Original Article

Is Methyl Methacrylate Fixator Reliable for the Treatment of Gartland Type IV Supracondylar Fractures?

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Abstract

Background: In childhood supracondylar fractures of the humerus, fixation with percutaneous Kirschner wire is the standard treatment. In the case of irreducible–unstable fractures, these can be defined as fractures in which reduction is not well-achieved or in which fixation cannot be achieved with the K-wire. Intraoperative management of these types of fractures may be difficult. Treatment with a methyl methacrylate fixator consisting of K-wire and methyl methacrylate cement, as defined by the senior author of the article, may be a good option for Gartland type IV supracondylar humeral fractures where the fracture is unstable in flexion and extension due to complete periosteal tearing. **Materials and Methods:** The short-term and mid-term results of 27 patients between the ages of 4–12 with Gartland type IV supracondylar fracture of the humerus treated with methyl methacrylate fixation were reviewed. The patients were scored in terms of function and cosmetic satisfaction. **Results:** A total of 19 of the 27 patients treated with the methyl methacrylate fixator had full elbow motion function and rated the outcome of the treatment as excellent, which was judged by orthopedic surgeons on the basis of Flynn's criteria. Six patients had nearly full elbow motion and evaluated their recovery outcome as good. Two patients reported nearly full range of motion (ROM) and evaluated the method as moderate in terms of treatment. **Discussion:** Treatment with the methyl methacrylate fixation method is an inexpensive method that allows early joint mobilization, provides strong biomechanical stability, ensures good outcomes, and should be considered in the treatment of irreducible and unstable supracondylar fractures of the humerus.

Keywords: *Fixator, methyl methacrylate, supracondylar humerus fractures, unstable fractures*

Introduction

Supracondylar fractures of the humerus are among the most common pediatric fractures, especially in preschool and primary school children between the ages of 4 and 8. There is no difference in incidence between genders.[1] Supracondylar humerus fractures are the second most common type of fractures in pediatric patients.[2,3] Gartland type IV fractures were not initially described by Gartland. Leitch *et al*. later reported that fractures that were unstable at flexion and extension can be described as Gartland type IV fractures.[4] Subsequently, Mitchell *et al*. described five preoperative radiographic parameters that predicted that the fracture was more likely to be of type IV: flexion of the distal fragment, valgus angulation, lateral translation, bone apposition, and extension of the fracture line into the diaphysis.[5] In the literature, both the type of fracture and surgical complications have been reported to result in up to 20% incidence of nerve injury in this type of fracture.[6] Chen *et al*. reported 10 nerve injuries in their 49-patient supracondylar case series.[6] Displaced

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supracondylar humerus fractures are most commonly treated surgically.[7-9] In addition, neurovascular injury and circulation problems may be observed[8-10] and deformities following the epiphyseal problems in the post-treatment period may also be encountered.[11,12] Therefore, treatment of these fractures may be a challenge for inexperienced orthopedic surgeons.[13] For childhood supracondylar humerus fractures, percutaneous Kirschner wire fixation is the standard treatment.[14] K-wires can be applied in various variations in the stabilization of the percutaneous closed reduction of the fracture. There are many publications in the literature regarding the placement of K-wires. Lateral and medial configurations in different numbers and angles have been described. In some cases, closed reduction cannot be achieved, especially in patients with Gartland type IV fractures with cortical comminution.[15] In such fractures, either open reduction or fixator treatment might be necessary. Previous studies showed that external fixator treatment has good outcomes and is safe in the treatment of children's supracondylar humerus fractures.[13,14]

The aim of this study was to present the early and mid-term results of Gartland type IV supracondylar humerus fractures treated with an artificial fixator, which is made up of methyl methacrylate and K-wires.

Materials and Methods

Patients, settings, ethics

The study was approved by the Research Ethics Committee of Selcuk University Faculty of Medicine and was conducted in accordance with the Declaration of Helsinki. All patients with Gartland type IV supracondylar humerus fractures who were treated by the same orthopedic surgeon with experience in pediatric and upper extremity trauma at the Department of Orthopaedics and Traumatology of Selcuk University Faculty of Medicine between 2014 and 2018 were retrospectively evaluated. Twenty-seven patients with Gartland type IV supracondylar humerus fractures, aged 4–12 years, treated with a methyl methacrylate external fixator were included in the study. Patients with neurological and vascular damage, patients with fractures that can be reduced open and with K-wire fixation, and patients with type II and type III fractures were not included in the study. Factors such as patient age, side of fracture, mechanism of fracture formation, and whether the fracture was open or closed were evaluated. Bone union status, elbow alignment, anterior humeral line (Roger's line),[11,16] Baumann's angle, and bearing angle were evaluated at postoperative follow-up. Range of motion (ROM) of the joint was measured by an orthopedic surgeon using an angle meter. Complications and Flynn's criteria for patient satisfaction were also evaluated.[17]

Statistical analysis

Continuous variables were expressed as mean and standard deviation (SD). Results were reported within a 95% confidence interval (CI) and with corresponding *P* values. The normality distribution of continuous data was tested using the Shapiro–Wilk test, hologram, skewness, and kurtosis values. Preoperative and postoperative comparisons were made using Mann–Whitney U test for non-normally distributed data and Student's *t*-test for normally distributed data. $P \leq 0.05$ was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics version 22. Mann–Whitney U test was used to examine the difference between ROM measurements of the operated elbow and the healthy contralateral side.

Surgical technique

All surgical procedures were performed within 12 hours following the fracture event. When we decided to do an open reduction and felt that a traditional K-wire fixation would not be sufficient to manage the fracture, we used a methyl methacrylate fixator to manage the fracture. Then, four K-wires were placed polyaxially from the lateral side of the distal humerus to the distal part of the fracture line. During insertion, attempts were made to insert from anterolateral to posteromedial, from posterolateral to anteromedial, and from completely lateral to medial at different angles in the polyaxial plane. Then, while preserving the radial nerve, four K-wires were similarly inserted proximal to the fracture line at different axes. After completion of reduction, the K-wires were bent over each other approximately 3 cm above the skin. In some cases, a close reduction was achieved using the K-wires as a joystick (in this condition, the K-wires should be bent over each other before reduction). However, in most cases, the fracture line could be reduced openly. After accomplishing the reduction, the bone cement (methyl methacrylate) was prepared, placed on the K-wires, and allowed to set when the fracture was in a completely reduced position [Figure 1]. Patients were fitted with a long-arm splint. A lateral approach was used for all open reduction procedures. When pinning the distal part of the fracture, care was taken not to pass through the medial cortex to preserve the ulnar nerve. As the flexibility of the fixator will increase with the use of thinner K-wire, at least 1.6-mm-thick K-wire was used in surgical procedures. On average, the K-wire was placed, 4–6 mm distal and no less than 4 mm proximal to the fracture line using sterilized scalpel.

Postoperative follow-up

Patients were instructed to have daily dressings with iodine solution. A sponge with povidone was left at the

base of the pins. One patient developed hypersensitivity to the iodine solution. On postoperative day 3, the splint was removed and motion was allowed [Figure 2]. The same splint was also used as a night splint to avoid pain and other disadvantages. The K-wires and fixator were removed approximately three weeks after bone union [Figure 3]. When the fixator was removed, the K-wires were first cut from the cement side under sedation. The K-wires were then removed. Plaster splints were not applied after removal of the fixators. They were closed with a bandage for two days and then left completely open. The fixators were removed at the end of two months according to the follow-up radiographs and physical examination findings. During the postoperative follow-up week 2 and week 4, it was difficult to evaluate the lateral radiographs because of the cement. We dealt with it using the relationship between the anterior humeral line and the capitellum. Patients were evaluated at two, six, 12, and 18 months after surgery and were excluded from follow-up at 18 months. Radiographs and joint ROM were evaluated. None of the patients underwent postoperative physiotherapy.

Results

Demographics

A total of 13 patients were female and 14 patients were male. The mean age of the patients was 7.9 years (min: 4; max: 12; SD: 2.22) [Table 1]. The radiographs were evaluated for Baumann's and carrying angles. Baumann's and carrying angles were evaluated on the radiographs at postoperative follow-up months 2 and 18 [Figure 4]. There were no statistical differences ($P > .05$) in the radiographic measurements. Early and mid-term results were evaluated at two [Table 2a] and 18 months [Table 2b] postoperatively according to Flynn's criteria.

Complications

Patients with preoperative nerve injury were excluded from the study. None of the patients developed permanent ulnar or radial nerve injury during the postoperative period; radial nerve neuropraxia was observed in two patients and was thought to be due to retraction. Radial nerve function in these patients fully recovered by postoperative month 2 and week 4, respectively. Pin-site infections were observed in two patients. These were treated with oral antibiotics and wound dressings. Pin fracture occurred in none of the patients.

Postoperative period

In the postoperative period, just before the fixators were removed (postoperative month 2), patients were given a cosmetic satisfaction questionnaire. These results were

Table 1: Patient demographics

Patient no.	Age, (years)	Gender	Cause of injury	Side	Fracture type
1	4	F	Fall	Right	Closed
2	8	F	Fall	Left	Closed
3	6	M	Fall	Left	Closed
4	12	M	Fall	Left	Closed
5	7	F	Fall	Right	Closed
6	10	M	Fall	Left	Closed
7	11	F	Traffic accident	Right	Type 1 open
8	7	M	Fall	Left	Closed
9	9	M	Fall	Left	Closed
10	7	F	Traffic accident	Right	Closed
11	12	M	Bicycle accident	Left	Closed
12	8	M	Fall	Right	Closed
13	5	F	Fall	Right	Closed
14	6	M	Fall from great height	Left	Type 1 open
15	7	F	Fall	Right	Closed
16	10	M	Fall	Left	Closed
17	5	F	Bicycle accident	Left	Type 1 open
18	6	M	Fall	Right	Closed
19	9	M	Fall	Right	Closed
20	5	F	Fall	Left	Closed
21	8	F	Fall	Right	Closed
22	11	F	Fall	Left	Closed
23	9	M	Fall	Left	Closed
24	6	M	Fall	Right	Closed
25	7	F	Bicycle accident	Right	Closed
26	8	M	Fall	Left	Type 1 open
27	10	F	Fall	Right	Closed

Table 2a: Cosmetic and functional outcomes according to Flynn's criteria (two months)

	Overall, *n* (%)	Functional outcome, *n* (%)	Cosmetic outcome, *n* (%)
Excellent	13 (48,14)	19 (70,37)	4 (14,8)
Good	6 (22,22)	4 (14,8)	6 (22,22)
Fair	4 (14,8)	2 (7,4)	10 (37,03)
Poor	4 (14,8)	2 (7,4)	7 (25,92)

Table 2b: Cosmetic and functional outcomes according to Flynn's criteria (18 months)

	Overall, *n* (%)	Functional outcome, *n* (%)	Cosmetic outcome, *n* (%)
Excellent	19 (70,37)	21 (77,77)	19 (70,37)
Good	6 (22,22)	6 (22,22)	4 (14,8)
Fair	2 (7,4)	0	4 (14,8)
Poor	0	0	0

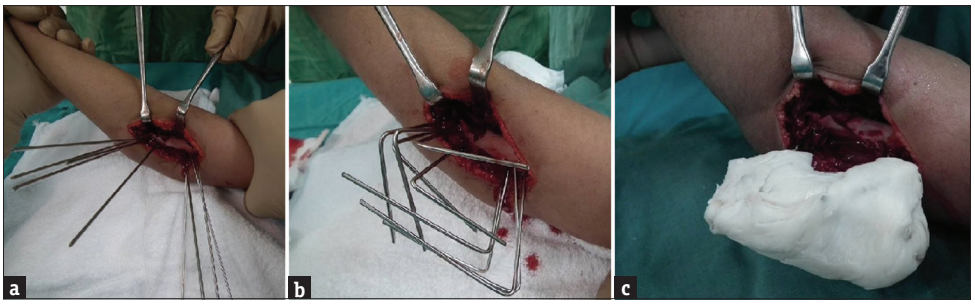

Figure 1: (a) Multiaxial K-wire intraoperative view. (b) Bending the K-wires to the opposite side. (c) Fracture reduction using bone cement

Table 3: ROM and carrying angle during postoperative month two

	Flexion Normal side	Flexion	Extension Normal side	Extension	Supination normal side	Supination operated side	Pronation side	Pronation operated side	Carrying angle normal side	Carrying angle
1	145	125	0	-20	80	75	80	70	10	10
2	135	120	0	-15	80	70	80	75	8	8
3	145	125	0	-10	75	70	80	80	10	10
4	140	115	0	-20	80	70	75	70	8	10
5	145	135	0	-5	70	60	80	80	11	10
6	145	130	0	-20	80	65	80	65	10	10
7	140	135	0	-10	80	80	80	80	15	13
8	145	140	0	0	70	70	80	75	10	10
9	145	125	0	-5	80	80	80	70	10	9
10	145	135	0	0	80	70	75	75	11	12
11	140	120	0	-10	80	60	80	80	10	10
12	145	125	0	-5	80	70	80	80	14	14
13	145	135	0	-15	80	70	80	80	11	10
14	145	125	0	-30	80	70	80	65	12	11
15	130	120	0	-5	70	60	80	75	10	10
16	140	135	0	-15	80	75	80	70	11	10
17	135	125	0	-10	80	75	80	75	9	9
18	145	130	0	-5	80	70	75	65	11	10
19	135	115	0	-20	80	75	80	80	12	12
20	140	135	0	0	75	65	80	75	8	8
21	140	135	0	-10	80	70	80	70	12	13
22	145	125	0	-15	80	80	75	75	11	11
23	145	130	0	-20	80	70	80	70	10	9
24	135	120	0	0	75	70	70	70	9	9
25	140	125	0	-10	80	75	80	75	14	15
26	145	135	0	-5	80	80	80	70	8	8
27	140	120	0	-30	80	75	80	80	14	12
Mean	141,4	127,4	0	-11,4	78,3	71,1	78,8	73,8	10,7	10,4
SD	4,3	6,9		8,5	3,4	5,8	2,5	5,1	1,9	1,8
P	<.001		<.001		<.001		<.001		0.661	

then compared with the results of the Cosmetic and Functional Satisfaction Questionnaire administered after the mid-term recovery period at month 18. According to the results of the first questionnaire, the majority of patients were dissatisfied with the appearance of the fixator. At the 18-month cosmetic and functional questionnaire, 85% of patients rated their cosmetic results as good or better. Dissatisfaction with cosmetic appearance at two months was found to be fixator-related, and cosmetic satisfaction increased from 37% to 85% at 18 months. Despite poor appearance, it was observed that patients achieved satisfaction in the long term and functional results were high at both two months and 18 months. K-wire migration was not observed in any of the patients. Cementation and polyaxial placement of the K-wires were thought to prevent K-wire migration. ROM measurements were taken at the two-month and 18-month follow-up visits. There were statistically significant differences between the ROM measurements, especially at the two-month postoperative visit while

Table 4 : ROM and carrying angle during postoperative month 18

	Flexion normal side	Flexion	Extension normal side	Extension lack	Supination normal side	Supination operated side	Pronation side	Pronation operated side	Carrying angle normal side	Carrying angle
1	145	145	0	-5	80	80	80	80	11	11
2	135	135	0	-5	80	80	80	80	8	8
3	145	135	0	-10	75	80	80	75	9	10
4	140	140	0	0	80	70	75	80	8	10
5	145	140	0	0	70	75	80	75	11	10
6	145	135	0	-10	80	75	80	75	10	9
7	140	135	0	-10	80	80	80	80	12	11
8	145	140	0	0	70	75	80	75	10	10
9	145	145	0	-5	80	70	80	70	10	9
10	145	140	0	0	80	75	75	75	11	12
11	140	140	0	0	80	70	80	80	9	9
12	145	140	0	-5	80	80	80	80	12	11
13	145	145	0	-5	80	75	80	80	11	10
14	145	145	0	-5	80	75	80	70	10	9
15	130	125	0	-5	70	60	80	75	9	9
16	140	135	0	-10	80	75	80	70	11	10
17	135	125	0	-10	80	75	80	75	8	9
18	145	140	0	0	80	70	75	70	12	12
19	135	135	0	-10	80	75	80	80	10	10
20	140	135	0	0	75	75	80	75	12	11
21	140	135	0	-10	80	75	80	70	11	11
22	145	130	0	-5	80	80	75	75	13	13
23	145	135	0	-10	80	75	80	75	9	9
24	135	135	0	0	75	70	70	70	11	13
25	140	130	0	-10	80	75	80	75	12	12
26	145	135	0	0	80	80	80	80	10	11
27	140	125	0	-5	80	75	80	80	8	8
Mean	141,5	136,3	0	-5	78,3	74,8	78,9	75,8	10,3	10,3
SD	4,3	5,8		4,2	3,4	4,5	2,5	3,8	1,37	1,43
P	<.05		<.05		<.05		0.05		0.923	

Figure 2: ROM after surgery

Figure 3: ROM after removing the K-wires

there were no statistical difference between radiographic measurments during postoperative month 18 [results of the statistical analyses are shown in Tables 3,4 and 5]. Although these results included statistically significant differences, none of the patients had malunion or functionally significant ROM problems.

Discussion

Supracondylar humerus fractures are one of the most common pediatric fractures in preschool and elementary school children between the ages of 4 and 8. Displaced supracondylar fractures of the humerus are most often treated surgically due to the fact that these fractures

Table 5: Other measurements obtained during postoperative month 18

	Bauman angle normal side	Bauman angle	Humeroulnar angle normal side	Humeroulnar angle	Capitellum percent** normal side	Capitellum percent
1	15	14	11	11	50	50
2	14	14	8	8	50	50
3	12	12	9	10	50	40
4	18	20	8	10	50	40
5	14	12	11	10	45	45
6	13	12	10	9	50	50
7	16	14	12	11	50	55
8	15	15	10	10	50	60
9	13	11	10	9	50	40
10	14	14	11	12	50	55
11	12	13	9	9	55	50
12	17	15	12	11	50	40
13	14	12	11	10	50	45
14	15	13	10	9	50	50
15	15	12	9	9	45	45
16	13	13	11	10	50	50
17	12	13	8	9	50	50
18	15	14	12	12	55	50
19	17	16	10	10	50	45
20	16	16	12	11	45	45
21	16	17	11	11	50	55
22	14	15	13	13	55	55
23	13	14	9	9	55	45
24	15	13	11	13	45	40
25	12	14	12	12	50	50
26	17	16	10	11	50	50
27	16	17	8	8	45	40
Mean	14,5	14,1	10.3	10,3	49,8	49,7
SD	1,7	1,98	1,43	1,37	2,93	5,6
P	0.383		0.923		0.101	

**Relationship between capitellum and anterior humeral line; it was calculated by comparing the portion of capitellum taking place in front of anterior humeral line to the whole anterior–posterior length of capitellum on the lateral X-ray of the elbow

require sufficient reduction to allow for remodeling, which is not sufficient for the realignment of coronal plane and rotational deformities.[6,10] Their management can be challenging for orthopedic surgeons. In severe, nonreducible fractures where open reduction is performed, K-wire fixation may also be inadequate. Studies have reported increased complication rates with open reduction.[15] Kirschner wire is a non-threaded material with poor bone attachment; it can resist bending forces to some extent but is not very resistant to slippage and rotation. Over time, the K-wire may become inadequate to resist displacement forces in the fracture line, ultimately leading to early loss of reduction. Such irreducible and unstable fractures require more stable fixation.[12,18] Fixator treatment remains the only method of treatment in this group where plate fixation cannot be performed due to the presence of epiphyseal regions in the pediatric age-group.

External fixators were first used by Slongo *et al*. to treat irreducible supracondylar fractures in children aged.[19] In this technique, they placed only one Schanz distal to the fracture line, one Schanz proximal to the fracture line, and a K-wire crossing the fracture line. However, in a study comparing K-wire and external fixator configurations, the external fixator provided adequate stability in pediatric supracondylar humerus fractures without ulnar nerve injury. In addition, greater stability was reported with the external fixator compared to the K-wire configurations in varus loading.[14] However, Güleç *et al*. performed a biomechanical study on the saw bone model for the use of a cemented external fixator in such fractures. In this study, the methyl methacrylate fixator showed greater resistance to three-point bending and torsional forces compared to the monolateral tubular fixator.[13] Fixator treatment also yielded good results in a study where fixator treatment was preferred because of the risk of ulnar nerve injury with percutaneous K-wire insertion on the medial side of the distal humerus.[20] Rinat *et al*. reported that linear

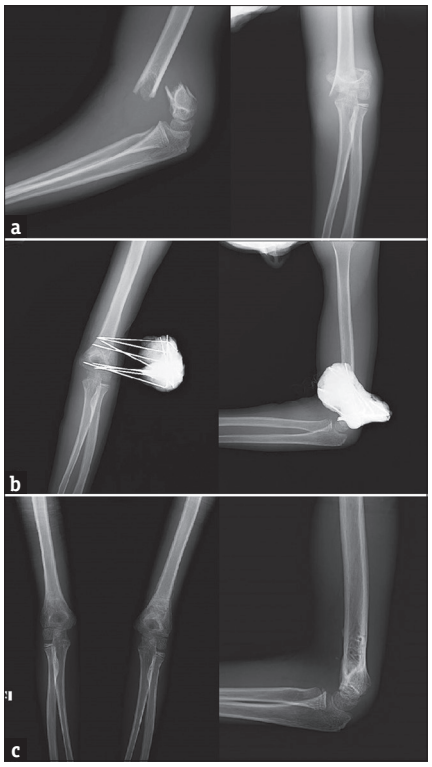

Figure 4: (a) X-ray view of displaced extension-type supracondylar humerus fracture. (b) Picture of postoperative X-ray. (c) X-ray view after removing the K-wires

external fixators had acceptable clinical and radiographic results, comparable to open reduction, and suggested that they may be preferred in patients with severe soft tissue damage, especially in flexion-type fractures.[8] Although lateral external fixation produces good results, it is not suitable for Schanz placement in supracondylar humerus fractures due to its proximity to the epiphysis and the presence of very small distal fragments. Typically, one and rarely two Schanz pins are used. In cases of single Schanz placement, biomechanical strength is inadequate and rotational stability is less.[19] Sometimes, the small bone fragment in the distal part of the fracture may disintegrate during Schanz pin placement. In a cadaver study, Schanz pins placed distally were found to be inadequate, and an oblique Kirschner wire was added to the external fixator separately from the lateral and medial wires to prevent rotation, and this procedure was studied biomechanically.[21] These findings indicate that there is insufficient stabilization of the distal portion in fixator treatment, and studies are being conducted to investigate methods to avoid this. Another study used a double fixator and achieved high stability, high anti-rotation, and good joint motion.[22] A recent study comparing Solongo's method with lateral entry pins found that fixator treatment may be a reliable method for treating supracondylar fractures. In previous studies in patients with cubitus varus, a methyl methacrylate fixator was used to fix the osteotomy line and showed good results in terms of ROM and cosmesis.[23]

Fixator treatment is a reliable method for irreducible and unstable supracondylar fractures.[13,14,19,24-26] However, the distal humerus provides limited space for fixator placement, and therefore, there is only enough space for one or two distal Schanz pins. However, our technique allows multiple K-wires to be placed both distal and proximal to the fracture. The methyl methacrylate fixator treatment, which is applied by delivering multiple K-wires distal to the fracture in multiple axes, is easier to apply, provides stronger stabilization, and has lower complication rates. It allows multiple K-wires to be placed distally at many different angles and axes, whereas the monolateral fixation method allows only a single Schanz pin to be placed in a single axis. In addition, because the K-wire has a much thinner structure than the Schanz pin, there is a much lower likelihood of the distal fracture fragment disintegrating during insertion compared to the Schanz pin. The Ilizarov technique can be considered an alternative technique to the technique mentioned in this study.[27,28] However, the Ilizarov technique requires the K-wires to pass through the distal medial cortex of the humerus. In addition, each wire must be delivered at specific angles and tightened to the frame. Therefore, distal placement of a large number of K-wires is impossible in the Ilizarov technique. It is an undeniable fact that the Ilizarov technique provides rigid stability on the fracture line even with only two K-wires. However, the risk of nerve injury during K-wire insertion is one of the most frightening complications of this technique. In our procedure, we tried to avoid ulnar nerve injury by not passing through the medial cortex, and we had the opportunity to place 4–5 wires at the desired angle from the distal side of the fracture. One of the most beneficial aspects of our technique is that, compared with monolateral external fixation and the Ilizarov technique, the cost of the methyl methacrylate fixator is significantly lower because only the wire and cement are required.

In this study, the postoperative results obtained during the follow-up of 27 patients were examined. According to Flynn's criteria, 19 of the patients rated their outcome as excellent and six of them rated their outcome as good. One patient rated the overall outcome as good but stated that the lateral cement fixator placed during treatment was cosmetically unpleasing. Overall, more than 90% of the patients rated their treatment outcome as good or excellent. In terms of cosmetic appearance, the rate of good and excellent results was 85%. ROM after fixator removal was rated as excellent with regard to the appearance of the support angles. Overall, the procedure

provides good results in terms of treatment, but does not provide a very good cosmetic appearance during treatment, similar to other external fixator procedures.

Limitations

There are several limitations to our study. First of all is the retrospective nature. Another limitation of this study is the limited number of patients. Further prospective studies with more number of patients are needed. Third and finally, there is no other group treated with traditional crossing or lateral K-wire technique to compare and find out more reliable method. Although this study indicates that methyl methacrylate fixator is a reliable method in the treatment of Gartland type IV supracondylar fractures, more accurate results will be obtained with comparative studies including different techniques.

Conclusion

We conclude that the methyl methacrylate fixator is a readily applicable, simple, safe, and inexpensive technique in the surgical treatment of irreducible and unstable supracondylar humerus fractures. The method provides good bone union, allows early joint motion, and provides good post-treatment ROM values with a high rate of patient satisfaction.

List of abbreviations

ROM = range of motion
SD = standard deviation
CI = confidence interval

Ethical approval

This study was carried out after the approval of Selcuk University Medicine Faculty Ethical Committee. (The number of ethical meeting: 2020 / 26. The number of ethical approval is 2020 / 574).

Consent for publication

Patient presented in this study provided written informed consent to publish.

Consent to participate

All patients included in this study provided informed consent to participate.

Data availability

Data related to this article are available upon request by contacting the first author via e-mail.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published, and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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