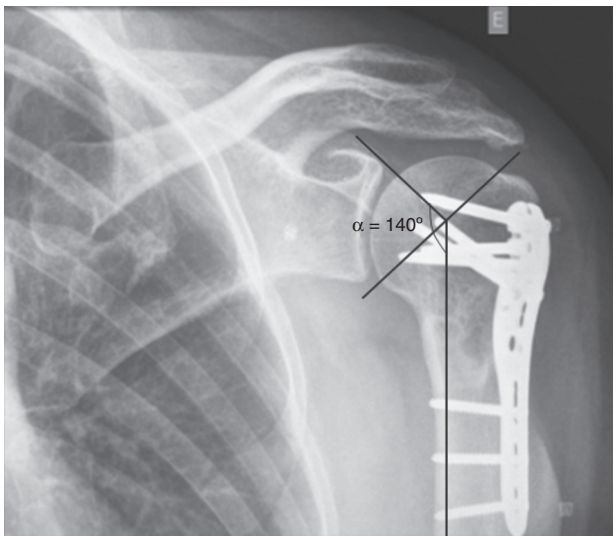

Fig. 2 – Measurement of the cervicodiaphyseal angle.

The radiographic measurements assessed were the cervicodiaphyseal angle (formed by the intersection between a line perpendicular to the anatomical neck and a line parallel to the axis of the humeral diaphysis), compared to the non-operated side in true shoulder anteroposterior view[1] (Fig. 2), and distance between the proximal end of the plate and the apex of the greater tuberosity on the true shoulder anteroposterior view (Fig. 3).

The presence of pseudoarthrosis, avascular necrosis, and osteolysis was investigated.

For the analysis of the difference of cervicodiaphyseal angle in anteroposterior incidence, a variation up to 15° varus was used as an evaluation parameter, following the line of thought described by Solberg et al.[17,18]

For the analysis of the distance between the plate and the apex of the greater tuberosity, patients were divided into two groups: the first group had values lower than 8 mm, and the second, values greater than or equal to 8 mm. This parameter

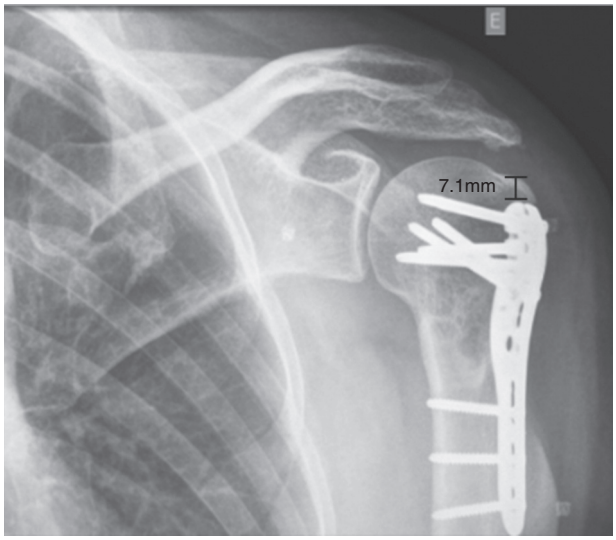

Fig. 3 – Measurement of plate height.

was chosen because it is the best positioning, according to the surgical technique of osteosynthesis with locking anatomical plate for the proximal humerus (PHILOS – Synthes®).

Subsequently, the correlation between changes in radiographic measurements and functional results was calculated.

In the statistical analysis, the variables were presented on tables with absolute and relative frequency distribution. Associations were tested using the chi-squared test, and the normality of the variables was assessed using the Shapiro–Wilk test. Continuous variables were evaluated using paired and unpaired Student's *t*-test, ANOVA, and non-parametric Mann–Whitney test, all with 5% significance level. Statistically significant results were considered those with *p*-values lower than 0.05.

The information collected was stored in a database developed in Excel® for Windows, and statistical analysis was performed with STATA 11 SE and SPSS 16.0.

Results

Functional outcome

For the 39 patients analyzed, the mean elevation of the operated limb was 123.9° (80–180°), with a standard deviation of 26.4°. As for the contralateral shoulder, a mean of 154.1° (110–180°), with a standard deviation of 19°, was obtained. A mean loss of 30° (20%) of elevation for the operated shoulder was observed when compared with the contralateral. The mean external rotation (ER) was 44.2° (5–80°) for the operated shoulder, with a standard deviation of 19.2°. For the contralateral shoulder, the mean was 62.9° (30–85°), with a standard deviation of 14.4°. A mean external rotation loss of 18.7° (30%) was observed for the operated shoulder when compared with the contralateral. The mean internal rotation (IR) was thumb-T9 (T4-L5) of the operated shoulder *versus* thumb-T7 (T4-L1), the mean of the contralateral.

In the UCLA score,[15] 24 (61.5%) patients had excellent and good results; 12 (30.8%), fair; and three (7.7%), poor. Of the total, 36 (92.3%) patients were satisfied and three (7.7%) were unsatisfied.

Thirteen patients (33.3%) had two-part fractures, with a mean UCLA score[15] of 31.3. Compared to the contralateral side, the loss in range of motion was: 14.7° for elevation (154.6–139.9°); 6.9° for external rotation (55.8–62.7°); and internal rotation remained at T7 for operated and contralateral shoulders.

Twelve patients (30.8%) had three-part fractures, with an average of UCLA score[15] of 27.6 points. Compared to the contralateral side, the loss in range of motion was: 34.6° for elevation (127–161°); 21.4° for external rotation (45.3–6.7°); and the average internal rotation went from thumb-T9 to thumb-T7 in the contralateral shoulder.

The worst scores in the study were in four-part fractures, observed in 14 patients (35.9%), with mean UCLA score[15] of 25.4 points. Compared to the contralateral side, the loss in range of motion was 40.8° for elevation (107–147°);, 27.4° for external rotation (32.4–59.8°); and mean internal rotation went from T10 in the operated shoulder to T7 in the contralateral shoulder (Table 1 and Fig. 4).

Younger patients (60 years or less) had the best results in the UCLA score[15] ($p = 0.004$), elevation ($p < 0.001$), external rotation ($p < 0.001$), internal rotation ($p = 0.003$), and variation of the cervicodiaphyseal angle ($p = 0.007$) when compared to older patients (over 60 years; Table 2).

Statistically significant results were observed ($p < 0.05$) when correlating the UCLA score[15] and flexion with the age of the patient and the number of parts of the fracture according to the Neer classification. The higher the age and the number of parts, the worst the flexion and UCLA score.[15]

Radiographic assessment

In the radiographic evaluation, one patient (2.43%) had avascular necrosis (the fracture had been classified as four-part preoperatively) and one patient (2.43%) presented infection (it was necessary to remove the synthesis material). It was not possible to assess the pre-established study measurements for these two patients.

Of the 39 patients studied, the mean cervicodiaphyseal angle in anteroposterior view was: 129° on the operated side (range: 82–170°; standard deviation: 19°) and 140° in the contralateral shoulder (range: 124–153°; standard deviation: 6.9°). The greatest differences were observed in four-part fractures, especifically in the anteroposterior view, which showed a difference of 21° when compared to the non-operated side.

Table 1 – Neer classification in relation to the studied variables.

Variables	Neer classification			*p*
	II (*n* = 13) Mean (SD)	III (*n* = 12) Mean (SD)	IV (*n* = 14) Mean (SD)	
UCLA	31.3 (3.4)	27.6 (5.5)	25.4 (5.7)	0.01
Elevation	139.9 (21.6)	126.8 (26.7)	106.6 (20.4)	0.002
External rotation	55.8 (12.9)	45.3 (19.3)	32.4 (18.0)	0.004
Measurement	6.3 (3.3)	8.0 (3.2)	5.6 (4.0)	0.22
Angle	136.5 (13.0)	130.9 (15.4)	120.3 (24.0)	0.08
Diff. elevation	14.7 (21.4)	34.6 (20.8)	40.8 (16.2)	0.003
Diff. angle	1.4 (9.4)	10.8 (12.3)	21.3 (27.2)	0.03

Measurement, measurement from the tip of the plate to the TM apex (mm); Angle, cervicodiaphyseal angle in anteroposterior incidence; Diff. elevation, difference in elevation in the affected shoulder when compared to the contralateral shoulder; Diff. angle, difference in cervicodiaphyseal angle in the affected shoulder when compared to the contralateral shoulder.

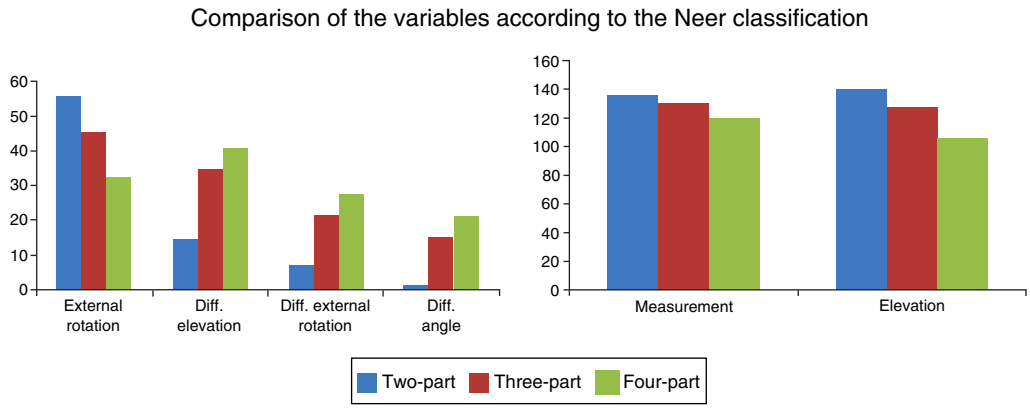

Fig. 4 – Comparison of the variables according to the Neer classification.

Table 2 – Age in relation to the studied variables.

Variables	Age		*p*
	≤60 years (*n* = 15) Mean (SD)	>60 years (*n* = 24) Mean (SD)	
UCLA	31.1 (3.1)	26.1 (5.8)	0.004
Elevation	146.9 (19.0)	109.6 (19.3)	<0.001
External rotation	58.7 (13.6)	35.1 (16.5)	<0.001
Internal rotation	T7	T10	0.003
Plate height at the greater tuberosity	7.4 (2.9)	6.1 (4.0)	0.27
Angle	135.1 (11.5)	125.2 (22.1)	0.12
Diff. elevation	22.7 (23.3)	34.9 (20.4)	0.09
Diff. external rotation	13 (14.5)	22.3 (16.0)	0.08
Diff. angle	4.4 (9.5)	15.8 (23.4)	0.007

Angle, cervicodiaphyseal angle in anteroposterior incidence; Diff. elevation, difference in elevation in the affected shoulder when compared to the contralateral shoulder; Diff. angle, difference in cervicodiaphyseal angle in the affected shoulder when compared to the contralateral shoulder.

Patients who had less than 15° variation in the cervicodiaphyseal angle measurement in anteroposterior view between the operated shoulder and the contralateral had better functional outcomes: better UCLA score[15] ($p < 0.001$), higher flexion ($p < 0.001$), better external rotation ($p < 0.001$), and better internal rotation ($p = 0.03$; Table 3).

Correlation was observed between cervicodiaphyseal angle measurement in anteroposterior incidence and elevation ($p = 0.009$) and UCLA score[15] ($p = 0.005$).

Table 3 – Difference in the cervicodiaphyseal angle in relation to the studied variables.

Variables	Difference in the cervicodiaphyseal angle in anteroposterior incidence		*p*
	<15° Mean (SD)	≥15° Mean (SD)	
UCLA	30.3 (3.2)	25.2 (6.2)	<0.001
Elevation	139.2 (22.6)	108.7 (20.7)	<0.001
External rotation	51.0 (15.6)	31.7 (16.1)	<0.001
Internal rotation	T8	T10	0.03
Plate height at the greater tuberosity	7.02 (3.2)	5.4 (4.1)	0.23

When measuring the distance between the proximal end of the plate and the apex of the greater tuberosity, a mean of 6.6 mm (range: 0–14 mm; standard deviation: 3.6 mm) was obtained.

The comparisons among the results of the UCLA score,[15] elevation, external rotation, and cervicodiaphyseal angle between the two groups were not significant in any case (Table 4).

Correlation between radiographic and functional outcomes

The worst functional outcomes were observed in cases where the difference between the operated and contralateral side was greater than or equal to 15° varus in the anteroposterior incidence. In such cases, the patients had lower mean flexion (108.7°) and worse UCLA score[15] (25.2). Patients who had variations lower than 15° had mean flexion of 139.2° and mean UCLA score[15] of 30.3. These results were statistically significant in the present study (Table 4).

For analysis of the distance between the proximal end of the plate and the apex of the greater tuberosity, patients were divided into two groups: the first, with values lower than 8 mm, and the second, with values greater than or equal to 8 mm. In all patients included in this study, the proximal end of the plate was located caudal to the apex of the greater tuberosity. When comparing the flexion results between these two

Table 4 – Distance from the plate to the apex of the greater tuberosity in relation to the studied variables.

Variables	Difference between the plate and the apex of the greater tuberosity		p
	<8 mm Mean	≥8 mm Mean	
UCLA	27.8	28.9	0.36
Elevation	118.7	128.9	0.23
External rotation	38.2	49.9	0.06
Plate height at the greater tuberosity	126.7	131.1	0.48

Measurement, measurement from the tip of the plate to the TM apex (mm); Angle, cervicodiaphyseal angle in anteroposterior incidence.

groups, the first presented mean flexion of 118.7° and the second of 128.9°. There was no statistically significant difference between both groups (Table 4).

Discussion

In the present study, it was observed that deviations greater than 15° varus relative to contralateral shoulder in anteroposterior view are not well tolerated by the patient and lead to with flexion loss and a worse UCLA score.[15]

Solberg et al.[17,18] reached a similar conclusion. In their study, the authors divided the results according to the obtained alignment relative to the contralateral shoulder. They considered less than 5° of varus angulation of the humeral head as a good reduction. In turn, a satisfactory reduction ranged from 5° and 20° of varus deformity of the humeral head. The authors concluded that patients with good or satisfactory reductions had better outcomes than patients with varus deformity greater than 20°, who presented flexion loss and worse functional outcome.

Resch,[19] in a 2011 review article, also considered these parameters to be important, and proposed a classification based on varus and valgus deviations. Brunner et al.[20] observed inferior results when the reduction of the fracture had cervicodiaphyseal angle with an increased varus; however, their results were not statistically significant. Robinson et al.[21] observed that severely displaced fractures tend to increase varus deformity and recommended osteosynthesis with the use of locking plates in patients with cervicodiaphyseal angle smaller than 100°.

The surgical technique of osteosynthesis with locking anatomical plate for the proximal humerus (PHILOS – Synthes®) determines that the distance from the plate in relation to the apex of the greater tuberosity should be 8 mm, since lower distances would cause subacromial impingement, and abduction and flexion deficits in the shoulder.[21,22] In the present study, a small difference, without statistical significance, was observed in functional outcome among patients, regardless of the distance between the proximal end of the plate and the apex of the greater tuberosity.

In the functional evaluation, three patients were not satisfied with the treatment, and their results were considered as poor (according to the UCLA score[15]). One of these cases (2.43%) had osteolysis of the greater tuberosity. One case of avascular necrosis (2.43%) was observed, and was also considered poor according to the UCLA score.[15] Brunner et al.[20] reported a higher number, with 8% necrosis in a multicenter study of 158 fractures. According to the literature, the incidence of osteonecrosis for proximal humerus fracture ranges from 4% to 16%.[23] Patients with avascular necrosis present the worst functional results. However, elderly patients, who have lower functional demand, tolerate this complication better.[24]

The 61.5% excellent and good results observed in the present study are below levels reported in the literature. In 2011, Hirschmann et al.[25] published a study with 64 patients with a minimum follow-up of four years, treated with locking plate, and reported 75% excellent and good results. They also concluded that these results continued to improve even one year after the surgery. Rose et al.[26] found 75% consolidation and excellent results.

In the present study, the higher the age of the patient and the number of parts of the fracture, the worst the flexion and the UCLA score.[15] These results were statistically significant $p < 0.001$, $p = 0.02$, $p = 0.008$, and $p = 0.01$, respectively). Yang et al.[27] found that the higher number of fracture parts and the lack of medial support (calcar comminution) were determiners of the functional outcome. Koukakis et al.[28] also had worse outcomes related to age.

In the present study, the cervicodiaphyseal angle was used as a comparative radiographic parameter with the contralateral shoulder for correlation with functional outcomes. However, there is no universal standardized method to measure this angle.[29] Other biases in the results of this study which were not analyzed are the co-morbidities of patients, prior and late postoperative integrity of the rotator cuff, and the use (or not) of medial support screws in locking plates.[30–33] Further studies with greater emphasis on such factors are needed to complement the present findings.

Conclusion

This study indicated that the alteration of the cervicodiaphyseal angle in anteroposterior view was significantly correlated with the range of motion; displacements greater than 15° varus were not well tolerated. This radiographic parameter can be one of the predictors of functional results in fractures of the proximal humerus treated with locking plates.

The greater the age of the patient and the number of parts of the fracture, the worse the functional outcomes are.

Conflicts of interest

The authors declare no conflicts of interest.

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