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# Comparison of Open Reduction and Internal Fixation Versus Closed Reduction and Percutaneous Fixation for Medial Malleolus Fractures

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## Abstract

**Introduction:** Surgical treatment of medial malleolus (MM) fractures can be performed through open or percutaneous approaches, although comparisons between these two approaches have not been undertaken. In this study, we compared patients with MM fractures treated with closed reduction and percutaneous fixation (CRPF) with patients treated with traditional open reduction and internal fixation (ORIF).

**Methods:** A group of 165 consecutive patients underwent surgical fixation of a closed MM fracture from 2011 to 2015 at a single institution. Thirty-one underwent CRPF and 134 underwent ORIF. Patient demographics, injury characteristics, treatment methods, and outcome variables were recorded through review of patient charts, radiographs, and surgical reports.

**Results:** The rate of MM fracture comminution was higher in the ORIF group compared with the CRPF group (9.7% vs 27.6%;  $P = 0.04$ ). All other patient and injury variables were similar between the two groups. There was no statistically significant difference observed between the CRPF and ORIF groups regarding outcomes, including nonunion, malunion, time to union, rate of hardware removal, and wound complications.

**Discussion:** Both CRPF and ORIF resulted in acceptable radiographic outcomes and low complication rates for the treatment of MM fractures.

Malleolar fractures occur commonly, with reports of annual incidence between 101 and 187 per 100,000.<sup>1,2</sup> Medial malleolus (MM) fractures are involved in approximately 50% of all ankle fractures<sup>3</sup> and may occur in isolation or as part of a bi- or tri-malleolar ankle injury.

When part of a bi- or tri-malleolar ankle injury, MM fractures are typically treated with surgical fixation. There is some evidence to support the use of conservative treatment for isolated MM fractures;<sup>4</sup> however, surgical treatment of isolated MM fractures, particularly when

displacement is present, is well supported in the literature.<sup>5,6</sup>

Several fixation techniques for MM fractures have been described, including unicortical partially threaded compression screws, bicortical fully threaded screws, buttress or neutralization plating, and tension band fixation.<sup>7-11</sup> Important considerations when deciding on a particular fixation technique include fracture geometry and the extent of comminution. These fixation techniques typically involve a traditional open approach to fracture reduction and fixation.

Although a variety exists regarding fixation options, a percutaneous approach to MM fixation has not been included in recommendations put forth by the AO group.<sup>7</sup> Percutaneous and minimally invasive approaches to MM fracture fixation have been previously described.<sup>12,13</sup> In comparison to an open technique, a percutaneous approach offers the potential advantage of decreased surgical morbidity, decreased postoperative pain, and decreased risk of wound complications.<sup>14-18</sup> However, without direct fracture visualization and fracture site débridement, it is possible that acceptable reduction could be hindered, leading to higher rates of nonunion and malunion.

We are unaware of any comparison of the two approaches to MM reduction. The purpose of this study was to compare two groups of patients treated with surgical fixation of MM fractures: one group treated with closed reduction and percutaneous fixation (CRPF) and another group treated with traditional open reduction and internal fixation (OR-

IF). We hypothesized that the two groups would be similar in regard to patient factors, injury variables, and outcomes.

## Materials and Methods

### Patients

After obtaining institutional review board approval, 490 consecutive patients who underwent fixation for an MM fracture from 2011 to 2015 were retrospectively identified using Current Procedural Terminology codes for open treatment of ankle fractures (MM, 27766; bimalleolar, 27814). Clinical records and radiographs were reviewed to identify those eligible for inclusion. To meet inclusion criteria, patients must have sustained a closed MM fracture that was managed definitively with internal fixation and must have been clinically followed until union occurred or the patient was given the diagnoses of nonunion. Exclusion factors were open fractures, pilon fractures, ipsilateral tibial shaft fractures, pathologic fractures, fractures in children (ie, <18 years of age), and patients without preoperative clinical and/or radiographic data. After applying exclusion criteria, there were 165 patients included in the study group, consisting of 31 in the CRPF group and 134 in the ORIF group. Group inclusion was determined through reading surgical reports, with the CRPF group including patients with a medial wound or with wounds limited to stab incisions made for hardware insertion only, and the ORIF group including longer incisions that

involved direct fracture visualization with either subsequent screw, plate and screw, or tension band fixation.

Injury patterns were assessed on initial injury radiographs; those included were isolated MM fractures, bimalleolar fractures, and trimalleolar fractures. Based on the Orthopaedic Trauma Association fracture classification system (44), the patterns included were groups 44-A2, A3, B2, B3, C1, C2, C3.<sup>19</sup>

### Surgical Protocol

All surgeries were performed at an academic tertiary care center in a standard manner by one of five attending orthopaedic surgeons who were fellowship trained in either orthopaedic trauma or foot and ankle surgery. All surgeons performed both CRPF and ORIF techniques. Fixation techniques varied based on surgeons' preference and patient and fracture specifics. For the ORIF technique, an incision was made over the fracture; the MM fracture was débrided and reduced under direct visualization. Fixation was then performed with either screws, a buttress plate, or a tension band construct. For CRPF, no incision was made for fracture reduction. A pointed reduction clamp was applied percutaneously to reduce the fracture. Guidewires were inserted to enable passage of cannulated screws through stab incisions. Fluoroscopy was used in all cases of ORIF and CRPF.

### Postoperative Care

Postoperation, patients returned to the clinic at 2 weeks, 6 weeks, 3 months, and 6 months. All patients

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were placed in a splint at the time of surgery for 2 weeks until the first postoperative clinic visit. At 2 weeks, sutures were removed and patients were placed in a short leg cast and kept non-weightbearing for another 4 weeks until the 6-week postoperative visit. At 6 weeks postoperatively, the general protocol enabled patients to remove the cast and begin weight-bearing as tolerated in a controlled ankle motion boot. If there was concern for fracture healing, syndesmotic healing, diabetic complications, or patient mobility, the non-weight bearing period was extended by 2 to 6 weeks.

At each follow-up visit, patients were examined by their treating surgeon, with special attention paid to wound inspection, neurovascular examination, palpation for tenderness, and active and passive range of motion. Radiographs were taken at each follow-up visit and included AP, lateral, and mortise views of the ankle. Radiographs were interpreted independently by the treating surgeon and by a musculoskeletal radiologist at the time of follow-up, and reviewed by one of two researchers not involved with the care of the patients at the time of data collection. Films were evaluated for maintenance of reduction, failure of fixation, and evidence of fracture line.

### Data Collection

Patient information including sex, age, body mass index, diagnosis of diabetes mellitus type I or II, diagnosis of peripheral vascular disease, and active use of tobacco was collected from clinical chart review by one of two reviewers not involved in the care of the patient. Other factors related to the injury characteristics were assessed by review of radiographs, clinical notes, and surgical reports. An injury was considered to be high energy if it occurred in a motor vehi-

cle collision or fall from greater than 15 feet, as defined earlier.<sup>20</sup> Clinical chart review was used to determine whether the MM fracture was open or closed and whether external fixation was used. Delay of surgery refers to the time elapsed between the date of injury and the date of definitive fixation.

Review of radiographs was used to determine the presence of fibula fracture, the presence of comminution of the MM fracture, and the orientation of fracture line, as described by Ebraheim et al.<sup>10</sup> Digital measurements were used to determine fracture fragment size and displacement; both were measured from initial injury films. Fragment size was measured as the distance from the tip of the MM fragment to its articular surface on mortise view, and displacement was measured as the greatest distance between the fractured articular surface points as seen on either anterior posterior or mortise views (Figure 1).

Fixation techniques and outcomes were assessed based on review of surgical reports, postoperative radiographs, and clinical notes by one of two reviewers not involved in the care of the patient. The primary outcome, fracture union, was defined as (1) resolution of the fracture line on radiographs, (2) painless weight-bearing, and (3) zero to minimal tenderness to palpation over the fracture site<sup>21</sup> (Figure 2). Nonunion was defined by failure to meet the above criteria by 6 months postoperatively (Figure 3). Although isolated malunion of the MM is rare,<sup>22</sup> we sought to understand the rate at which sustained joint incongruity occurred and thus defined malunion as  $\geq 2$  mm of articular surface step-off seen radiographically once the fracture had united<sup>23</sup> (Figure 4). Wound complications included any minor or major postoperative wound issue that required

Figure 1



AP radiograph of the ankle. The solid line represents the displacement measurement of the articular, and the dashed line represents the measured length of the fractured fragment.

extended local wound care, antibiotics, or repeat surgery for incision and drainage.<sup>24</sup>

### Statistical Analysis

Binary variables were compared between groups using the chi-square test for proportions. Averages were compared using the Student *t*-test for normal distribution or Wilcoxon rank-sum test for nonnormal distribution. An alpha level of 0.05 was set as the standard cutoff for statistical significance. Analysis was performed using SAS 9.4 software.

### Results

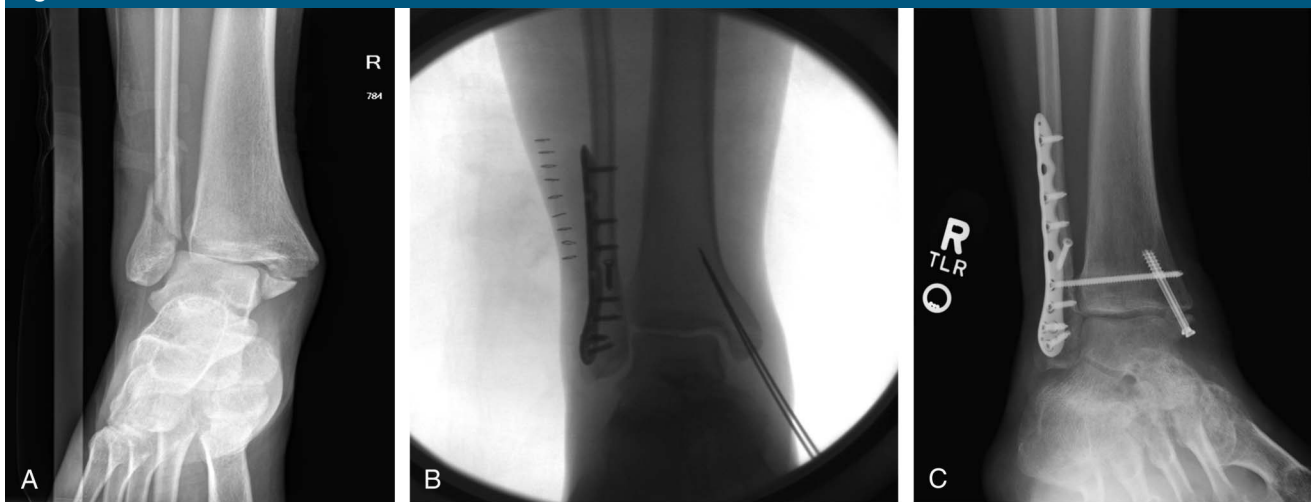
Patient demographics and injury variables are shown in Table 1. Patient demographics and comorbidities were similar between the two groups. Regarding injury variables, the CRPF had a lower rate of MM fracture comminution (9.7% vs 27.6%;  $P = 0.04$ ). The rate of initial external fixation was higher in the CRPF group compared with that of

Figure 2



**A and B**, AP and oblique radiographs of a 46-year-old man who sustained a twisting injury and underwent closed reduction and percutaneous fixation (**C and D**) of an isolated medial malleolus fracture. **E and F**, At 3 months postoperatively, the fracture had fully healed.

Figure 3



Oblique (**A and C**) and AP (**B**) radiographs of a 37-year-old male smoker who had a motor vehicle collision and sustained a bimalleolar ankle fracture (**A**). He underwent open reduction and internal fixation (**B**); however, he went on to develop nonunion, as seen on radiographs at seven months postoperatively (**C**).

the ORIF group (20.6% vs 10.4%), although this difference was not statistically significant ( $P = 0.07$ ).

The energy level of the injury mechanism, presence of fibula fracture, delay of definitive management,

and fracture orientation, size, and displacement were similar between the two groups.



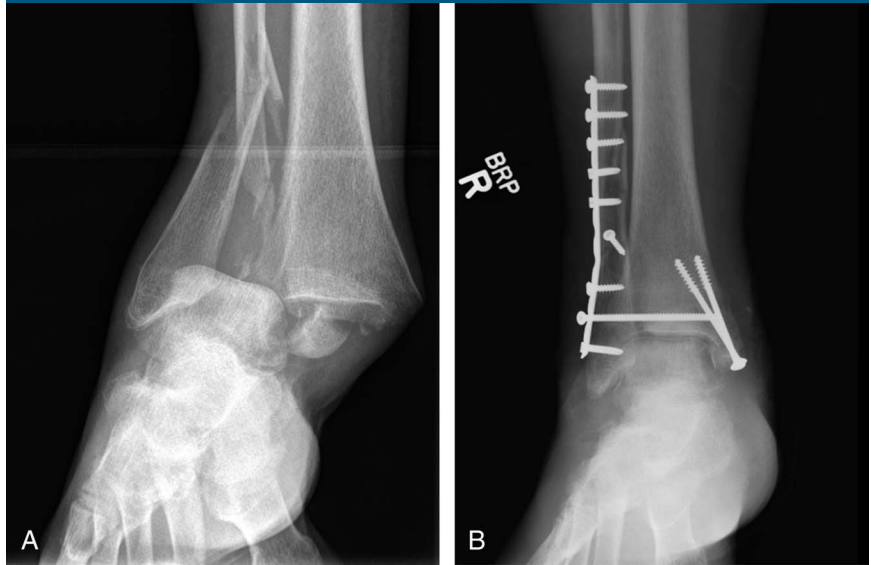
Screw types in the CRPF group were both fully threaded (25.8%, n = 8) and partially threaded (74.2%, n = 23) (Table 2). The ORIF group consisted of a mixture of buttress plate fixation (25.4%, n = 34), tension band construct (3.7%, n = 5), and screws only (70.9%, n = 95) (Table 2).

Overall median follow-up time was 44 weeks, and this was similar between the two groups (Table 3). Rate of acceptable reduction was  $\geq 90\%$  and similar in both groups, as was the average time to union (CRPF, 8.9 weeks; ORIF, 9.6 weeks). There were five cases of nonunion observed, four of which occurred in the ORIF group (3.0%) and one of which occurred in the CRPF group (3.2%;  $P = 0.94$ ). Malunion was similarly rare and comparable between the two groups (CRPF, 3.2%; ORIF, 4.5%;  $P = 0.76$ ). Removal of hardware was performed in 12.7% of patients undergoing ORIF compared with 6.5% of patients undergoing CRPF ( $P = 0.33$ ). There were four medial wound complications in the ORIF group (3.0%) and none in the CRPF group (0%;  $P = 0.33$ ).

### Discussion

In the present study, the characteristics and outcomes of patients treated for MM fractures with CRPF and those treated with traditional ORIF were compared. At baseline, patient characteristics were similar between the two groups, whereas the ORIF group had a higher rate of fracture comminution. Other injury variables, as well as outcomes assessed in the present study, did not differ significantly between the two treatment groups. These findings support the hypothesis that outcomes are similar between these two groups; however, these results should be interpreted with caution, given the selection bias inherent to this study design.

Figure 4



AP radiograph (A) of a 72-year-old woman with diabetes and peripheral vascular disease who had a motor vehicle collision and sustained a bimalleolar ankle fracture. Although reduction appeared acceptable at the time of percutaneous fixation, she went on to develop malunion of the medial malleolus fracture, as seen on the radiograph made at 4 months postoperatively (B).

Table 1

Patient and Variables			
Factor	Percutaneous	Open	P
Patients	31	134	
Patient factors			
Male sex (%)	11 (35)	62 (46)	0.28
Age, yrs	54 (18–84)	48 (18–89)	0.11
Body mass index, kg/m <sup>2</sup>	29 ± 6	31 ± 7	0.23
Diabetes mellitus (%)	4 (12)	21 (16)	0.70
Peripheral vascular disease (%)	3 (10)	10 (7)	0.68
Tobacco usage (%)	3 (10)	23 (17)	0.30
Injury factors			
High-energy mechanism (%)	8 (26)	26 (19)	0.63
Fibula fracture (%)	26 (84)	105 (78)	0.49
Transverse fracture (%)	26 (84)	98 (73)	0.21
Fragment size, mm	18 ± 6	17 ± 6	0.55
Fragment displacement, mm	9 ± 9	8 ± 7	0.23
Comminution (%)	3 (10)	37 (28)	<b>0.04</b>
Definitive management delay, d	15 ± 9	16 ± 19	0.88
Removal of hardware (%)	2 (6)	17 (13)	0.33
Wound complication (%)	0 (0)	4 (3)	0.33

Values given are raw numbers with percentages in parentheses, mean ± SD, or median with ranges in parenthesis. Statistically significant values are bolded.

**Table 2**

Fixation Techniques		
Technique	Raw	Percentage
Percutaneous (n = 31)		
Screw type		
Fully threaded	8	26
Partially threaded	23	74
Number of screws		
1	1	3
2	30	97
Open (n = 134)		
Fixation construct		
Plate	34	25
Tension band	6	4
Screws only	94	71

**Table 3**

Outcomes			
Factor	Percutaneous	Open	P
Patients	31	134	
Outcome			
Follow-up, wk	45 (13–140)	44 (13–222)	0.89
Anatomic reduction (%)	30 (97)	123 (92)	0.34
Time to union, wk	9 ± 4	10 ± 12	0.78
Nonunion (%)	1 (3)	4 (3)	0.94
Malunion (%)	1 (3)	6 (4)	0.76
Removal of hardware (%)	2 (6)	17 (13)	0.33
Wound complication (%)	0 (0)	4 (3)	0.33

Values given are median with ranges in parentheses, raw numbers with percentages in parentheses, or mean ± SD.

Screw fixation alone was the most common construct used for fracture stabilization, accounting for 100% of cases in the CRPF group and 70.9% of cases in the ORIF group. The remainder of the ORIF group was stabilized with plate fixation (25.4%) or tension band construct (3.7%). In a comparison of techniques used for the treatment of 111 consecutive MM fractures, Ebraheim et al<sup>10</sup> reported overall that the treatment group breakdown was 67% screw fixation, 21% tension banding, 7% Kirschner wire fixation, and 6% plating. Although these differences

are likely attributable in part to variability in surgeon preferences, they may also reflect a difference in injury characteristics, given the higher rate of transverse fracture patterns (75% vs 57%) and comminution (24% vs 11%) observed in the present study compared with the former.

Nonunion was a rare complication in this series, occurring in 3.0% of patients overall, without significant variation between groups (CRPF, n = 1; ORIF, n = 4). Ebraheim et al<sup>10</sup> reported an overall nonunion rate of 14% among MM fractures and cited

a high rate of comorbidities as a factor that potentially elevated this number. Other studies have suggested that nonunion of MM fractures is particularly rare.<sup>22,25</sup> Owing to the rarity of this complication, it is possible that our sample size was too small to detect statistically significant differences between the two groups.

Malunion of the MM typically occurs setting of a bi- or tri-malleolar ankle injury.<sup>26,27</sup> Because of the anatomy of the ankle, malalignment of the MM is associated with coronal shift of the talus and concomitant malalignment or shortening of the fibula. Furthermore, there may be significant ankle malunion related to the fibula and talar shift without malunion of the MM component. Therefore, ankle malunion may be unrelated to medial malleolar fixation. As such, to isolate MM malunion for interpretation, we defined it radiographically as articular incongruity  $\geq 2$  mm at the MM fracture site because this amount of step-off has been associated with abnormal joint kinematics.<sup>23</sup> Malunion was a rare complication in the present series (4.2%); therefore, our data may be underpowered to demonstrate a statistically significant difference between groups.

Although it is plausible that the CRPF technique could result in unacceptable reduction owing to incomplete fracture visualization or lack of fracture site débridement (ie, hematoma and periosteum), the findings of the present study do not support this theory. Future studies that use postoperative CT rather than radiographs may offer higher sensitivity for detection of articular step-off,<sup>28</sup> and highly powered studies may be necessary to detect small differences in this variable.

All patients in the CRPF group of the present study underwent fixation with screws only, whereas a combined 25.4% of patients in the ORIF

group underwent fixation with either plate or tension band construct. Following this, removal of hardware was performed at a lower rate in the CRPF group (6.5%) compared with the ORIF group (12.7%), although this difference was not statistically significant. Similarly, although there were no medial wound complications in the CRPF group, there were four (3.0%) in the ORIF group. Previous rates of wound complication following malleolar fracture fixation reported in the literature range from 4% to 22%.<sup>29-32</sup> One feature of this study that may have contributed to the low rate of wound complications was our exclusion of open fractures, which are known to be associated with higher rates of wound complications.<sup>32,33</sup> Although our sample was likely too small to observe a statistically significant difference, we postulate that traditional open approaches, which use a more extensile approach and possibly a plate, may be associated with device removal and wound complications more often. This would be consistent with previous research showing a lower wound or fixation complication rate at the lateral ankle with a less invasive surgical approach.<sup>15</sup>

When screw fixation alone is used to stabilize MM fractures, the surgeon may choose between partially threaded cancellous screws and fully threaded screws. There is evidence to suggest that fully threaded bicortical screws are superior to partially threaded cancellous screws regarding biomechanical properties<sup>11,34,35</sup> and radiographic loosening.<sup>11</sup> However, partially threaded cancellous screws that lag the fracture by screw design are an accepted standard.<sup>7</sup> In the CRPF treatment group, partially threaded screws were favored at a rate of 67.6%. Although it is possible that weaker pullout strength can result in screw loosening and backout, this did not translate to a higher

rate of hardware removal in the percutaneous group of the present study.

No patient variables differed significantly between CRPF and ORIF groups. Koval et al<sup>3</sup> demonstrated that among elderly patients, the risk of early complications after ankle fracture is 16 times higher when patients are treated surgically. It is possible that in the present study, surgeons used knowledge of potential risk factors (eg, age, comorbidities) to select patients for surgery and mitigate risk, thus limiting the observed differences in variables between the two groups. Provisional external fixation was used more often in the CRPF group although this was not statistically significant. Given that external fixations tend to follow higher energy injuries with increased risk of wound complication,<sup>32,33,36</sup> it makes sense to the surgeons who would pursue a treatment that would offer less inherent risk of wound complication when possible. It is also possible that external fixation assisted with reduction, such that surgeons were more comfortable using CRPF without extensive further reduction.

Comminution, however, was more common in the ORIF group (27.6% vs 9.7%;  $P = 0.04$ ). This finding makes sense, given that comminuted fracture patterns are more difficult to reduce and are more likely to require ORIF for direct visualization and fracture reduction that is not possible with CRPF. Considering the principles of fracture management in conjunction with the findings of the present study, it would follow that patients most appropriate for CRPF may be those without comminution, and possibly in the setting of significant soft-tissue injury (because of concern for wound infection) that necessitates provisional external fixation. In addition to potentially limiting the risk of soft-tissue infection in a higher risk setting, the

provisional external fixation may manipulate the soft tissues enough to allow for adequate reduction with percutaneous techniques.

This study has limitations that are inherent in its retrospective design. Inclusion in the CRPF versus ORIF group was not controlled, and therefore differences or a lack thereof between the two groups regarding outcomes could not be attributed to surgical approach. Because of the heterogeneous nature of ankle fractures and the medical conditions of patients who sustain them, factors contributing to a surgeon's decision to treat with CRPF versus ORIF are not determined definitively. Although we examined the comparisons between the two groups for several patient comorbidities and injury factors, other factors such as bone quality or polytrauma were not assessed and may have influenced surgical decision making. Regarding outcomes, our results are limited to radiographic assessments, wound complications, and return to operating room for device removal. Because of variations in post-operative clinical assessment tools used among the five surgeons, pain and functional levels were not assessed in a standard fashion and are therefore omitted from the present series. In addition, patients did not routinely follow-up beyond 1 year, and therefore assessments of long-term complications such as post-traumatic arthritis were not possible. Finally, assessment of reduction quality as well as that of nonunion or malunion was performed using radiographic interpretation and documented clinical findings. We acknowledge that computed tomography offers more sensitivity for detection of these outcomes;<sup>28</sup> however, we maintain that radiographic data in conjunction with clinical examination are both practical and clinically relevant for this purpose.

In conclusion, both CRPF and ORIF resulted in acceptable radiographic outcomes and low complication rates for the treatment of MM fractures. Compared with the ORIF group, patients in the CRPF group had less fracture comminution. CRPF may be a reasonable choice for patients with simple MM fracture patterns in the setting of tenuous soft tissues. Comparisons between these two approaches are limited because of inherent selection bias in the present study. Future prospective studies may improve our understanding of functional and long-term outcomes of patients treated with CRPF versus traditional ORIF.

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