ORIGINAL ARTICLE

Risk factors related reduction loss in nonoperatively treated Type II supracondylar humerus fractures

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ABSTRACT

BACKGROUND: Controversies continue about the optimal treatment method for extension Type II supracondylar humerus fractures (SCHFs). Although most patients are successfully treated with closed reduction and plaster casting, in some patients, the reduction initially obtained is lost during the time in the plaster cast. The aim of this study was to determine the risk factors causing reduction loss.

METHODS: A retrospective examination was made of the data of 103 patients with Type II extension SCHF treated with closed reduction and plaster cast fixation between 2012 and 2018. Reduction loss was evaluated in respect of patient variables, fracture characteristics as obliquity and metaphyseal fragmentation, fixation method, and plaster cast parameters.

RESULTS: The 103 patients evaluated comprised 62 males and 41 females with a mean age of 5.4±2.5 years (2–11.6 years). Successful treatment was achieved with closed reduction and plaster cast fixation in 81 (79%) patients and reduction loss was observed in 22 (21%) patients. The reduction loss of fractures showing high oblique in the sagittal plane was 3.17-fold higher than low sagittal oblique fractures (95% CI: 0.99–10.03, p<0.05). The risk of reduction loss in fractures with metaphyseal fragmentation was found to be 6.5-fold higher (95% CI: 1.6–26.5, p<0.01). No statistically significant relationship was determined between reduction loss and Gartland subtype, age, gender, the presence of rotation initially, plaster cast angle, and the soft-tissue/inner cast width ratio.

CONCLUSION: According to our study group, 79% of extension Type II fractures can be successfully treated with closed reduction and plaster casting. Sagittal plane obliquity and metaphyseal fragmentation are risk factors for reduction loss independent of Gartland subtype.

Keywords: Cast treatment; Gartland Type II; humerus; loss of reduction; obliquity; supracondylar.

INTRODUCTION

Supracondylar humerus fractures (SCHFs) constitute 3.3% of all pediatric fractures and are the leading fractures in the elbow region, at the rate of 57%.[1,2] The frequency of SCHF reaches a peak between the ages of 5 and 7 years and they are seen more often in boys than girls.[1] While trying to protect themselves during a fall, falling on the outstreched hand with the elbow in extension forces the supracondylar area into hyperextension.[3] Therefore, 98% of SCHFs are extension type fractures according to the orientation of the distal part. The Wilkins modification of the Gartland classification is widely used in the identification of extension type fractures.[4] Type I fractures are non-displaced, Type II fractures are displaced with the posterior cortex remaining intact (Type IIA – without rotation, Type IIB –- with rotation), and Type III fractures are fully displaced fractures.

In contrast to the broad consensus that Type I fractures can be treated nonoperatively and Type III fractures, surgically, there is ongoing controversy about the ideal treatment method for Type II fractures. While some authors have recommended that all Type II fractures are treated surgically,[5,6] others have recommended that the majority can be treated

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with a non-operative method.[7–9] This is due to the broad spectrum of the degree of displacement of Type II fractures and the moderate level of inter-observer agreement of the Wilkins modification.[10] Despite widespread research into the reasons for reduction loss developing after pin fixation of displaced fractures, the reasons for loss of reduction (LOR) developing after plaster cast fixation of Type II fractures are less known. Knowledge of the causes of LOR in Type II fractures will both increase treatment success with selection of patients suitable for plaster cast treatment and protect against the complications of unnecessary surgical treatment due to the possibility of selective pinning. The aim of the study was to investigate the risk factors related to the patient, the fracture characteristics, and the fixation method, causing reduction loss in patients with a Type II SCHF.

MATERIALS AND METHODS

Approval for the study was granted by the Institutional Review Board. A retrospective examination was made of the medical and radiographic data of patients with an extension Type II SCHF treated with closed reduction and plaster cast immobilization in our hospital between 2012 and 2018. The patients included were aged 2–12 years with an isolated extension Type II SCHF. Patients were excluded if they had an open fracture, multiple trauma, or incomplete medical records. Information related to age, gender, side of fracture, and fixation type was retrieved from the medical records.

At the time of presentation, the fractures were separated as Type IIA and IIB fractures according to the Wilkins modification of the Gartland classification. The fracture line was classified according to coronal and sagittal patterns in the Bakh classification.[11] According to the coronal patterns, the fractures were separated as typical transverse (obliquity <10° between epicondyles), lateral oblique (high lateral side, obliquity ≥10°), medial oblique (high medial side, obliquity ≥10°), and high fractures (fracture plane entering and exiting above the olecranon fossa but within the distal humeral metaphysis). In the sagittal plane, patients with a fracture line <20° were evaluated as low sagittal (LS) and those >20° as high sagittal (HS) (Fig. 1). In the coronal plane, medial or lateral impaction, or the presence of fragmentation were recorded (Fig. 2). The presence of rotation was accepted as a difference in diameter or a beak appearance on the anterior surface of the proximal fragment at the fracture level on the lateral radiograph of the elbow.[12]

The reduction procedure was applied in the Emergency Department without anesthesia. The fixation procedure was applied with the elbow in 90–100° flexion with a posterior splint or circular plaster cast according to the attending physician's preference. Reduction quality was evaluated radiographically after plaster cast fixation. The reduction was checked radiographically every week and the plaster cast removed after 4–6 weeks.

Using the Cobb angle measuring tool in the PACS system (ExtremePACS version 4.3, Ankara, Turkey), radiological measurements were made on the elbow anterior-posterior and lateral radiographs at presentation, early post-reduction, and at the end of plaster cast treatment. All the measurements, including the Baumann angle and the shaft condylar angle (SCA), were performed by the single experienced pediatric orthopedic surgeon (T.Y.). As the Baumann angle varies by 6° for every 10° of rotation of the arm and deviation of up to 7° is accepted as normal, a change in the angle of >12° was accepted as coronal LOR.[13] The correction to the Baumann angle was applied as recommended according to the radioulnar overlap ratio of Pace et al.[14] A loss of >10° in the SCA from post-reduction to removal of the plaster cast was accepted as LOR in the sagittal plane.

The plaster cast angle was measured on the elbow lateral radiograph. In patients with a circular plaster cast, the ratio was measured between the inner width of the plaster cast and the soft-tissue width of the forearm and the arm at an equal distance from the anticubital fossa and at the level of the elbow on anterior-posterior and lateral radiographs (Fig. 3).

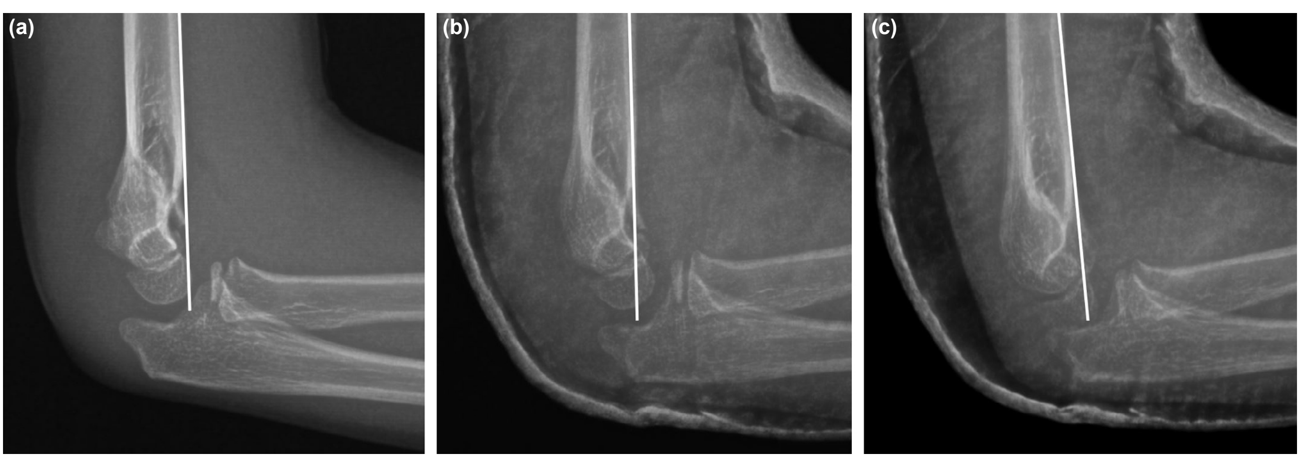

Figure 1. Loss of reduction in a high sagittal fracture pattern treated nonoperatively. Initial **(a)**, post-reduction **(b)** and on the 10th day **(c)**.

Figure 2. Varus and extension malunion after fracture healing in a medial comminuted and high sagittal fracture. Initial **(a and b)** and final follow-up **(c and d)** radiographs.

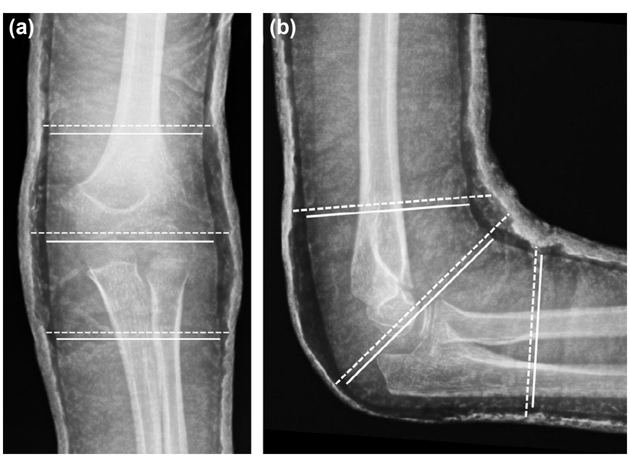

Figure 3. Measurement of soft tissue/inner cast width ratio at arm, elbow and forearm level. Anteroposterior **(a)** and lateral **(b)** elbow radiography.

Statistical Analysis

Data obtained in the study were analyzed statistically using SPSS software (version 15, SPSS Inc., Chicago, IL, USA). Continuous variables showing normal distribution were stated as mean±standard deviation values, those not showing normal distribution as median and interquartile range values, and categorical variables were stated as number (n) and percentage (%). The parameters of age, Baumann angle, SCA, and plaster cast measurements were compared with the Student's t-test or the Mann–Whitney U-test as appropriate. In the analysis of categorical data, the Chi-square test was used. Predictive factors causing LOR were analyzed with logistic regression analysis. A value of $p<0.05$ was accepted as statistically significant.

RESULTS

Evaluation was made of 103 patients who met the inclusion criteria, comprising 62 (60%) males and 41 (40%) females with a mean age of 5.4±2.5 years (2–11.6 years) and mean follow-up time of 32.4±7.5 days (25–65 days). A circular plaster cast was applied after closed reduction in 75 (73%) cases and a posterior splint to 28 (27%). Successful treatment was achieved with closed reduction and plaster cast fixation in 81 (79%) cases and reduction loss was observed in 22 (21%). The comparisons of the demographic data of the patients with successful and unsuccessful treatment are shown in Table 1. No statistically significant difference was determined between the successful and unsuccessful treatment groups in respect of age, gender, initial degree of rotation, and Baumann angle and SCA initially and post-reduction ($p>0.05$).

Of the 22 patients who developed reduction loss, there was seen to be loss of alignment in extension only in 16, in the coronal plane in three, and in both the coronal and sagittal planes in three. LOR developed in the first 7–10 days in 14 patients, and after the 10th day in eight patients. The LOR in the sagittal plane was determined to have developed in a greater number of the HS oblique group in the Bakh classification ($p=0.03$). In the logistic regression analysis, the rate of reduction loss of HS oblique fractures in the sagittal plane was determined to be 3.17-fold higher than those with LS fracture (95% CI: 0.99–10.03, $p<0.05$) (Table 2).

Coronal plane fracture obliquity and medial/lateral metaphyseal impaction were not seen to have any effect on varus or valgus oriented reduction loss ($p=0.64$, $p=0.25$, respectively). There was observed to be reduction loss in the coronal plane in 5 (31%) of the 16 patients with metaphyseal fragmentation, and in 1 (1.6%) of the 87 patients with no fragmentation ($p<0.001$). The risk of reduction loss was found to be 6.5-fold higher in fractures with metaphyseal fragmentation (95% CI: 1.6–26.5, $p<0.01$). No significant difference was determined between the Type IIA and Type IIB subgroups according to the Wilkins classification in respect of the rate of LOR development ($p=0.84$).

No significant difference was determined between patients applied with circular plaster cast and those applied with pos-

Table 1. Patient demographics and fracture charactarestics

	No LOR (n=81)	LOR (n=22)	p-value*
Age (year), (mean±SD), (range)	5.5±2.6 (2–11.6)	5±1.9 (2–8.5)	0.34
Gender, n (%)			
Male	47 (58)	15 (68)	0.38
Female	34 (42)	7 (32)	
Side, n (%)			
Right	26 (32)	9 (41)	0.44
Left	55 (68)	13 (59)	
Wilkins type, n (%)			
IIA	57 (70.4)	15 (68.2)	0.84
IIB	24 (29.6)	7 (31.8)	
Bakh coronal, n (%)			
Transvers	45 (55.6)	11 (50)	0.64
Oblique	36 (44.4)	11 (50)	
Bakh sagittal, n (%)			
Low sagittal	47 (58)	7 (31.8)	0.03
High sagittal	34 (42)	15 (68.2)	
Metaphysis comminution, n (%)	8 (9.9)	8 (36.4)	0.005
Metaphysis impaction, n (%)	33 (40.7)	12 (54.5)	0.25
Initial rotation, n (%)	21 (25.9)	6 (27.3)	0.9
Initial Baumann Angle, (mean±SD)	77.1±5.4	78.3±6.2	0.36
Initial Shaft Condylar Angle, (mean±SD)	25.3±9	22.8±10.5	0.29
Cast angle (mean±SD), (range)	81.1±7.9 (54–100)	80.8±8.2 (65–100)	0.88
Lateral Humero-ulnar angle (mean±SD), (range)	87.5±6.6 (68–103)	87.9±7.7 (72–106)	0.78

LOR: Loss of Reduction; SD: Standard deviation. *From Chi-square test for categorical variables and the t-tests for continuous variables.

Table 2. Results of multivariate logistic regression analyses

	Odds ratio	95% Confidence Interval		p-value
Age	0.97	0.77	1.22	0.80
Gartland type (IIA vs IIB)	0.61	0.19	1.96	0.41
Medial or lateral metaphysis comminution	6.50	1.60	26.50	0.01
Bakh sagittal (Low sagittal vs high sagittal fractures)	3.17	0.99	10.03	0.05
Bakh coranal (Typical transvers vs oblique fractures)	0.45	0.13	1.56	0.21

terior splint in respect of LOR (p=0.28). Although a significant difference associated with the recovery of soft-tissue swelling was determined between the soft-tissue/cast inner width ratio values at early post-reduction and the first follow-up examination in the patients applied with a circular plaster cast (p<0.001), this difference was not statistically significant in respect of LOR (p>0.05). No statistically significant difference was determined between the successful treatment group and the LOR group in respect of the plaster cast flexion angle and the arm angle within the plaster cast (p=0.88, p=0.78, respectively) (Table 1).

Union was obtained in all the patients. No vascular or neural injuries were determined which would change the treatment selection.

DISCUSSION

The aim of the treatment of SCHFs is to obtain fracture alignment, maintain this alignment throughout the fracture union process, and to protect the patient against complications that can develop. While most authors recommend surgical treatment of all patients with Type II SCHF to reach these outcomes,[5,6] others have advocated that the majority of patients can be successfully treated with a non-operative method.[7–9,15]

Although reduction loss is seen more in non-operative treatment, it has been reported as a complication in closed reduction and percutaneous pinning treatment that can lead to poor functional and cosmetic outcomes.[7–9,16–18] It has been reported at rates of 10–22% in groups treated conservatively.[7,8,17] Despite the current determination of specific criteria for reduction loss, the factors held responsible are associated with the patient, the severity of displacement, the cause of the injury, and the fixation quality.[17] This entails the necessity for greater investigation of the concept of stability in Type II fractures and the need to consider optimal treatment selection on an individual basis.

Most authors determine the treatment selection in Type II fractures according to the Wilkins modification of the Gartland classification. However, there are two main problems in treatment selection according to this classification. The first is that despite the separation of Type II fractures into two subgroups, there may be a broad spectrum of fracture geometry and amount of displacement even among fractures in the same group. This means that there could be different levels of soft-tissue damage, which affect fracture stability. The second problem in defining fractures according to the Wilkins modification of the Gartland classification is that interobserver agreement is at a moderate level. The greatest compliance problem is in the differentiation of Types IIA and IIB and the associated treatment options.[10,19]

These ongoing discussions of Type II fracture definitions limitate in the comparison of treatment selection and results. For SCHF meeting the Type II criteria, the American Academy of Orthopaedic Surgeons clinical practice guideline on the treatment of pediatric SCHFs recommends closed reduction and percutaneous pin fixation for all without any separation into subgroups. However, Camus et al.[9] reported that the results of Type IIA and IIB fractures treated with closed reduction and plaster casting were similar. The only difference was that the rate of abnormal AHL was greater in the Type IIA group than in the Type IIB group, and this was reported to be probably due to greater care taken in the reduction of Type IIB fractures, which are more unstable. In the our study, no significant difference was found between the Type II subgroups in respect of the development of LOR. From these results, it was thought that the LOR in conservative treatment cannot be explained by the Wilkins modification alone.

That fracture obliquity has a negative effect on fracture displacement in long bone fractures which is well known.[20] Typically, SCHFs are defined as a transverse fracture line crossing between the epicondyles. However, not all SCHF conform to this definition, and Bahk et al.[11] reported that fractures showing obliquity of >10°in the coronal plane and >20° in the sagittal plane show significant differences in fracture characteristics, treatment, and outcomes, compared to those with a transverse fracture line. There are few studies in the literature related to the effect of fracture obliquity on LOR in SCHF and these have focused on the effect of obliquity on the surgical treatment results.[11,21,22] One of these studies, by Segal et al.,[22] reported the application of surgical treatment to Type II and Type III fractures in 240 patients with a mean age of 9 years. The risk of LOR was found to be 2.9-fold greater in sagittal oblique fractures. In the subgroup analysis, no relationship was determined between the fracture configuration in Type II fractures and LOR. To the best of our knowledge, there are no studies in the literature that have reported the effect of fracture obliquity on LOR in non-operative treatment. In the present study, no relationship was found between coronal plane obliquity and LOR and the result that there was greater reduction loss in fractures with an oblique fracture line in the sagittal plane was not surprising. The area where the fracture develops already has a narrow contact surface, and in fractures with an oblique fracture line, the contact surface, and stability are further negatively affected.

De Boeck et al.[23] observed that even if reduction was obtained initially in minimally displaced SCHF with medial column fragmentation, collapse over time resulted in the development of varus deformity. Reduction loss in the presence of medial fragmentation has been shown in pin fixation and biomechanical studies.[24] In the present study, reduction loss was observed more often in patients with metaphyseal fragmentation. Moreover, cases with impaction were seen to be more stable and no reduction loss was determined at the degrees defined in the presence of impaction. It can be considered that pinning would be appropriate for more stable fixation in the presence of metaphyseal fragmentation.

In the non-operative treatment of Type II SCHF, it is recommended that following reduction, the elbow is positioned at >100° flexion for fixation. However, this approach can lay the ground for compartment syndrome with the swelling compressing the circulation around the elbow.[6] In the present study, no circulation problems were seen in any patient that would necessitate a change in the treatment. In the present study, the mean flexion angle was approximately 80° and no significant difference was determined between the successfully treated group and the LOR group in respect of the plaster cast flexion angle and the humero-ulnar angles. These findings were consistent with the literature.[17]

Although a posterior splint is theoretically a more stable type of fixation than a circular plaster cast, the rates of reduction loss of both these fixation types were found to be similar in the current study. Another important point in plaster cast treatment is that edema resolves over time and there are concerns of reduction loss because of the fracture hematoma resorption and extensive padding. Although many parameters have been studied related to reduction loss that develops following plaster cast fixation of radius distal end fractures, there are very few similar examples related to distal humerus fractures. Fitzgibbons et al.[17] found that padding had no effect on the failure of plaster casting, but a larger arm circumference was determined to be associated with LOR. It was suggested that this could be related to loss of plaster cast stability because of the broad soft-tissue cylinder and the resolution of soft-tissue edema over time. In patients applied with a circular plaster cast in the present study, a reduction in soft-tissue swelling was observed between early post-reduction and the first follow-up examination, but no statistically significant difference was determined in respect of LOR and this reduction. Most of the patients were evaluated in respect of LOR within the first 7–10 days, and this period may not have been sufficient for the formation of a gap within the plaster cast which would cause LOR.

Malunion in extension of the distal humerus reduces the flexion movement of the elbow and clinical studies have reported a statistically significant correlation between final SCA and the degree of elbow flexion.[25] In a study by Spencer et al.,[15] no rotational deformity, coronal malalignment, or significant extension of the distal fragment on the initial X-ray were found to be statistically significant for successful conservative treatment. In the same study, conservative treatment was reported to be suitable for patients with SCA of >15° following reduction. In another retrospective study, Ariyawatkul et al.[26] accepted a cutoff value of >18° difference in the SCA or LCHA compared to the unaffected side in the decision for surgical treatment in patients defined as Type IIA or IIB according to a difference of 5° from the Baumann angle of the uninjured side, and fixation in all Type IIB patients was recommended. One of the hypotheses of this study was that patients with a greater degree of SCA displacement initially would have greater LOR in the sagittal plane, but the study findings did not support this. Moreover, no relationship was determined between initial rotational deformity and Baumann angle and LOR.

There were some limitations to this study, primarily the retrospective design and that the treatment selection was at the discretion of several surgeons and this could have caused patient selection bias. Another limitation was that the early radiological values were considered in the analysis but the clinical efficacy and data of the contralateral extremity were not evaluated. The angular measurements evaluated for LOR could be affected by factors such as age and gender, and to eliminate these, the measurements of the healthy arm can be used. However, in our routine practice, the healthy arm is not examined radiologically.

Conclusion

The results of this study demonstrated that 79% of Type II SCHFs were successfully treated with closed reduction and plaster cast fixation. Independently of the Type II subgroups defined by Wilkins, metaphyseal fragmentation, and high obliquity in the sagittal plane constituted a high risk for LOR. Based on the findings of this study, it can be said that fractures without metaphyseal fragmentation and which are low oblique in the sagittal plane are suitable candidates for plaster cast treatment. Patients other than this group should be closely monitored and evaluated for more stable fixation when necessary.

Ethics Committee Approval: This study was approved by the Metin Sabanci Baltalimani Bone Diseases Training and Research Hospital Clinical Research Ethics Committee (Date: 12.01.2021, Decision No: 66-454).

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ORİJİNAL ÇALIŞMA - *ÖZ*

Non-operatif tedavi edilen Tip II suprakondiler humerus kırıklarında redüksiyon kaybı ile ilişkili risk faktörleri

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AMAÇ: Ekstansiyon Tip II suprakondiler humerus kırıkların optimal tedavi yöntemi seçimi üzerindeki tartışmalar sürmektedir. Çoğu hasta kapalı redüksiyon ve alçılama ile başarılı şekilde tedavi edilse de bir grup hastanın başlangıçta elde edilen redüksiyonu alçıda kaldığı süre boyunca kaybedilir. Bu çalışmanın amacı redüksiyon kaybına neden olan risk faktörlerinin tespitidir.
GEREÇ VE YÖNTEM: 2012–2018 yılları arasında kapalı redüksiyon ve alçı tespiti ile tedavi ettiğimiz 103 Tip II ekstansiyon suprakondiler humerus kırığı hastasının verilerini geriye dönük olarak inceledik. Redüksiyon kaybına neden olan hasta değişkenleri, kırık oblisitesi ve metafiz parçalanması gibi kırık karakter özellikleri, tespit yöntemi ve alçıya ait parametreleri değerlendirdik.
BULGULAR: İncelenen 103 hastanın 62'si erkek, 41'i kız yaş ortalaması ise 5.4±2.5 (aralık, 2–11.6) yıl idi. Seksen bir hasta (%79) kapalı redüksiyon ve alçı tespiti ile başarılı şekilde tedavi edilirken, 22 (%21) hastada redüksiyon kaybı izlendi. Sagittal planda high oblique kırıkların redüksiyon kaybı oranı transvers olanlara göre 3.17 kat yüksekti (%95 CI: 0.99–10.03, $p<0.05$). Metafizer parçalanma olan kırıklarda redüksiyon kaybı riski 6.5 kat yüksek bulundu (%95 CI: 1.6–26.5, $p<0.01$). Redüksiyon kaybı ile Gartland subtipi, cinsiyet, yaş, başlangıçtaki rotasyon varlığı, alçı açısı ve yumuşak doku/alçı iç çap genişliği oranları arasında anlamlı ilişki bulunmadı.
TARTIŞMA: Çalışma grubumuzdan elde ettiğimiz sonuçlara göre ekstansiyon Tip II kırıklar kapalı redüksiyon ve alçılama ile %79 oranında başarılı şekilde tedavi edilebilir. Sagittal plan oblisitesi ve metafiz parçalanması redüksiyon kaybı için Gartland subtipinden bağımsız risk faktörleridir.
Anahtar sözcükler: Alçı tedavisi; Gartland Tip II; humerus; oblik; redüksiyon kaybı; suprakondiler.

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