ORIGINAL ARTICLE

Does plate-screw density affect the functional outcomes in the treatment of proximal humerus fractures?

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ABSTRACT

BACKGROUND: The aim of the study is to evaluate the relationship between plate-screw density (PSD), functional results, and complication rates in the treatment of proximal humerus fractures (PHFs) with proximal humerus locking anatomical plate (PHLAP).

METHODS: Consecutive 43 patients (22 females and 21 males) who underwent PHLAP for the treatment of PHF between 2010 and 2016 were evaluated. AO classifications were used for the classification of fractures. Based on the biomechanical stability theory of Erhardt et al., the patients were divided into two groups as <60% and >60% according to the number of screws fixed to the humeral head for the determination of PSD. The patients were divided into two groups as PSD <60% (n=21) and PSD>60% (n=22) according to the number of screws fixed to the humeral head for the determination of PSD. Functional results were evaluated using the Constant-Murley shoulder score (CMS). Radiological evaluation was performed with collodiaphyseal angle (CDA), varus-valgus angulation, avascular necrosis (AVN), and arthrosis. The groups were compared in terms of demographic characteristics, functional results, radiological scores, and complications.

RESULTS: The mean age was 54.47±17.43 years and the mean follow-up time was 19.51±5.27 months. Although the CMS scores of patients with a PSD of over 60% were higher than those below 60%, the CMS score did not differ statistically. In groups, the mean CDA of the operated shoulder was significantly lower than that of the non-injured side (p=0.002). Eight patients had varus angulation, whereas two patients had humerus head AVN. No significant relationship was observed between PDS and functional scores, radiological results, and complications.

CONCLUSION: Functional results of PSD >60% are higher than PSD <60% group but there is no statistical difference between groups according to functional, radiological results, and complications.

Keywords: Functional score; plate-screw density; proximal humeral fractures; proximal humerus locking anatomical plate.

INTRODUCTION

Although proximal humerus fractures (PHFs) constitute 5% of all fractures, PHF is the 3rd most common type of fracture in elderly patients and eighty percent of PHF is treated conservatively.[1,2] Unstable fractures and 3-4-part fractures frequently require surgical treatment.[3,4] Proximal humerus locking anatomical locked plate (PHLAP), intramedullary nail, K-wire and tension band fixation technique, fixed-angle plates, 1/3 tubular plates, and primary arthroplasty are preferred surgical fixation methods in PHF.[5,6] PHLAP is the gold standard treatment method in the elderly osteoporotic fractures because it allows early movement and provides stable fixation.[7] However, in osteoporotic fractures, various prob-

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lems such as reduction loss, screw cut-out, screw loosening, nonunion, and avascular necrosis (AVN) are encountered after the PHLAP application.[8] Surgeon related complications such as intra-articular screw penetration were also frequent. Progressive AVN and varus angulation are the most common complications and these complications are related to fracture severity.[8,9] Various techniques have been developed to prevent loss of reduction, such as cement application, pin application in addition to plates and screws, application of fibular grafts, and medial additional plates.[9,10] Screws that support the calcar region increase the stability on the plate.[11] Erhardt et al.[12] recommended that a minimum of 5 screws including an inferomedial support screw in the head fragment should be used for the fixation of PHFs with a disrupted medial hinge. Besides, the number of screws fixed to the humeral head has been shown to affect the fixation stability in the literature.[12] According to this recommendation, the patients in the current study divided into two groups and the cut-off rate were used as 60% for plate-screw density (PSD). PHLAP has 9 screw holes and due to applied screws, we divided patients into two groups. PSD is defined in the literature for long bone fixation techniques, for more stable fixation, and decreasing the complications such as reduction loss, etc.[13] The aim of the present study was to evaluate the effect of PSD fixed on the humeral head on radiological and functional results in PHFs treated with PHLAP. We hypothesized that patients with high screw density applied proximally will obtain better radiological and functional results.

MATERIALS AND METHODS

The patients with PHF who were treated with PHLAP (TST, Istanbul, Turkey) between February 2010 and December 2016 were examined retrospectively after the ethics committee approval (Approval ID:2015/01-11). Patients with PHF, closed fractures, neurologically intact patients, no previous trauma history or shoulder pathology, PHLAP fixation, and a minimum follow-up of 12 months were included in the study (Fig. 1). Conservative treatment, accompanying nerve injury, treatment with a non-PHLAP technique, pathologic fracture, accompanying ipsilateral upper limb injury, and the follow-up period of fewer than 12 months were excluded from the study. Forty-three patients (22 females and 21 males) who met the inclusion criteria were included in the study. Eighty-five surgically treated patients with PHF were screened in this period. Forty-two patients excluded from the study, because 12 patients were treated with a humeral prosthesis, 13 patients were treated with a humeral nail, and six patients' medical records, and 11 patients follow-up were by different clinics made. PHLAP with nine holes for the humerus head was used in all patients. PHLAP has nine holes for proximal fixation, distal hole number is changing with plate length. Based on the biomechanical stability theory of Erhardt et al., the patients were divided into two groups as <60% and >60% according to the number of screws fixed to the humeral head for the determination of PSD. According to screw to hole ratio, the patients with five or fewer screws applied to the humeral head constituted the <60% PSD group (21 patients), while patients with six or more screws applied to the humeral head constituted >60% PSD group (22 patients) (Figs. 2 and 3). Functional results were evaluated using the Constant-Murley shoulder score (CMS). Radiological evaluation was performed with collodiaphyseal angle (CDA), varus-valgus angulation, and AVN. The groups were compared in terms of demographic characteristics, functional results, radiological scores, and complications.

Surgical Procedure and Post-operative Follow-up

The surgical procedure was performed by two senior upper extremity surgeons, using the deltopectoral approach under fluoroscopy guidance when the patient was in a beach

Figure 1. A 54 years-old male patient with AO type 11-B2 proximal humerus fracture. Shoulder **(a)** X-ray and computed tomography sections **(b)** sagittal, **(c)** coronal, and **(d)** axial views show the comminuted fracture.

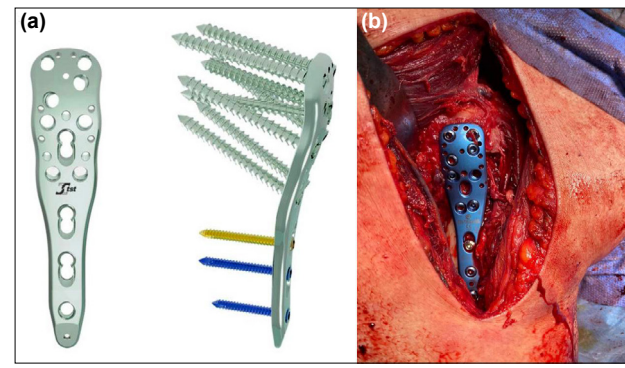

Figure 2. (a) Medical illustration of proximal humerus locking anatomical plate (PHLAP) with 9 holes for humerus head. **(b)** Intraoperative image of the PHLAP (white arrows show the calcar screws).

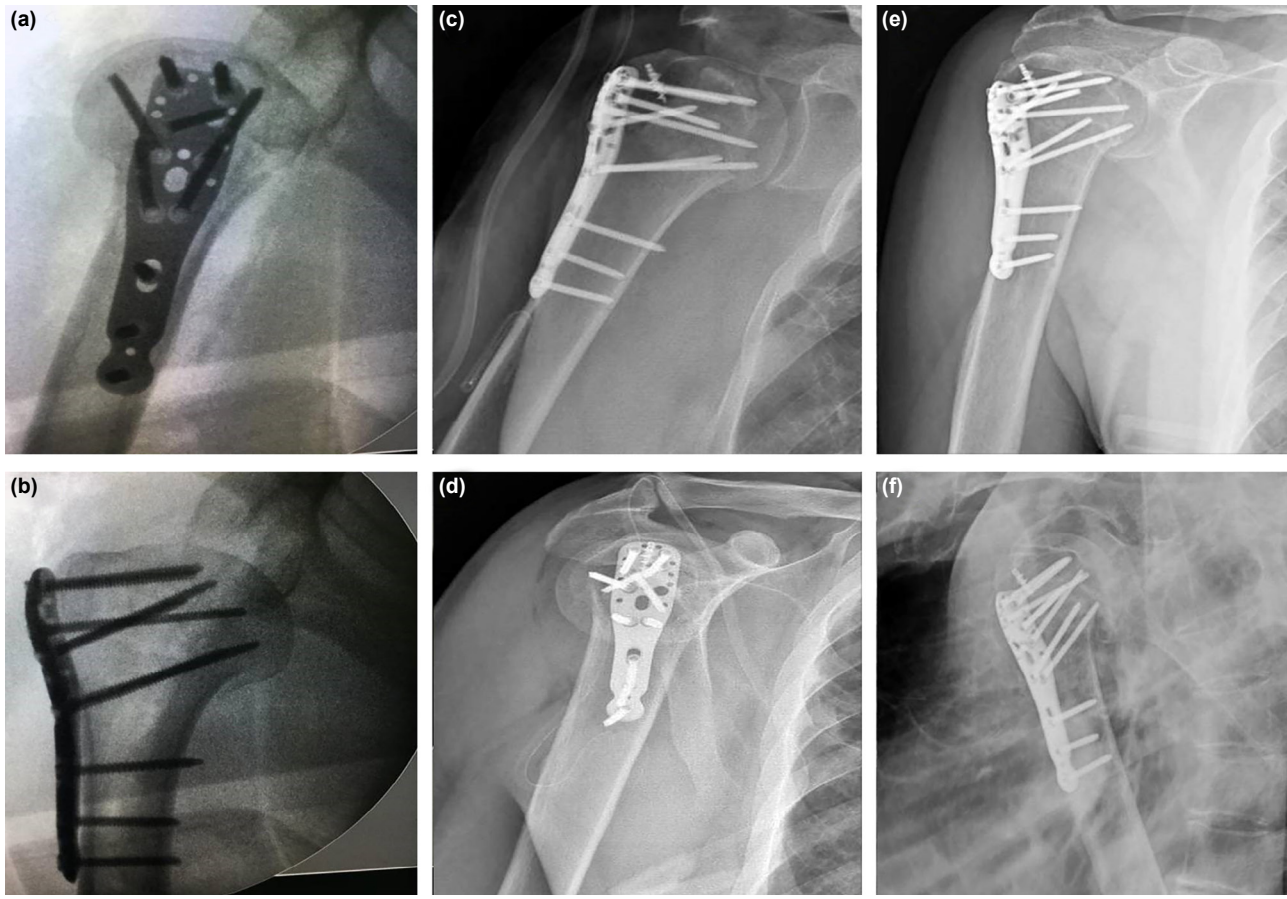

Figure 3. Intraoperative fluoroscopy images **(a)** anteroposterior (AP) and **(b)** lateral (L). Early postoperative (postoperative 1st day) views **(c)** AP **(d)** L and postoperative 17th-month control views **(e)** AP **(f)** transtorasic.

chair position, under interscalene nerve block, and/or under general anesthesia. After open reduction was achieved, plate position, reduction, and screw lengths were checked by fluoroscopy. The plate was positioned laterally and fixated with two K-wires. After fluoroscopy control, a non-locking screw applied for compressing the plate to the humeral shaft. Then, the humeral head was drilled only one cortex. The humeral head was not drilled and then the screw length was measured and a 4 or 5 mm short screw was applied. At the end of the screw application, fluoroscopy control was made in standard anteroposterior, lateral views. Furthermore, anteroposterior views of internally and externally rotated humeral views were seen for screw length. In the fixation of fractures, especially 2 locking cortical screws were used as the calcar screws in all patients. The screws fixed to the humeral head except the calcar screws were locking spongiosis screws, both locking and non-locking screws were used for distal fixation because the distal part of the plate has locking and non-locking holes. The patients were followed up functionally and radiologically at the 2nd week, 6th week, 12th week, 6th month, and the 1st year after the surgery. While the film of the operated side was taken at every control, the control film of the uninjured side was taken in the last control. All patients used a 30° abduction brace on the shoulder for 2 weeks postoperatively. Passive joint rehabilitation was started immediately in the postoperative period. Then, pendular exercises and elbow exercises were started as much as the patients can tolerate. After callus formation seemed on X-Ray (during the 4th-8th weeks) active assistive exercises were started. X-rays were evaluated by two orthopedic surgeons who did not know which group the views belonged to.

Statistical Analysis

Number Cruncher Statistical System 2007 (Kaysville, Utah, USA) program was used for statistical analysis. Descriptive statistical methods (mean, standard deviation, median, first quarter, third quarter, frequency, percentage, minimum, and maximum) were used when evaluating the study data. The suitability of quantitative data to normal distribution was tested by the Shapiro–Wilk test and graphical examinations. Mann–Whitney U test was used to compare the quantitative variables that did not show normal distribution between the two groups. Kruskal–Wallis tests were used for comparison of more than two groups of quantitative variables that did not show normal distribution. Wilcoxon signed-ranks test was used for intra-group comparison of quantitative variables that did not show normal distribution. Pearson chi-square test, Fisher's exact test, and Fisher-Freeman-Halton exact test were used to compare qualitative data. Pearson correlation analysis

was used to evaluate the relationships between quantitative variables. Statistical significance was accepted as p<0.05.

RESULTS

The demographic characteristics of the patients are presented in Table 1. No statistically significant difference was observed between PDS groups in terms of gender, age, CMS, final CDA, complication rate, time to operation, operation time, and length of hospital stay (p>0.05). There was no statistically significant difference between the PSD groups in terms of CMS and CDA (Table 2). There was no statistically significant difference between AO-Classification, PSD, and CMS, but PSD is statistically closed to meaningfully high in 11-C3 fracture types (Fig. 4, and Table 3). Final CDA values were significantly lower in all patients compared to the uninjured side (p=0.002). In patients with PSD >60, although the CMS results were better, no statistical difference was found (79.54±15.15 and 69.84±9.99, p>0.05; respectively). There was no significant correlation between PSD and age, CMS, and CDA (r=0.125, r=0.208 and r=–0.006, p>0.05; respectively). CMS scores were significantly better in patients under 65 years of age (p=0.002). A moderate negative correlation was observed between CMS and age (r=–0.555, p<0.001) (Table 3). CMS scores were better in patients with no complication than patients with complication, but it is not statistically meaningful (79.70±15.18 and 61±18.89, respectively). No significant difference was found between complication and age, PSD, time to operation, classification of fractures, and length of hospital stay (p>0.05). Eight patients had varus angulation and two patients had AVN in the humerus head. The superficial infection developed in two patients in the post-operative period and was treated with the first-generation cephalosporin. There was no significant correlation between PSD and complications (p=0.876).

Table 1. Other system and organ injuries

	Mean±SD	Min-Max
Age (years)	54.47±17.43	16–82
Plate-screw density (%)	67.64±11.77	42.8–100
Operation duration (minutes)	123.02±25	60–180
Follow-up (months)	19,51±5,27	12–34
Constant-Murley Score	76.35±18.67	28–100
Collo-diaphyseal angle (postoperative final)	129.03±12.83	92–163
Collo-diaphyseal angle (non-injured)	134.22±2.97	126–142
Time to surgery (days)	7.02±5.87	0.25–25
Hospitalization (days)	9.91±5.82	2–28
	n	**%**
Gender		
Female	22	51.2
Male	21	48.8
Fracture side		
Right	26	60.5
Left	17	39.5
Plate-screw density (%)		
<60	21	48.8
>60	22	51.2
AO Classification		
A3	4	9.3
B1	2	4.7
B2	6	14.0
B3	4	9.3
C1	7	16.3
C2	5	11.6
C3	15	34.9
Constant-Murley Score		
Poor	11	25.6
Fair	12	27.9
Good	7	16.3
Excellent	13	30.2
Complication	23.3	10
Accompanying injury	25.6	11
Comorbidity	37.2	16

SD: Standard deviation.

DISCUSSION

The most important finding of our study is that although the average CMS is quantitatively high in patients with PSD >60%, there is no statistically significant difference. Another important finding is that functional scores are worse in patients over 65 years of age. To the best of our knowledge, the present study is the first to examine the relationship between PSD and functional results and complications. PHLAP provides stable osteosynthesis by applying locked screws at different angles, allowing early rehabilitation and contributing to the improvement of functional results.[7] However, complications such as AVN of the humeral head and cut out of the proximal screws can be observed as a result of fixations with PHLAP.[8] Hertel et al.[14] emphasized that providing medial calcar support is important to prevent complications such as varus angulation of the humeral head and AVN. In PHLAP fixation, complications can be reduced by providing medial support with calcar screws applied tangentially to the inferomedial of the humeral head.[11,15] During the shoulder motion compressive stress is greater on the medial side than the lateral side. The rotator cuff has continuous stress on the humeral head and this may provide varus angulation on PHFs.[11,14] Medial support by medial calcar screws has been stated in many studies.[11,16,17] The calcar screws are especially preferred to prevent the varus angulation of the humeral head.

Table 2. The relationship between age and PSD and functional and radiological outcomes

	Age <65	Age >65	p	PSD <60	PSD >60	p
	Median (Q1, Q3)	Median (Q1, Q3)		Median (Q1, Q3)	Median (Q1, Q3)	
PSD (%)	66.6 (58, 75)	66.6 (62, 75)	[a]0.869	–	–	–
CMS	84 (75, 95)	70.5 (47.5, 76)	[a]0.005**	71 (58, 89.5)	79 (71, 94)	[a]0.265
CDA	132 (126.6, 136.5)	132.5 (121.5, 135.5)	[a]0.660	133 (126, 136.25)	132 (124, 137)	[a]0.640
	n (%)	n (%)		n (%)	n (%)	p
CMS						
Poor	4 (14.8)	7 (43.8)	[b]0.043*	4 (33.3)	7 (22.6)	[b]0.932
Fair	6 (22.2)	6 (37.5)		3 (25)	9 (29)	
Good	6 (22.2)	1 (6.3)		2 (16.7)	5 (16.1)	
Excellent	11 (40.7)	2 (12.5)		3 (25)	10 (32.3)	
Complication	4 (14.8)	6 (37.5)	[c]0.137	2 (16.7)	8 (25.8)	[c]0.698

[a]Mann-Whitney U test, [b]Fisher-Freeman-Halton exact test, [c]Fisher's exact test, *p<0.05, **p<0.01, Q1: First quarter; Q3: Third quarter; PSD: Plate-screw density; CMS: Constant-Murley Score; CDA: Collo-diaphyseal angle.

[17,18] Biomechanical studies have shown that the inferior and posterior regions of the humerus head are stronger and the inferomedial calcar screws provide more support than the screws applied to the center of the humeral head.[19] Zhang et al.[17] used cortical screws to support inferomedial in their study, which they stated that CDA was important in the failure of PHLAP. In the present study, especially 2 locking calcar screws were used in all patients for the better fixation stability of fractures. The rate of AVN in the current study is lower according to the literature, while 2 calcar screws could prevent AVN due to stable fixation.[10,17,18] The most common complications after fixation of PHFs with PHLAP are AVN of the humeral head, varus angulation, and cut out of the screws from the humeral head.[20] AVN and screw cut out frequently require revision surgeries.[21] Although it was previously stated that surgical treatment does not give a certain advantage to conservative treatment in terms of complications, it is one of the most important advantages that surgical treatment allows early joint movements.[22] In our study, the complication rate was compatible with the literature and the most common complication was varus angulation. No patient had a screw cut out and nonunion. Furthermore, no patient required revision surgery due to complications. Furthermore, no relationship was found between age and AVN and varus/valgus angulation in the present study. The final CDA was lower than the uninjured side. However, no statistical relation was found between complications and CMS, age, PSD, and fracture classification. The mean CMS score was lower in patients with complications, but it was not statistically meaningful. Because of the small sample group, we think that it is not meaningful.

In the present study, although functional scores were higher in patients with PSD >60%, no statistically significant result was obtained. In the similarity of functional outcomes in both groups, we assumed that it was effective to use at least 2 calcar screws rather than the number of screws applied to the humeral head. Korkmaz et al.[23] found similar results in patients over 65 and under 65 who underwent PHLAP and stated that PHLAP is lighter and biocompatible due to its titanium alloy feature. In the present study, the functional scores of the patients over 65 were lower when the age relationship with CMS was evaluated. Although the bone union is achieved with PHLAP, decreased range of motion, and persistence of pain complaints in elderly patients cause CMS to decrease.[20] In the present study, we think that the functional scores of the patients over 65 years of age decreased due to insufficient range of motion and decreased muscle strength in the post-operative period.

In the literature, it has been stated that Neer classification can easily identify fractures, but it is not useful for intraoperative decision making.[24] Therefore, the AO classification was used in our study. The AO classification is divided into different subgroups according to fracture fragments, the joint extension of the fracture, and the relation of the humeral head to the joint. PSD slightly increased in AO11-B3 and C3 fractures in the present study (p=0.065). In our study, AO11-C3 type fractures are proportionally higher than other fracture types. When C3 type fractures were examined, it was found that there was no statistically significant difference in terms of CMS scale and complications. Rodia et al.[6] reported that AO11-C3 preferred hemiarthroplasty instead of the plate for comminuted fractures. In AO11-C3 fractures, which constitute 34.8% of the patients in our study, surgeons used more screws to provide stable fixation. We think that stability will be increased and similar functional results will be obtained in different types of fractures, and osteosynthesis

Table 3. The relationship between PSD and CMS and other parameters

	PSD	
	r	**p**
Age (years)	0.125	0.425
CMS	0.208	0.180
CDA	-0.006	0.968
AO-Classification	0.165	0.065
	Median (Q1, Q3)	**p**
CMS		
Poor	66.6 (54.5, 75)	[d]0.877
Fair	66.6 (62, 75)	
Good	68.75 (56, 75)	
Excellent	66.6 (66, 75)	
Complication		
No	66.6 (58, 75)	[a]0.876
Yes	66.6 (62.5, 75)	
	CMS	
	r	**p**
Age (years)	-0.555	<0.001**
PSD (%)	0.208	0.180
Time to surgery (days)	-0.060	0.704
Hospitalization (days)	-0.169	0.278
AO-Classification	-0.124	0.858
	Median (Q1, Q3)	**p**
Gender		
Female	75.5 (64, 84)	[a]0.263
Male	84 (70, 95)	
Age (years)		
<65	84 (75, 95)	[a]0.005**
>65	70.5 (47.5, 76)	
PSD (%)		
<60	71 (58, 89.5)	[a]0.265
>60	79 (71, 94)	

[a]Mann-Whitney U test, [d]Kruskal-Wallis test, r: Pearson correlation coefficient, **p< 0.01, Q1: First quarter; Q3: Third quarter; PSD: Plate-screw density; CMS: Constant-Murley Score; CDA: Collo-diaphyseal angle.

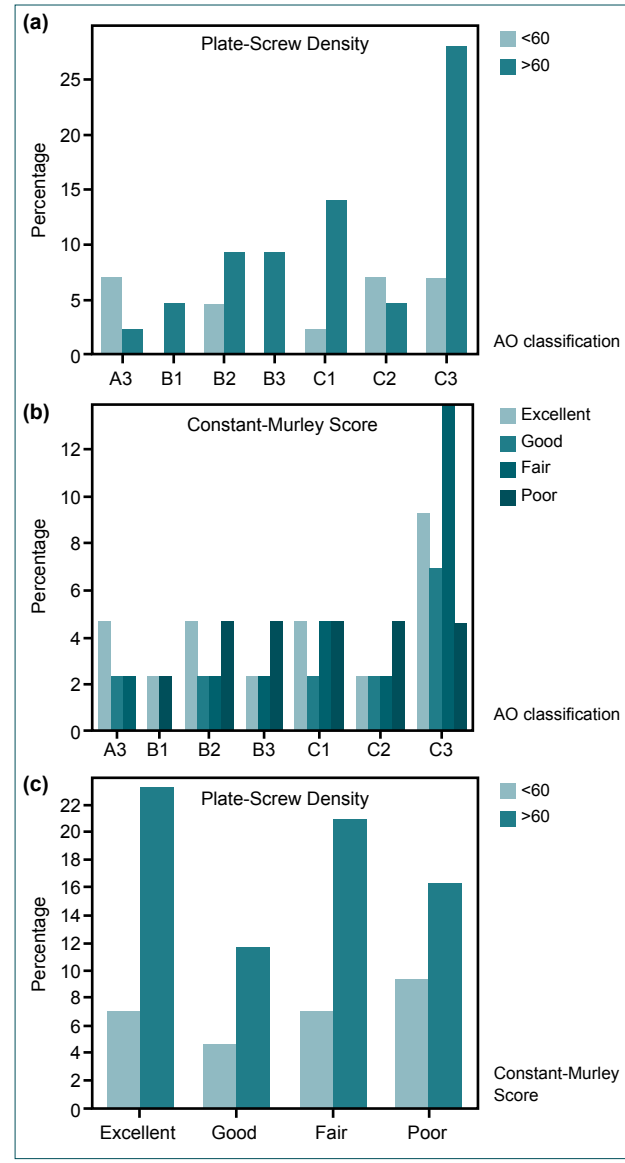

Figure 4. The relationship between AO-Classification, PSD, and CMS.

can be performed with PHLAP comminuted PHFs by increasing the number of screws applied to the humerus head. The previous literature stated that the frequency of comminuted PHF increases with elderly and osteoporosis.[25] However, no relationship was found between AO classification and age, complications, and CMS in the present study.

Although it was previously stated that surgical treatment does not give a certain advantage to conservative treatment in terms of complications, it is one of the most important advantages that surgical treatment allows early joint movements.[22] In our study, the complication rate was compatible with the literature and the most common complication was varus angulation. No patient had a screw cut out and nonunion. Furthermore, no patient required revision surgery due to complications. Furthermore, no relationship was found between age and AVN and varus/valgus angulation in the present study. The final CDA was lower than the uninjured side. However, no statistical relation was found between complications and CMS, age, PSD, and fracture classification. The mean CMS score was lower in patients with complications, but it was not statistically meaningful. Because of the small sample group, we think that it is not meaningful. Erhardt et al.[12] emphasized that the number of screws applied to the humeral head in PHFs is im-

portant in screw cut out and that a minimum of five screws should be applied in stable osteosynthesis. The limitations of the study are retrospective design, small sample size, no randomization, and reporting short-term results. The strengths of the study are homogeneity of parameters such as age and gender of the patients in both PSD groups and the first study to evaluate the relationship between PSD and functional results and complications in the literature.

Conclusion

In the surgical treatment of PHFs, PSD does not significantly affect both functional and radiological results and complications in the PHLAP application. The use of a minimum of 2 calcar screws may be more effective rather than the number of screws applied to the humeral head.

Ethics Committee Approval: This study was approved by the Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (Date: 04.01.2016, Decision No: 2015/259).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Proksimal humerus kırıklarının tedavisinde plak-vida yoğunluğu fonksiyonel sonuçları etkiler mi?

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AMAÇ: Çalışmanın amacı, proksimal humerus kırıklarının (PHK) proksimal humerus kilitli anatomik plak (PHKAP) ile tedavisinde plak-vida yoğunluğu (PVY), fonksiyonel sonuçlar ve komplikasyon oranları arasındaki ilişkiyi değerlendirmektir.

GEREÇ VE YÖNTEM: Şubat 2010–Aralık 2016 tarihleri arasında PHK tedavisi için PHKAP uygulanan ardışık 43 hasta (K: 22, E: 21) değerlendirildi. Kırıkların sınıflandırılmasında AO sınıflandırması kullanıldı. Hastalar humerus başına uygulanan vida sayısına göre PVY <%60 ve PVY >%60 olarak iki gruba ayrıldı. Fonksiyonel sonuçlar Constant-Murley omuz skoru (CMS) kullanılarak değerlendirildi. Radyolojik değerlendirme kollodiafizer açı (KDA), varus-valgus açılanması, avasküler nekroz ve artroz ile yapıldı. Gruplar demografik özellikler, fonksiyonel sonuçlar, radyolojik skorlar ve komplikasyonlar açısından karşılaştırıldı.

BULGULAR: Plak-vida yoğunluğu %60'ın üzerinde olan hastaların CMS skorları PVY'u %60'ın altındakilerden daha yüksek olmasına rağmen, CMS skorları arasında istatistiksel olarak farklılık görülmemiştir. Gruplarda, ameliyat edilen omzun ortalama KDA'sı yaralanmamış tarafa göre anlamlı olarak daha düşüktü (p=0.002). Sekiz hastada varus açılanması, iki hastada humerus başı avasküler nekrozu vardı. PVY ile fonksiyonel skorlar, radyolojik sonuçlar ve komplikasyonlar arasında anlamlı bir ilişki gözlenmedi.

TARTIŞMA: Proksimal humerus kırıklarının cerrahi tedavisinde PVY, PHKAP uygulamasındaki fonksiyonel, radyolojik sonuçları ve komplikasyonları anlamlı olarak etkilememektedir.

Anahtar sözcükler: Fonksiyonel skor; plak-vida yoğunluğu; proksimal humerus kırıkları; proksimal humerus kilitli anatomik plak.

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