Factors Affecting Outcomes of Adult Forearm Fractures Treated by Locking Compression Plate

Ali UTKAN[*], Burak KOÇAK[**], Kubilay Uğurcan CERİTOĞLU[***], Aydın ARSLAN[****], Bülent ÖZKURT[*****]

Abstract

Aim: Although internal fixation of forearm fractures by dynamic compression plates had been studied extensively, the details of optimal fixation by locking compression plates are not clearly defined. Besides the factors affecting the functional outcome is still the subject of considerable debate. The present study is designed to evaluate factors affecting the outcomes of adult forearm fractures treated via locking compression plate.

Method: The patients with Gustillo Anderson type 3 open fractures or the ones treated in intensive care unit were excluded and thirty-six forearm fractures treated by locking compression plate were prospectively followed. Disability Arm Shoulder Hand (DASH) and Anderson criteria scores for assessment of outcomes obtained at sixth month were evaluated. The patients were followed up for 4 (3-6) years on average.

Findings: In 18 (50%) patients, fractures were caused by simple fall. The mean healing time of the fractures was 13.2 ± 2.1 weeks. Patients, who smoked or had open fractures or complications, had longer healing time. Mean DASH score was calculated as 13.9 ± 5.9. Upon

Özgün Araştırma Makalesi (Original Research Article)
Geliş / Received: 08.06.2018 **& Kabul / Accepted:** 21.06.2018
[*] MD, University of Health Sciences, Ankara Numune Research and Training Hospital, Orthopedics and Traumatology Clinic, Ankara Turkey, E-mail: utkana@yahoo.com ORCID ID https://orcid.org/0000-0002-3653-3998
[**] MD, University of Health Sciences, Ankara Numune Research and Training Hospital, Orthopedics and Traumatology Clinic, Ankara Turkey, E-mail: drburakkocak26@gmail.com ORCID ID https://orcid.org/0000-0003-4327-3431
[***] MD, University of Health Sciences, Ankara Numune Research and Training Hospital, Orthopedics and Traumatology Clinic, Ankara, Turkey, E-mail: kceritoglu@gmail.com ORCID ID https://orcid.org/0000-0002-7111-6831
[****] Corresponding Author, MD, Istanbul Gelişim University, School of Health Sciences, Istanbul, Turkey, E-mail: draarslan@hotmail.com ORCID ID https://orcid.org/0000-0001-5036-517X
[*****] PhD, MD. Prof., University of Health Sciences, Ankara Numune Research and Training Hospital, Orthopedics and Traumatology Clinic, Ankara, Turkey, E-mail: drbulentozkurt@yahoo.com ORCID ID https://orcid.org/0000-0002-6135-1870

presence of open fracture or postoperative complication there was a significant deterioration in scores. Although the cause of the injury had some effect on functional results the mechanism (whether the injury was direct or indirect) made no difference.

Conclusion: Fracture type was the most important factor affecting both healing time and outcome. Being an open fracture or the presence of postoperative complication deteriorates the outcome. The functional results were somewhat poorer in fractures caused by simple fall.

Keywords: Forearm fracture, osteosynthesis, locking compression plate.

Kilitli Kompresyon Plağı ile Tedavi Edilmiş Erişkin Önkol Kırıklarının Sonuçlarını Etkileyen Faktörler

Öz

Amaç: Önkol kırıklarının dinamik kompresyon plağı kullanılarak yapılan internal tespiti ile ilgili birçok çalışma bulunmakla birlikte, kilitli kompresyon plakları ile yapılacak en uygun fiksasyonun detayları henüz yeterince tanımlanmamıştır. Ayrıca fonksiyonel sonucu etkileyen faktörler halen tartışma konusudur. Bu çalışmanın amacı, kilitli kompresyon plağı kullanılarak tedavi edilen önkol kırıklarının klinik sonuçlarına etkiyen faktörleri değerlendirmektir.

Yöntem: Gustillo Anderson tip 3 açık kırığı olan veya yoğun bakımda yatan hastalar hariç tutularak, kilitli kompresyon plağı ile tedavi edilen 36 önkol kırığı hastası prospektif olarak değerlendirildi. Altıncı ayda Disability Arm Shoulder Hand (DASH) skoru ve klinik sonuçların değerlendirilmesi için kullanılan Anderson kriterleri skorları ile değerlendirildi. Hastalar ortalama 4 (3-6) yıl takip edildi.

Bulgular: On sekiz hastada (%50) kırık nedeni basit düşmeydi. Ortalama iyileşme süresi 13.2±2.1 hafta olarak bulundu. Sigara içen hastaların veya açık kırığı olanların ya da ameliyat sonrası komplikasyon gelişen hastaların iyileşme süresi daha uzundu. Ortalama DASH skoru 13.9±5.9 hesaplandı. Açık kırık veya komplikasyon varlığının skorlar üzerinde anlamlı olumsuz etki yaptığı belirlendi. Yaralanma nedeninin fonksiyonel sonuçlara az da olsa etkisi olmasına rağmen yaralanma mekanizmasının (direkt ya da dolaylı olmasının) istatistiksel anlamlı bir etkisi saptanmadı.

Sonuç: Hem iyileşme zamanı hem de klinik sonuçlara etki eden en önemli faktörün kırık tipi olduğu tespit edildi. Açık kırık yada ameliyat sonrası komplikasyon varlığı sonuçları kötü yönde etkilemektedir. Basit düşmeye bağlı gelişen kırıklarda fonksiyonel sonuçlar biraz daha kötü olmaktadır.

Anahtar Sözcükler: Önkol kırıkları, osteosentez, kilitli kompresyon plağı.

Introduction

Although the incidence of the fractures of the forearm is generally low in adults, these fractures could result in considerable disability if the native forearm geometry is not restored[1-3].There are some intramedullary nails that provide control of rotational malalignment at the fracture line but their usage is vulnerable to complications and internal fixation with the plate is still considered as the gold standard[4-9].

The internal fixation of forearm fractures with Dynamic Compression Plate (DCP) had been studied extensively but there are only few studies with Locking Compression Plates (LCP). The purpose of the present study is to investigate factors affecting functional and radiographic outcomes of adult forearm fractures treated by LCP focusing on factors that influence the perception of disability of the patients.

Material and Method

All the patients treated for forearm fractures in our clinic from March 2011 to March 2014 were prospectively followed up. Of these, the patients who were below 18 years of age, those having Gustillo-Anderson type 3 open fractures or patients treated in the intensive care unit and one mental motor retarded patient were excluded and the remaining thirty-six patients included in the current study. All the fractures were treated with LCP and none of these were lost to follow up at least for three years. Approval for the study was granted by the hospital Ethics Committee. The fractures were classified according to AO/ASIF (Arbeitsgemeinschaft fur Osteosynthesefragen, Association for the Study of Internal Fixation) classification. If the bones were broken at the point of impact by direct blow the injury was accepted as direct whereas if broken by bending or rotational forces was accepted as indirect injury.

The patients were operated approximately 2 (0-5) days following the injury and the fractures were fixed with 3.5 mm self-tapping cortical or locked screws through LCP having combi holes by paying attention to AO principles and biological fixation systems.

Figure 1: AP and lateral X-rays of 45-year-old man hit by a car

a,b. Preoperative

c,d. Postoperative 2 weeks

e,f. Postoperative 16 weeks

The decisions concerning the length of the plate, number of screws used, whether to make pressure to the fracture line and the order in which the cortical and locked screws would be placed were not standardized and were given during the operation by the surgical team. Bone grafting was not used in any fracture. Patients who did not have any problem were discharged on the second day.

The patients were followed up appropriately. At the sixth month the validated Turkish version of Disabilities of the Arm, Shoulder and Hand (DASH) outcome measure[10,11] were obtained. The final results were scored by criteria for assessment of functional outcome as described by Anderson[12] (Table 1). The patients were followed up for 4 (3-6) years on average.

Table 1: Functional outcome as described by Anderson

Excellent	union with less than 10 degrees loss of flexion-extension and less than 25 % loss of pronation-supination
Satisfactory	union with less than 20 degrees loss of flexion-extension and less than 50 % loss of pronation-supination
Unsatisfactory	union with less than 30 degrees loss of flexion-extension and less than 50 % loss of pronation-supination
Failure	non-union with or without loss of motion

Statistical analyses were performed using SPSS Statistics for Windows, version 21.0 (IBM Corp., Armonk, NY). Shapiro Wilk test was used to evaluate whether the distribution of continuous variables were normal or not. Mann Whitney U test and Kruskal-Wallis variance analysis were used to compare healing times and DASH scores of subgroups. Fisher's Exact test was used in order to evaluate Anderson scores of subgroups. A p-value of <0.05 was considered to be statistically significant.

Findings

There were 28 male (77.8%) and eight female (22.2%) patients and the mean age was 40.4±17.1 (19-76) years. Five of the fractures were (13.9%) radius shaft, 13 were (36.1%) ulnar shaft, 14 were (39.9%) both bones of the forearm and four were (11.1%) Monteggia fractures. Eighteen fractures (50%) were due to simple falls and 18 (50%) injuries were due to other causes (intra vehicular or extravehicular traffic accidents,

industrial accidents and violence). When the mechanism causing the fracture was analyzed, 26 (62%) were due to direct trauma, 10 (28%) were due to indirect trauma.

Twenty-nine fractures (81%) were closed, six (16%) were type 1 and one (3%) was type 2 open fracture. There were 12 (33%) simple, 16 (45%) wedge, 8 (22%) complex fractures. Based on subgrouping, the highest number of patients were in subgroups A1.2 and A3.2 according to AO/ASIF classification. Twenty-six patients (72.2%) were active smokers before surgery while 10 (27.8%) had never smoked. Four patients had additional injuries, which were listed in Table 2.

Table 2: List of comorbitities

Patient number	**Comorbidity**
22	Ipsilateral 5.metacarp fracture
33	Ipsilateral shoulder dislocation
34	Ipsilateral radius head fracture
36	Bilateral clavicula and ipsilateral humerus shaft fracture

After the surgery, one patient has developed brachial plexus paralysis due to the supraclavicular block used for regional anesthesia. It completely healed at fourth month. Nine patients had superficial wound site infections that were treated by antibiotics but did not necessitate additional surgical interventions. These ten patients considered as having complications. Fourteen percent of the patients with closed fractures and 71% of the patients with open fractures developed superficial wound site infections yet completely healed after prompt treatment.

All the fractures healed without additional procedures and there was no implant failure. Radiological and clinical fracture healing time were identified as 13.2 ± 2.1 (7-24) weeks (Table 3).

Table 3: Comparison of healing times according to fracture

	Healing time (week)		*P**
	mean ± sd	**min-max**	
Fracture type (N)			0.013
Simple (12)	11.6 ± 2.3	7-16	

Wedge (16)	13.0± 2.7	9-16	
Complex (8)	15.5 ± 3.1	9-24	
Fracture region (n)			
Radius (5)	12.6±3.1	7-16	
Ulna (13)	11.6±1.6	9-14	0.105
Radius and ulna (14)	14.4±3.7	9-24	
Monteggia (4)	13.7±1.7	12-16	

* Kruskal-Wallis variance analysis

Healing time was significantly differed based on the type of fracture ($p<0.05$), but not based on the fractured region. Simple fractures healed earlier than the others. The patients who had fractures due to simple falls had similar healing time compared to others (Table 4).

Table 4: Comparison of healing time

	Healing time (week)		*P**
	mean ± sd	**min-max**	
Etiology (n)			0.308
Simple fall (18)	13.6±3.2	7-20	
Other (18)	12.6±2.7	9-24	
Trauma (n)			0.396
Direct (26)	12.7±2.6	9-24	
Indirect (10)	14.0±3.7	7-20	
Postop. complication presence (N)			0.037
No (26)	11.9±1.8	7-16	
Yes (10)	13.6±2.4	8-24	
Open fracture (N)			0.024
No (29)	12.4±2.5	7-16	
Yes (7)	15.5±3.4	10-24	
Smoking (N)			0.020
No (10)	11.6± 1.6	7-16	
Yes (26)	13.6± 2.2	9-24	

* Mann Whitney U test

Also having a direct or indirect trauma did not effect the healing time. Patients who had complications had longer healing time compared to those with no complications ($p<0.05$) and smokers had longer healing time compared to non-smokers ($p<0.05$).

For the functional assessment of the patients, DASH score at sixth month was calculated as 13.9±5.9 (0-32). The comparisons of DASH scores regarding etiology, mechanism, presence of complications or open fracture and the fracture type is given in Table 5.

Table 5: Comparison of DASH scores

	DASH score		*P*
	mean ± sd	**(min-max)**	
Etiology (N)			
Simple fall (18)	16.1± 7.1	(0-32)	0.022*
Other (18)	11.1 ±3.7	(0-22)	
Trauma (N)			
Direct (26)	11.9 ± 7,9	(0-32)	0.07*
Indirect (10)	16.1 ± 4.9	(0-25)	
Postop. complication (N)			
No (26)	11.2 ± 5.8	(0-26)	0.029*
Yes (10)	17.2 ± 6.4	(7-32)	
Open fracture (N)			
No (29)	12.2 ± 7.8	(0-32)	0.037*
Yes (7)	16.6 ± 3.6	(10-22)	
Fracture type (N)			
Simple (12)	8.5 ± 4.7	(0-15)	0.019†
Wedge (16)	15.6± 7.9	(9-26)	
Complex (8)	14.8± 7.2	(7-32)	

* Mann Whitney U test

† Kruskal-Wallis variance analysis

The correlation between the DASH score of the patients and the type of fracture revealed that, the DASH scores of patients having simple, wedge and complex fractures were different ($p<0.05$). Patients with simple fractures had lower DASH scores than

patients with wedge and complex fractures. Scores differed significantly based on whether the fractures were due to falls, whether they were open fractures or whether patients developed complications.

According Anderson criteria 18 patients had excellent results, 15 had satisfactory results and three patients had unsatisfactory results (Table 6).

Table 6: Comparison of functional outcome according to Anderson

	Excellent		**Satisfactory**		**Unsatisfactory**		*P**
	N	**%**	**N**	**%**	**N**	**%**	
Etiology							
Fall	9	50	7	39	2	11	0.105
Other	9	50	8	44	1	6	
Trauma							
Direct	14	54	11	42	1	4	0.243
Indirect	4	40	4	40	2	20	
Postop complication							
No	16	64	7	28	2	8	0.000
Yes	2	18	8	73	1	9	
Open fracture							
No	17	59	10	34	2	7	0.011
Yes	1	14	5	72	1	14	
Fracture type							
Simple	10	83	2	17	-	-	
Wedge	6	38	9	56	1	6	0.001
Complex	2	25	4	50	2	25	
Fracture group							?
Radius	1	20	4	80	-	-	
Ulna	11	85	2	15	-	-	
Radius and ulna	5	36	8	57	1	7	
Monteggia	1	25	1	25	2	50	

* Fisher's exact test

When Anderson scores were compared, the cause of the fracture or having a direct versus indirect trauma was not significant. The percentage of patients having excellent

Anderson scores was higher among patients without complications compared to those who developed ($p<0.001$). Anderson scores differed based on the type of fractures ($p<0.01$). Patients with simple fractures had higher percentages of excellent scores compared to both wedge and complex fracture patients ($p<0.01$). There was no difference between the Anderson scores of patients with wedge and complex fractures. Patients who did not have open fractures had higher percentages of excellent scores ($p<0.05$).

Discussion

The LCP is a plate with combi holes where conventional and locked screws can be used in a combined manner allowing for having compression on the fracture line[13-15]. These plates increase the strength of fixation in osteoporotic bones and they can be used as bridging plates to provide relative stability but their usage in the treatment of simple fractures is not clearly reported in the literature and the guidelines concerning their usage in forearm fractures are ill defined. Azboy[16]compared LCP versus DCP in the treatment of diaphyseal forearm fractures and concluded that results were similar and correct selection and application of surgical technique was more important.

In forearm fractures it is difficult to radiologically confirm the healing of the fractures especially when absolute stability is provided[17]. In the present study, the disappearance of the gap in the fracture line on two sided X-rays and having no pain on the fracture line upon palpation were regarded as union. The fractures of all patients healed in an average of 13 weeks. The healing time of the fractures did not differ based on sex or the injury being caused by direct or indirect trauma. The average healing time for open fractures was slower. (15.5 weeks). In their study, Shah[7]reported that, mean healing time was 10.5 weeks for simple fractures, 12.3 weeks for wedge fractures and 14.6 weeks for complex fractures. Likewise in the current study healing time for complex fractures was longer than those of the simple and wedge fractures.

The deleterious effects of smoking on acute fractures as well as on orthopedic procedures are well known in the literature[18,19]. In the present study the patients who smoked had statistically significant longer healing period. Anderson[12] had a group of 244 patients whom they treated via compression plates and they identified the postoperative infections as a complication at a rate of 2.4%. In the current study, nine patients developed superficial infections. None of the patients required further surgical

intervention and all of them healed with antibiotic treatment. Healing times of the patients developing postoperative complications were significantly longer than those who did not have complications.

In Golfarb's[20] study mean DASH scores was found as 12±10 after 2.8 years on average. In the present study mean DASH score was 13.9±5.9 at sixth month. The mean score was 16.6 in patients having postoperative complications and 17.2 in patients with open fractures. The differences were significant in both of them. Likewise the scores of the patients with simple, wedge and complex fractures differed significantly.

DASH scores did not differ based on sex, age, types of fracture, having direct or indirect injury or having additional injuries. Interestingly, patients who had fractures due to falls had significantly higher scores. On the contrary patients whose bones were broken due to accidents or violence were more satisfied with the outcome documented by lower DASH scores.

Anderson[12] reported that functional outcomes were excellent or satisfactory in 85% of their patients. In the present study, based on Anderson scores, of the 36 patients 50% had excellent, 42% had satisfactory and 8% had unsatisfactory results. Patients who developed complications, who had open fractures and who had wedge or complex type of fractures had statistically significantly worse Anderson scores.

Heterogeneity caused by different type of fractures and the relative small sample size avoiding exploring surgical details were the major limitations of the study.

Conclusion

The patients who broke their bones after a simple fall had similar Anderson scores in comparison to other patients therefore their outcome was accepted comparable however their perceived disability as measured with the DASH were worse. In other words patients admitted after a simple fall felt relatively less capable in comparison to remaining patients, Although the difference in DASH scores was small to be considered clinically important this issue needs to be investigated with a larger study.

REFERENCES

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. *Injury*. 2006;37(8):691-697.

2. Kasten P, Krefft M, Hesselbach J, Weinberg AM. How does torsional deformity of the radial shaft influence the rotation of the forearm? A biomechanical study. *J Orthop Trauma*. 2003;17(1):57-60.

3. Tynan MC, Fornalski S, McMahon PJ, Utkan A, Green SA, Lee TQ. The effects of ulnar axial malalignment on supination and pronation. *J Bone Joint Surg Am*. 2000;82-A(12):1726-1731.

4. Gadegone W, Salphale YS, Lokhande V. Screw elastic intramedullary nail for the management of adult forearm fractures. *Indian Journal of Orthopaedics*. 2012;46(1):65-70.

5. Ruedi T, Buckley R, Moran C. *AO Principles of Fracture Management*. 2nd ed. Thieme Medical Publishers; 2007.

6. Saka G, Sağlam N, Kurtulmuş T, et al. New interlocking intramedullary radius and ulna nails for treating forearm diaphyseal fractures in adults: a retrospective study. *Injury*. 2014;45(Suppl 1):16-23.

7. Shah AS, Lesniak BP, Wolter TD, Caird MS, Farley FA, Vander HKL. Stabilization of adolescent both-bone forearm fractures: a comparison of intramedullary nailing versus open reduction and internal fixation. *J Orthop Trauma*. 2010;24(7):440-447. doi: 10.1097/BOT.0b013e3181ca343b.

8. Kim SB, Heo YM, Yi JW, Lee JB, Lim BG. Shaft fractures of both forearm bones: The outcomes of surgical treatment with plating only and combined plating and intramedullary nailing. *Clinics in Orthopedic Surgery*. 2015;7(3):282-290.

9. Yörükoğlu AÇ, Demirkan AF, Akman A, Kitiş A, Usta H. The effects of radial bowing and complications in intramedullary nail fixation of adult forearm fractures. *Eklem Hastalık Cerrahisi*. 2017;28(1):30-34. doi: 10.5606/ehc.2017.05.

10. Düger T, Yakut E, Öksüz Ç, et al. Kol, omuz ve el sorunları (Disabilities of the Arm, Shoulder and Hand - DASH) anketi Türkçe uyarlamasının güvenirliği ve geçerliği. *Fizyoterapi Rehabilitasyon*. 2006;17(3):99-107.

11. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand). The

Upper Extremity Collaborative Group (UECG). *Am J Ind Med*. 1996;29(6):602-608.

12. Anderson LD, Sisk D, Tooms RE, Park WI. Compression-plate fixation in acute diaphyseeal fractures of the radius and ulna. *J Bone Joint Surg Am*. 1975;57(3):287-297.
13. Perren SM. Evolution of the internal fixation of long bone fractures. The scientific basis of biological internal fixation: choosing a new balance between stability and biology. *J Bone Joint Surg Br*. 2002;84(8):1093-1110.
14. Wagner M. General principles for the clinical use of the LCP. *Injury*. 2003;34(Suppl 2):31-42.
15. Matthews SJ, Nikolaou VS, Giannoudis PV. Innovations in osteosynthesis and fracture care. *Injury*. 2008;39(8):827-838. doi: 10.1016/j.injury.2008.06.016.
16. Azboy I, Demırtas A, Uçar BY, Bulut M, Alemdar C, Ozkul E. Effectiveness of locking versus dynamic compression plates for diaphyseal forearm fractures. *Orthopedics*. 2013;36(7):e917–922. doi: 10.3928/01477447-20130624-23.
17. Davis BJ, Roberts PJ, Moorcroft CI, Brown MF, Thomas PB, Wade RH. Reliability of radiographs in defining union of internally fixed fractures. *Injury*. 2004;35(6):557-561. doi: 10.1016/S0020-1383(03)00262-6.
18. Al-Hadithy N, Sewell MD, Bhavikatti M, Gikas PD. The effect of smoking on fracture healing and on various orthopaedic procedures. *Acta Orthop Belg*. 2012;78(3):285-290.
19. Scolaro JA, Schenker ML, Yannascoli S, Baldwin K, Mehta S, Ahn J. Cigarette smoking increases complications following fracture: a systematic review. *J Bone Joint Surg Am*. 2014;96(8):674-681.
20. Goldfarb CA, Ricci WM, Tull F, Ray D, Borrelli J. Functional outcome after fracture of both bones of the forearm. *J Bone Joint Surg Br*. 2005;87(3):374-379.