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Research Article

Single-Stage Conversion of External Fixation into Internal Fixation for Compound Fractures in War-Wounded Patients: A Cohort Study in Iraq

Ammar Talib Al-Yassiri*, Ali Bakir Al-Hilli, Mohammed Hatem Al-Sabti, Ali Mohammed Al-Sabti
Department of Surgery, College of Medicine, University of Baghdad, Baghdad, Iraq
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Abstract

Background: War-induced. Compound fractures cause considerable damage to the limbs, affecting mobility and quality of life; surgeons consider managing compound fractures to be a difficulty. Although multi-stage conversion from external to internal fixation is still common, multiple studies worldwide are promoting single-stage conversion. ***Objective***: To assess the efficacy and safety of a single-stage conversion from external to internal fixation using the functional results of many Iraqi war-wounded patients who were initially treated with external fixation. ***Methods***: A retrospective cohort study analyzed the data of 40 war-wounded patients (39 males and 1 female) ranging in age from 18 to 50 years. All patients came with war-related complex fractures, which were stabilized and referred for external fixation. Following a single-stage conversion to internal fixation, the patients were followed up to assess the functional outcomes of this approach using Ketenjian's functional criteria. ***Results***: A study of 40 patients (45 limbs), mostly male (97.8%), demonstrated a statistically significant link between non-union and time to convert from external to internal fixation. However, fracture type, Gustilo categorization, fixation method, and complication rates had no significant impact on Ketenjian's score results. ***Conclusions***: The single-staged external to internal fixation conversion is regarded as a safe and reliable procedure with good overall functional outcomes; it could be performed by experienced surgeons instead of two-staged conversions, taking into account the patient's general health and the state of the local soft tissue.

Keywords: Compound fractures, External fixators, Fracture fixation, Gunshot wounds.

تحويل التثبيت الخارجي أحادي المرحلة إلى تثبيت داخلي للكسور المركبة لدى جرحى الحرب: دراسة أترابية في العراق

الخلاصة

خلفية: بسبب الحرب تسبب الكسور المركبة أضرارا كبيرة للأطراف، مما يؤثر على الحركة ونوعية الحياة؛ يعتبر الجراحون أن علاج الكسور المركبة تمثل صعوبة. على الرغم من أن التحويل متعدد المراحل من التثبيت الخارجي إلى التثبيت الداخلي لا يزال شائعا، إلا أن دراسات متعددة في جميع أنحاء العالم تعزز التحويل أحادي المرحلة. **الهدف**: تقييم فعالية وسلامة التحويل أحادي المرحلة من التثبيت الخارجي إلى التثبيت الداخلي باستخدام النتائج الوظيفية للعديد من جرحى الحرب العراقيين الذين عولجوا في البداية بالتثبيت الخارجي. **الطريقة**: حللت دراسة أترابية بأثر رجعي بيانات 40 جريح حرب (39 من الذكور و 1 من الإناث) تتراوح أعمارهم بين 18 و 50 عاما. جاء جميع المرضى مع كسور معقدة مرتبطة بالحرب، والتي استقرت وأحيلت للتثبيت الخارجي. بعد التحويل أحادي المرحلة إلى التثبيت الداخلي، تمت متابعة المرضى لتقييم النتائج الوظيفية لهذا النهج باستخدام معايير Ketenjian الوظيفية. **النتائج**: أظهرت دراسة أجريت على 40 مريضا (45 طرفا) ، معظمهم من الذكور (97.8٪)، وجود صلة ذات دلالة إحصائية بين عدم الاتحاد والوقت للتحويل من التثبيت الخارجي إلى التثبيت الداخلي. ومع ذلك، لم يكن لنوع الكسر وتصنيف Gustilo وطريقة التثبيت ومعدلات المضاعفات تأثير كبير على نتائج درجات Ketenjian. **الاستنتاجات**: يعتبر تحويل التثبيت الخارجي إلى الداخلي أحادي المرحلة إجراء آمنا وموثوقا به مع نتائج وظيفية عامة جيدة ؛ يمكن إجراؤه من قبل جراحين ذوي خبرة بدلا من التحويلات على مرحلتين، مع مراعاة الصحة العامة للمريض وحالة الأنسجة الرخوة المحلية.

* ***Corresponding author***: Ammar T. Al-Yassiri, Department of Surgery, College of Medicine, University of Baghdad, Baghdad, Iraq; Email: ammar.t@comed.uobaghdad.edu.iq
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INTRODUCTION

Compound fractures, resulting from various high-energy traumatic factors such as road traffic accidents, falls from heights, and occupational injuries, are on the rise due to the rapid development of the social economy and international industrial efforts [1]. Gunshot wounds, explosives, and other armed conflict-related factors can also cause these fractures, particularly among civilians and armed forces in nations with ongoing conflicts [2]. Compound fractures can result in extensive damage, which can significantly impact the mobility of the limbs and overall quality of life. This damage can include skin and soft tissue damage, muscle tissue loss, acute and

chronic joint-related complications, and life-threatening vascular injuries. The degree of soft tissue injury, wound contamination, and infection are the most important prognostic factors during compound fractures' long treatment cycles [3-5]. Managing compound fractures is considered a challenge to surgeons; Gustilo-Anderson typing remains the most adopted method for classifying compound fractures [6]. The standard treatment for compound fractures with severe soft tissue injury follows a staged protocol for damage control, which includes emergency debridement, the application of external fixation, and a plan to switch to definitive internal fixation when the soft tissue condition improves during follow-up [5,7]. When there is a Gustilo type of fracture, the carrying time of the external fixator, and the conversion time to internal fixators are all connected in important ways that affect complications after surgery, including infection, pain, limited movement, and the overall prognosis [1,6,8]. For example, it was shown that the longer the external fixation is in place, the more likely it is that it will become unstable, come loose, and make the soft tissue injury worse. It is also linked to deep infections, high rates of malunion and nonunion, and joint morbidity [7,9]. Therefore, studies have proved that planned conversion to internal fixation in stage II is the safest option to avoid the disadvantages of external fixators [9,10]. Studies have even focused on evaluating and proving the efficacy and safety of immediately applying internal fixation for open fractures of various Gustilo-Anderson types in a timed manner [11,12]. The main disagreement in the standard staged treatment protocol is still about when and how to switch from external fixation to internal fixation at phase II. Specifically, there is disagreement about whether this should be done right away after removing the external fixation in a single-stage manner or should be put off for a while and then internal fixation should be done as a separate procedure [13,14]. Functional postoperative complications, including pain and limitation of movement, are important determinants of the method's success and the timing of conversion to internal fixation. They could represent a useful tool for evaluating the efficacy and safety of each of the two methods in question [15]. The goal of this study is to find out if switching from external to internal fixation in a single step is effective and safe. This will be done by looking at the functional outcomes of several Iraqi patients with compound fractures who were first treated with external fixation according to the standard staged treatment protocol.

METHODS

Study Design and setting

In this study, the data of 40 war-wounded patients (39 males and 1 female) aged 18 to 50 years were retrospectively examined. These patients came with complicated fractures to their affiliated specialist trauma facility. Five of these patients had two distinct open fractures, for a total of 45 complicated fractures. According to Gustilo's categorization, the majority of these fractures were Gustilo-Anderson type III (35 fractures), followed by Gustilo-Anderson type II (8 fractures), and finally Gustilo-Anderson type I (2 fractures). The victims were initially taken to the emergency department, stabilized, and then referred to a specialized trauma facility for ultimate orthopedic treatment. The patients received the standard staged protocol treatment for compound fractures, which began with wound debridement and the application of external fixation. A single-stage conversion procedure to internal fixation ensued, employing various methods based on the fracture's location and type, such as conventional plates and screws, intramedullary nails, and the MIPO technique for internal fixation. The method of internal fixation was chosen based on the condition of the soft tissue and the presence or absence of early infection. The patient is seen one week following the procedure to check on the wound condition; this is followed by another visit on day 14 postoperatively, then a monthly follow-up appointment for six months, and lastly a visit every three months for a year. This was necessary to document the time to union, the existence of late infection, nonunion, and malunion, as well as to determine the need for revision surgery. Once union was established, the functional Ketenjian's criteria were determined for each instance in the 24th week to assess the level of postoperative pain and movement limitation. The data used in the study came from the orthopedics department's records at the linked trauma hospital. The records of complex fracture patients for the period between January 1st, 2020, and January 1st, 2024 were reviewed, and data on participants eligible for this study was obtained. The archives also include written and informed consent for the surgical operation, along with the option to participate in future investigations.

Inclusion Criteria

A total of 40 compound fracture patients with 45 different fractures were selected for evaluation based on the following criteria: Adult war-wounded patients of both sexes, who were over 18 years of age, presented with compound fractures in their extremities. They underwent external fixation at phase I, followed by immediate single-stage internal fixation at phase II, and had a post-operative follow-up period of 12 months or more, complete with full clinical and imaging data.

Exclusion Criteria

We excluded patients who refused to participate in future studies, those who only received external fixation for a compound fracture, those who underwent multiple stages of switching from external to internal fixation,

patients who lost follow-up, those who had to amputate a limb due to vascular injury or necrosis during follow-up, and those taking corticosteroids or immunosuppressants for other illnesses.

Surgical procedure

All patients were treated in accordance with the standard orthopedic protocol for the therapy of open wounds previously described by Ye et al. [6] Antibiotics and tetanus immunoglobin were administered soon after admission, and wound debridement was done to remove the devitalized tissue, foreign bodies, and possible sources of contamination while retaining the periosteal blood supply as much as possible, followed by fracture reduction, correction of any displacement, and maintaining fracture lines aligned, followed by the fluoroscopic-guided application of the suitable external fixation method. The closure method was then chosen based on the degree of soft tissue damage and skin loss, with options including primary tension-free suturing, secondary suturing, or substitution while maintaining drainage during phase I; patients with severe contamination received repeated debridement depending on the wound situation. If the granulation tissue is clinically determined to be in good condition, patients with skin and tissue loss undergo flap transportation, flap dissociation, or a free skin transplant during phase II. Patients underwent a single-stage procedure to remove temporary external fixation and replace it with internal fixation once soft tissue swelling, skin wrinkles, and local infection symptoms (such as swelling and inflammatory secretions) were resolved. The methods of internal fixation that were implied varied according to the case, from conventional plates and screws to intramedullary nailing, along with the use of minimally invasive percutaneous osteosynthesis techniques (MIPO) and less invasive stabilization systems (LISS) in applying plates for several cases. To the best of our knowledge, the majority of literature discussing conversion timing and method has evaluated the outcomes after performing intramedullary nailing. The timing of fracture union was then established during follow-up using clinical judgment and imaging investigations.

Definition of Conversion time and infection

The current investigation performed the conversion to internal fixation immediately after removing the temporary external fixation, resulting in a conversion time roughly equal to the external fixation's carrying time. Ye *et al*. defined the carrying time as the time between the initial suture or repair of an open fracture incision and internal fixation [6]. The current investigation also applies this definition to the concept of conversion time. The International Association for Internal Fixation Research [16] guidelines helped us figure out what an infection after internal fixation is and how to diagnose it. They say, "Infection after internal fixation was defined as bone tissue infection with or without surrounding soft tissue infection after the replacement of an external fixator with internal fixation due to pathogenic microbial contamination or low immunity of patients." We categorize this infection into three groups for effective management.

Ketenjian functional evaluation criteria

The Ketenjian criteria is a functional grading system that assesses orthopedic postoperative problems such as pain and movement limitation. This functional score encompasses four outcomes, which are determined by the patient's clinical assessment. Excellent: which refers to the complete absence of pain and limitation of movement. Good refers to the occurrence of intermittent soreness with continuous use and minimal movement restriction. Fair: which refers to the existence of pain during everyday activities coupled with more than 50% limitation of movement. Poor, on the other hand, refers to persistent pain and a 75% limitation of movement.

Statistical analysis

Statistical Package for the Social Sciences (SPSS) version 29.0.2.0 was utilized for statistical analyses. Data are presented as ranges, means ± standard deviations. The Chi-square test was used to analyze the significance of the association between categorical variables. *P-values* less than 0.05 were considered statistically significant.

RESULTS

In this study, 40 patients and 45 affected limbs were included. There are 44 males, accounting for 97.8%, and 1 female, accounting for 2.2%. The age range was 18 to 50 years old, with a mean of 30.18 ± 7.967 (Table 1). Of the fractures included, 28.9% (n=13) were proximal tibia fractures, 26.7% (n=12) were femur shaft fractures, 15.6% (n=7) were distal tibia and fibular fractures, 11.1% (n=5) were tibial plateau fractures, and 4.4% (n=2) were humerus fractures. Each of the following fractures accounts for 2.2% of the cases: olecranon process, proximal radius, supracondylar humerus, pilon, intercondylar humerus, and intra-articular femur (n=1). There is no statistically significant association between the bone involved and Ketenjian's score outcome with a p-value of 0.13 (Table 2). Regarding Gustilo classification, 77.8% (n=35) were classified as type III, 17.8% (n=8) as type II, and 4.4% (n=2) as type I. There is no statistically significant association between Gustilo’s classification and Ketenjian's score outcome with a p-value of 0.906 (Table 3).

Table 1: Demographic characteristics of patients and Function Ketenjian's score

Gender	Male	44(97.8)
	Female	1(2.2)
Age (range)	30±7.9	
Time to convert (days)	15.51±8.317	≤14 days: 36(80) 15–28 days: 6(13.3) >28 days: 3(6.7)
Time to union	11.8±4.906	
Function Ketenjian score	Poor	2(4.4)
	Fair	3(6.7)
	Good	3(6.7)
	Excellent	37(82.2)

Values were expressed as frequencies, percentages, and mean±SD.

Table 2: Bone involved with outcome

Bone involved	Function Ketenjian criteria				Total	*p-value
	Poor	Fair	Good	Excellent		
Tibia proximal	0	1	0	12	13	0.13
Olecranon process	0	0	0	1	1	
Radius proximal	0	0	1	0	1	
Tibia plateau	1	0	0	4	5	
Femur shaft	1	2	0	9	12	
Tibia distal + Fibula distal	0	0	1	6	7	
Humerus supracondylar	0	0	0	1	1	
Pilon	0	0	0	1	1	
Humerus intercondylar	0	0	1	0	1	
Femur intra-articular	0	0	0	1	1	
Humerus	0	0	0	2	2	
Total	2	3	3	37	45	

*Chi square test.

The time to convert from external fixation to internal fixation ranged from 3 to 49 days, with a mean of 15.51 days and a standard deviation of 8.317 days. It was divided into three categories. Group 1, which includes periods of 14 days or less, represented 80% (n=36) of the data. Group 2, consisting of periods between 15 and 28 days, accounted for 13.3% (n=6), while group 3, with periods beyond 28 days, represented 6.7% (n=3). No statistically significant association exists between time to convert and Ketenjian's score outcome with a p-value of 0.274 (Table 3). The time for union varied from 6 to 26 weeks, with a mean of 11.8 weeks and a standard deviation of 4.906 weeks. Two cases underwent surgical revision.

Table 3: Gustilo classification, time to convert, complications and outcome

Variables		Function Ketenjian criteria				*p*-value*
		Poor	Fair	Good	Excellent	
Gustilo classification	I	0	0	0	2	0.906
	I	0	0	1	7	
	III	2	3	2	28	
Time to convert (day)	≤14 days	1	2	2	31	0.274
	15–28 days	1	1	0	4	
	>28 days	0	0	1	2	
Type of definitive fixation	Conventional plate and screw	1	2	1	6	0.438
	Nail	0	0	0	5	
	MIPO	1	1	2	26	
Infection	Negative	2	3	2	31	0.647
	Positive	0	0	1	6	
Nonunion	Negative	2	3	3	36	0.974
	Positive	0	0	0	1	

*Chi square test.

Regarding the type of definitive fixation, 22.2% (n=10) had conventional plate and screw fixation, 11.1% (n=5) had nail fixation, and 66.7% (n=30) had MIPO fixation. There is no statistically significant association between the type of definitive fixation and Ketenjian's score outcome with a p-value of 0.438 (Table 3). According to Ketenjian criteria, 82% (n=37) were graded as excellent, 6.7% (n=3) as good, 6.7% (n=3) as fair, and 2.2% (n=2) as bad. Regarding complications, there were seven occurrences of infections and one incident of non-union. There is no statistically significant association between infection or non-union and the Ketenjian score outcome (p = 0.647 and 0.974, respectively) (Table 3). Moreover, there is no statistically significant association between infection or non-union and type of definitive fixation with *p*= 0.27 and 0.167, respectively (Table 4).

Table 4: Complications and type of definitive fixation

Complications		Type of definitive fixation			*p-value
		Conventional plate and screw	Nail	MIPO	
Infection	Negative	9	3	26	0.27
	Positive	1	2	4	
Nonunion	Negative	9	5	30	0.167
	Positive	1	0	0	

* Chi square test.

However, there is a statistically significant association between non-union and time to convert with $p<0.001$, while there is no statistically significant association between infection and time to convert with a p-value of 0.669 (Table 5).

Table 5: Infection, non-union and time to convert

Complications		Time to convert (day)			*p-value
		≤14	15–28	>28	
Infection	Negative	31	5	2	0.669
	Positive	5	1	1	
Non-union	Negative	36	6	2	<0.001
	Positive	0	0	1	

*Chi square test.

The results revealed that the infection rates for type I, II, and III open fractures were 50% (in only one patient), 0%, and 17.1%, respectively (Table 6).

Table 6: Gustilo classification, infection and non-union

Complications		Gustilo classification			*p-value
		I	II	III	
Infection	Negative	1	8	29	0.188
	Positive	1	0	6	
Non-union	Negative	2	7	35	0.094
	Positive	0	1	0	

*Chi square test.

DISCUSSION

External fixation is a crucial method in treating open fractures of the extremities [1]. The impact of the external fixator on bone blood supply is minimized due to the minor soft tissue trauma effect [17,18]. High-energy injuries are the primary cause of open fractures in the extremities, sometimes accompanied by significant damage to the surrounding soft tissues. The combined treatment of both fractures and soft tissue injuries can lead to improved prognoses [6]. Early debridement, soft tissue covering, and prompt fracture repair are important [19]. Nevertheless, relying only on external fixation, particularly for unstable fractures, can lead to complications such as malunion, reduction loss, refracture, and pin tract infection. Reports indicate that the occurrence of these complications is as high as 55% for malunion, 23% for loss of reduction, and 21% for refracture [20-22]. Furthermore, prolonged use of the external fixator poses significant challenges to the patient's daily life, causing considerable inconvenience. Moreover, some studies have reported a correlation between extended use of the external fixator and the development of mental health conditions in patients [23,24]. Hence, it is the rational course of action to address these complexities associated with the utilization of external fixation as a definitive therapy approach and replace it with internal fixation as soon as feasible. Furthermore, the combination of multiple injuries and compromised general medical conditions often accompany open fractures resulting from high-energy trauma, making it difficult for patients to tolerate early internal fixation [25,26]. As of now, the majority of specialists have embraced the paradigm of damage control orthopedics (DCO) for treating severe open fractures [27]. Blachut *et al*. [32] described the treatment of open tibial fractures with planned temporary external fixators, followed by internal fixation and displayed positive results. The question of whether to immediately apply internal fixation after removing temporary external fixators is likewise an ongoing topic of controversy. According to certain scholars, if a temporary external fixator is kept in place for more than 14 days, the final internal fixation should only be replaced after the pin path has healed and the inflammatory indices have returned to normal, which typically takes 5-7 days [24,27,28]. Nowotarski *et al*. [29] compared infection rates between replacement with internal fixation at phases I and II. They discovered that one can directly replace temporary external fixators with internal fixation within 1-2 weeks. Our study included the treatment of 40 patients with 45 affected limbs utilizing this single-stage procedure. The infection rate in this study was 15.5%, which is slightly higher compared to the infection rate of 12.3% reported by Ye *et al*. [6]. It is important to note that this study worked specifically on war-wounded victims, not civilians with compound fractures, and utilized different methods of fixation. The primary outcome measure for this study is Ketenjian's score. This study revealed that 96.6% of the patients experienced outcomes ranging from fair to excellent. Hence, the proposed approach of utilizing temporary external fixation followed by internal fixation (single-staged) is safe and effective in managing open fractures in the extremities. Although there is evidence suggesting that planned conversion treatment is safe for severe open fractures of extremities, further investigation is needed to determine the best timing for internal fixation. Bhandari *et al*. [23] conducted a meta-analysis on tibial shaft open fractures. They spotted that the infection rate rose when the temporary external fixator was left in place for more than 28 days and when the conversion interval at phase II exceeded 14 days. Therefore, they recommended avoiding the use of the external fixator for more than 28 days and limiting the conversion interval at phase II to no more than 14 days. According to certain scholars, if a patient's general condition or the state of the surrounding soft tissue improves after 5–10 days, it may be possible to replace a temporary external fixator with a definitive internal fixation [14,30,31]. Others suggest that you can safely leave temporary external fixators in place for 5–14 days [29,32,33]. In this study, the mean duration for converting from external fixation to internal fixation is 15.5 days. Furthermore, most patients (80%) underwent

conversion during the initial 14 days. Nevertheless, as long as the soft tissue surrounding the fracture site was in favorable condition, there was no correlation between the timing of conversion, whether it occurred early or late, and the clinical outcome of the patients. This study includes numerous types of fractures in both the upper and lower extremities. However, the location of the fracture did not correlate with Ketenjian's outcome score, as most patients experienced fair to excellent outcomes. Conventional plate and screw fixation frequently fixes the upper limbs, while MIPO and nail fixation primarily treats the lower limbs. Moreover, there was no correlation observed between the type of definitive fixation and Ketenjian's outcome score. Based on reports [34,35], there is a close association between the Gustilo-Anderson type and a higher incidence of infection in open fractures. Higher types have been associated with an increased infection rate and a greater incidence of fracture nonunion complications. Our study found that the infection rates for type I, II, and III open fractures were 50% (in only one patient), 0%, and 17.1%, respectively (Table 6), and the total infection rate was 15.5%. These results somehow align with the outcomes documented in the literature [36]. Our analysis revealed that there were no significant differences among the three groups. Nevertheless, the results suggest a relationship between the extent of limb damage (Gustilo-Anderson type) and the infection rate for open fractures following sequential temporary external fixation and internal fixation as most of the cases of type III had excellent Function Ketenjian's criteria, the present study found no association between the Gustilo-Anderson classification and the Ketenjian's outcome. These satisfactory outcomes despite the Gustilo-Anderson severity can be explained by the proper handling of damaged tissue, good surgical experience, and the prompt initiation of rehabilitation, which is made possible by the removal of the bulky external fixation device. In this study, the complications after the definitive fixation, such as infections and non-union, showed no association to the Ketenjian's outcome. Most of the patients who had these complications experienced satisfactory outcomes, as all patients were treated for infection and nonunion, with no cases of chronic osteomyelitis or nonunion observed among our patients. Furthermore, there is no association between complications (infections and non-union) and the type of definitive fixation. Any of the three main types of definitive fixation (conventional plate and screw, nails, and MIPO) is considered safe and reliable for positive patient outcomes. It is worth noting that most of the conventional plates are used for upper limb fractures. Regarding the complications and time to convert, only one patient had non-union, and that was associated with the time to convert, which was 37 days, while no association was found between the time to convert and infections. The mean time for union in this study was found to be 11.8 weeks. It is worth mentioning that two cases had revision surgeries and both had excellent outcomes.

Limitations of the study

This study had significant limitations. The absence of a control group for comparison with the usual two-staged conversion compounded the limited sample size of Gustilo-Anderson type I cases, resulting in an infection rate that exceeds those reported in the literature.

Conclusion

The single-staged external to internal fixation conversion is considered a safe and reliable procedure with good overall functional outcomes; it could be performed by experienced surgeons instead of two-staged conversions, keeping in mind the general condition of the patient and the state of the local soft tissue.

Conflict of interests

No conflict of interests was declared by the authors.

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Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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