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Outcomes following surgical fixation of Gustilo-Anderson IIIb open tibial fractures

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There is no consensus as to the optimal skeletal fixation method for Gustilo-Anderson IIIb fractures. External fixation methods have previously shown higher rates of superficial infection, whilst internal fixation has shown higher risk of deep infection, but lower risk of other complications. This paper investigates outcomes in open tibial fractures based on fixation method.

A retrospective review was performed for patients presenting to an ortho-plastic unit with GA IIIb tibial fractures between June 2013 and October 2021.

85 patients were identified. The most common implant was an intramedullary nail (IMN), used in 29 patients (34.1%); open reduction and internal fixation (ORIF) was performed in 16 patients (18.8%). 18 patients (21.2%) were definitively managed with a frame alone. Mean follow-up from was 18 months (2-77). Patients with ORIF needed a mean of 3.37 operations; it was 2.48 for IMN which was significantly different from frames at 5.00 (p=0.000).

The mean time to bony union after definitive fixation was 11.4 months. This differed depending on the implant used for fixation, with ORIF at 7.1 months, 10.1 for IMN, and frames at 17.2 months; ORIF significantly differed from frames (p=0.009).

Superficial infection was common, seen in 38.8% of patients, and only 3 patients (4%) developed deep infections involving metalwork, with no difference in rates of either based on fixation method

This study supports that ORIF has faster healing times, with less time to union compared to frames. It also shows that no implant was superior to another in terms of outcomes.

Keywords: Open fracture, tibia, infection, internal fixation, frame, Gustilo-Anderson.

INTRODUCTION

Open fractures are severe bony and soft tissue injuries, associated with high rates of complication, and significant morbidity and cost to healthcare systems[18]. Annually 11.5 open long bone fractures occur per 100,000 people according to previous studies[4], of which diaphyseal tibial fractures are the most common, however there is still controversy surrounding their optimal management[14].

The Gustilo-Anderson (GA) classification classifies open injuries into 3 main categories (I, II and III), of which GA III injuries are the most severe with extensive soft tissue damage and contamination. GA III open fractures were later further classified into A, B and C types. A-type injuries have adequate soft tissue for coverage, whilst B-type injuries are the most severe, displaying extensive periosteal stripping and require soft tissue coverage[6,14]. Higher grade injuries predictably attract a higher rate of complications such as delayed or non-union, infection and amputation[17].

GA IIIB fractures require a combined ortho-plastic approach, as recommended by the British Orthopaedic Association and British Association of Plastic, Reconstructive and Aesthetic Surgeons Audit Standards for Trauma (BOAST) published in 2017[3]. This guidance states that initial debridement should be within 24 hours for open fractures, or within 12 if it is high energy trauma. Definitive soft tissue cover should be within 72 hours of injury, with definitive internal fixation only to be carried out when it can be immediately followed by definitive coverage. A single-stage "Fix and Flap" ortho-plastic approach has been shown to improve outcomes, with significantly lower deep infection rates than staged operations. Recent studies have suggested deep infection rates are between 1.5-4.2%[12,19]. Previous studies have also shown that using this approach can reliably achieve low (0.98%)

deep infection rates, high rates of primary union and limb salvage[1].

The literature has shown that there is significant variation in practice between orthopaedic surgeons regarding definitive fixation of open tibial fractures[15]. Ring fixators have been traditionally used as an an effective method of stabilising tibial fractures in the setting of deformity and bone loss[7,9,16]. A recent American randomised controlled trial randomised GA III tibial fractures to either modern external ring fixation, or internal fixation (IMN/ORIF)[11] This showed that ring fixation has a significantly higher probability of at least one significant complication (defined as amputation, infection, soft-tissue problems, non-union, malunion, or a loss of reduction/implant failure) within 12 months than the internal fixation group (62.1% vs 43.7% respectively). It also showed that ring fixation was significantly more likely to lead to loss of reduction (16.9%) compared to internal fixation 2.5%. There was no significant difference in rates of deep infection between the two groups. There is no current consensus as to the optimal fixation method for GA IIIB tibial fractures. A recent meta-analysis looking at management of these fractures highlighted external fixators, ring fixators, monolateral rails, intramedullary nailing (IMN) and open reduction internal fixation (ORIF) as options for fixation. Broadly they found external fixation techniques have higher rates of superficial infection, whilst internal fixation (ORIF/IMN) has higher risk of deep infection[14].

Our aim was to compare fixation methods for tibial fractures, looking at rates of superficial and deep infection, type of union, and time to union. We also aimed to report on time to first debridement and time to definitive fixation/coverage.

MATERIALS AND METHODS

A retrospective review of prospectively collected data was performed for patients presenting to our Ortho-Plastic unit with GA IIIB open tibial fractures between June 2013 and October 2021. Patients were either referred directly from our Accident and Emergency (A&E) department, or referred from hospitals within the region following initial debridement and stabilisation. As per our previous studies, we have only included patients who underwent a single-stage "Fix and Flap" Ortho-plastic approach, and the standard initial management protocol for these fractures is outlined in the methods section of our previously published work[1]. All patients were initiated on intravenous (IV) antibiotics from arrival in A&E until definitive wound closure as per local trust antibiotic guidelines. IV Co-amoxiclav was given 3 times daily, unless the patient was penicillin allergic in which case they received IV metronidazole, teicoplanin and gentamicin. All patients received IV gentamicin in theatre at the time of first debridement (5mg/kg, reduced to 3mg/kg in renal impairment).

Initial debridement and stabilisation were performed on the first available trauma list, unless a more urgent procedure was required such as in cases of severe contamination or compartment syndrome. Choice of definitive fixation method was left up to surgeon preference for each case, patients were not randomised to either internal fixation or external fixation techniques. All definitive operations were led jointly by both consultant Orthopaedic and Plastic surgeons. A minimum of 5 deep tissue or bone samples were taken for microbiology during definitive surgery for microscopy, sensitivities and extended cultures. All patients were followed up in a combined ortho-plastic clinic, with input from the infectious diseases team, complex wound nurses and physiotherapists.

Non-union was defined as a fracture persisting for 9 months or more, with no evidence of progression of healing for the previous 3 months. Delayed union was defined as above, but with some progression of bone healing within the last 3 months. Secondary union was defined as union achieved only with further surgical intervention (bone grafting or stem cell injection).

Perioperative data was recorded for all patients. This included patients' demographics, site and mechanism of injury, timing of first debridement and of definitive surgery, method of skeletal stabilisation, and type of soft tissue coverage. Post-operative outcomes were recorded. Complications recorded were superficial wound infection, metalwork (deep) infection, delayed union, non-union, amputation, and reoperation rates. The type of union (union/delayed union/non-union) and time to union as documented at the time of clinical review based on plain radiographs were also recorded.

Statistical analysis of categorical data was performed using Chi-Squared, and Kruskal-Wallis tests. P values of <0.05% were considered statistically significant.

All Ts were produced using Microsoft Word 2019. Figures were designed using either Microsoft excel 2019, or Microsoft Power point 2019. A 12 months minimal follow-up filter was applied when we analysed the outcome data to maximise the chance for capturing postoperative complications.

RESULTS

85 patients with GA IIIB tibial fractures were treated by our service between June 2013 and October 2021. The mean age was 41.5 (SD 18.3), and 38 patients (42%) were active smokers at presentation. The mean Charlton comorbidity index was 0.84 (SD 1.57) indicating an average 10 year survival of between 96-98%.

The most common site of injury within the tibia was a distal third tibial shaft fracture (44.7%), followed by mid shaft (30.6%), pilon fractures (12.9%) and proximal shaft fractures (10.6).

Time to surgery

The mean time from presentation to first debridement either locally or at our unit was 12.34 hours (SD 7.87h) (Fig. 1). The mean number of days from presentation to undergoing definitive surgery was 8.73 days (SD 8.09) (Fig. 2). The time to definitive surgery ranged from definitive surgery done on the day of injury, to 53 days post injury. The reason for these delays were delay in transfer from other hospitals, lack of availability of surgeons for joint ortho-plastic lists, or patients not being medically optimised for surgery yet. Only 17 patients (20%) had definitive surgery within 3 days of injury, 30 patients (35%) in 3-7 days, whilst 38 patient (45%) had definitive surgery after more than 7 days. Patients had a mean total number of 3.5 operations (SD 1.7).

Surgical implants

At the time of definitive surgery, tibial fractures were fixed using a variety of surgical implants, broadly categorised into either internal or external fixation. The most common implant was an IMN, used in 29 patients (34.1%). ORIF with plate and screws was done in 16 patients (18.8%), and 2 patients (2.4%) had combined fixation with IMN and ORIF. In terms of external fixation, this was either with a frame alone, or a frame or external fixator that was used to augment internal fixation. 18 patients (21.2%) were definitively managed with a frame alone, 5 (5.9%) had a frame and ORIF, and 11 (12.9%) had an external fixator and ORIF (Fig. 3).

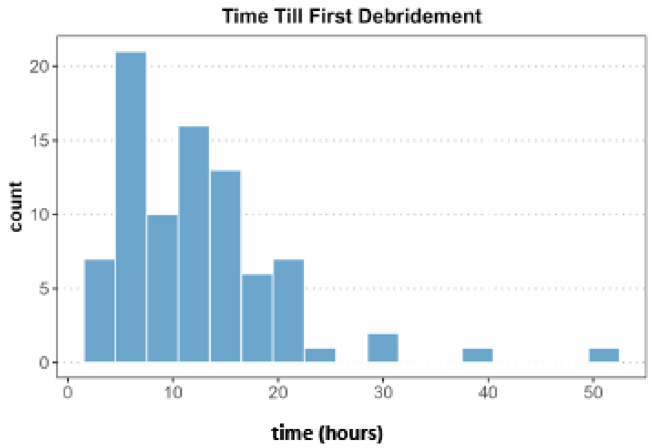

Figure 1. — Time in hours from injury to first debridement.

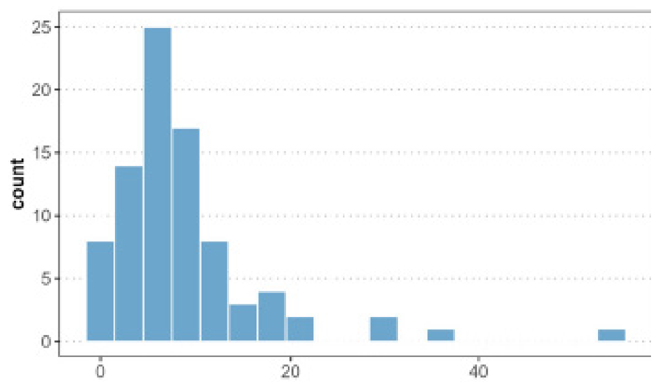

Figure 2. — Days from injury to definitive surgery.

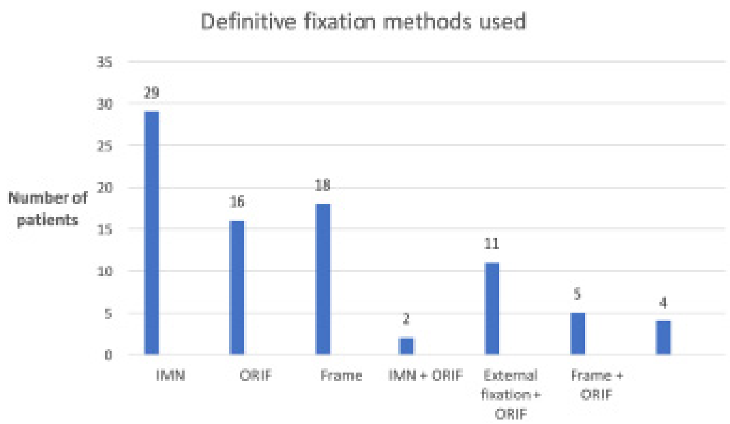

Figure 3. — Number of patients receiving each method of definitive fixation.

Post-operative follow-up

Patients were followed up in joint ortho-plastics clinics post-operatively. 12 patients (14.1%) did not have clinic review post operatively. Of these, 5 died (5.9%), 4 (4.7%) were lost to follow up and 3 (3.5%) were repatriated to other hospitals. The average time of follow-up from injury to October 2021 was 42.4 months (SD 23.2), the range was 6-100 months. The average time of follow-up from injury to the patients' most recent clinic appointment was 18.0 months (SD 15.85), with a range of 2-77 months. A further 3 patients were reviewed in clinic initially, and then subsequently lost to follow-up

Fracture outcomes

Primary union occurred in 43 patients out of the 73 patients who were followed up (58.9%), with delayed union in 17 patients (23.3%). 3 patients (4.1%) went on to achieve secondary union, and 1 patient (1.4%) had union progressing at the time of their most recent clinic appointment. 3 patients (4.1%) had non-unions. Outcomes were categorised into union, delayed union, secondary union, union progressing, non-union, lost to follow-up, death prior to union, amputation, or repatriation to another hospital. Pearson Chi-Square tests showed there was no statistically significant difference between these outcomes based on the method of fixation used, the position of the fracture within the tibia, or smoking status.

The mean time to union from definitive fixation was 11.4 months (SD 7.5). ORIF had a mean time to union of 7.1 months, IMN took 10.1 months, and frames took 17.2 months. ORIF combined with either external fixator or frame had a mean time to union of 9.1 and 9.3 months respectively. The mean time to union was significantly different depending on the implant used for fixation on Kruskal-Wallis testing (p=0.021), on post-hoc analysis with Bonferroni correction showing the significant difference was between ORIF and frame (p=0.009). We found no statistically significant difference in time to union based on smoking status at the time of injury, position of the fracture within the tibia, presence of wound infection, or presence of metalwork infection. There was also no statistically significant correlation between time to union and time to initial debridement or definitive surgery.

60 patients went on to achieve either union or delayed union. 34 had their first debridement within 12 hours of injury, of which 23 went on to primary union and 11 to delayed union. 24 had debridement after 12-24 hours of which 18 went on to primary, and 6 delayed union. There were 2 patients who underwent first debridement after more than 24 hours and both went on to primary union. A Fisher's exact test showed there was no significant difference between union or delayed union depending on time to first debridement (p=0.361). Of patients who went on to primary or delayed union, 13 had definitive fixation in less than 3 days, 18 in 3-7 days, and 29 in more than 7 days. There was also no statistically significant difference between union or delayed union depending on time to definitive surgery (p=0.369).

Infection

74 patients (80%) had negative microbiology tissue samples taken at the time of definitive surgery. Staphylococcus Epidermis was the most common organism grown at the time of operation, with 4 positive cultures. Infection was split into superficial wound infections, and deep infections involving metalwork. 33 patients (38.8%) developed superficial wound infections. Staphylococcus Aureus was the most common bug grown, with positive wound cultures in 19 patients, followed by Enterobacter Cloacae and Pseudomonas Aeruginosa, both with positive cultures in 3 patients. Only 3 patients (4%) developed deep infections involving metalwork, and these were all patients who had also had a superficial wound infection.

The rate of superficial infection for ORIF was 43.8%, for IMN 34.5%, and a higher rate of 66.7% in frames (Table I). The rates of deep infection for ORIF was 12.5%, for IMN 3.4%, and 0% for frames (Table II). There was no statistically significant difference in these rates of superficial or deep infection based on the implant used, or based on smoking status, or days until definitive fixation. There was a statistically significant difference in the rate of deep infection depending on the position of the fracture within the tibia (p=0.030), with proximal tibial fractures having the highest rate of infection at 22.2% (2/9). Distal tibial shaft fractures had a deep infection rate of 2.6% (1/38), mid shaft 0% (0/26), pilon fractures 0% (0/11). Fracture position did not have a significant effect on superficial infection rates.

Limb salvage

There were 3 patients which required amputations, all of which were as a result of flap failures leading to loss of soft tissue coverage. 1 patient was one who had undergone ORIF, whilst 2 had frames. There was no

Table I. — Cases of superficial infection for each surgical implant used

		Superficial infection		
		NO	YES	TOTAL
Surgical implant used	**IM NAIL**	19	10	29
	ORIF	9	7	16
	FRAME	6	12	18
	IM NAIL + ORIF	2	0	2
	FRAME + ORIF	4	1	5
	EX FIX + ORIF	8	3	11
	Others	4	0	4
Total		52	33	85

Table II. — Cases of deep infection for each surgical implant used

		Deep infection		
		NO	YES	TOTAL
Surgical implant used	**IM NAIL**	28	1	29
	ORIF	14	2	16
	FRAME	18	0	18
	IM NAIL + ORIF	2	0	2
	FRAME + ORIF	5	0	5
	EX FIX + ORIF	11	0	11
	Others	4	0	4
Total		82	3	85

significant difference in amputation rate dependent on the implant used.

DISCUSSION

Open fractures are serious injuries which pose ongoing challenges for Orthopaedic surgeons, with GA IIIB fractures having the highest rates of associated complications such as infection, non-union and amputation[5,17]. Numerous studies have looked at how to improve rates of infection and other complications associated with open fractures, which can have devastating consequences[1,2,5,9,10,12,13,19].

Time to surgery

The current BOAST guidelines for open fracture state that initial debridement should occur immediately for those with aquatic, farmyard or sewage contamination, within 12 hours of injury for high energy injuries, and within 24 hours for other low energy injuries[3]. GA IIIB type injuries are typically high energy injuries, and the mean time to initial debridement from presentation was 12.3 hours in our cohort. There was no significant difference in rates of wound infection dependent on time to initial debridement in our study, and this is consistent with recent literature[8].

BOAST guidelines also state that definitive internal fixation should occur only when soft tissue coverage can immediately follow, and that this soft tissue coverage should be achieved in less than 72 hours. The mean time to definitive fixation in our hospital was 8.73 days, with only 20% of patients having definitive fixation within 72 hours of injury; 45% of patients waited more than 7 days for definitive fixation. This clearly does not meet national guidelines for timing of definitive stabilisation, however we showed that despite this, there was no difference in rates of superficial or deep infection depending on time to definitive fixation. This may suggest that the quality of coverage and fixation achieved, and ensuring the patient is managed on an appropriate list at an appropriate high-volume ortho-plastic centre is more crucial in determining outcome than time to definitive fixation and skin coverage.

Choice of implant

Multiple methods for definitive fixation of open tibial fractures exist, including both internal and external fixation. There is no consensus in the current literature about the optimal fixation method for GA IIIB tibial fractures[11,14,15]. A recent randomised controlled trial showed ring fixation had significantly higher rates of at least one complication such as superficial infection, nonunion, malunion, loss of reduction or amputation, when compared with internal fixation[11]. A meta-analysis agreed that ring fixators may have higher rates of superficial infection, but that internal fixation has a higher risk of deep infection[14].

IMN was the most commonly used method of fixation at our centre at 34.1% of patients, followed by external ring fixator frame (21.2%) and ORIF (18.8%). Superficial infection was common, seen in 38.8% of patients, which is comparable to the literature, with other studies showing up to 54% incidence of superficial infection[14]. Our results show that there was no significant difference in rates of either superficial or deep infection depending on surgical implant used, however there was a definite trend towards higher superficial infection rates in frames at 66.7%, compared with 43.8% and 34.5% for ORIF and IMN respectively. This trend is supported by recent research which suggests higher rates of superficial infection in frames[11,14]. Only 3 patients (4%) developed deep infections involving metalwork, which fits with recent literature, suggesting this is between 1.5-4.2% with a single stage fix and flap approach[12,19]. There was a significant difference in the rate of deep infection depending on the position of the fracture within the tibia (p=0.030), with proximal tibial fractures having the highest rate of deep infection at 22.2%.

The mean time to bony union after definitive fixation was 11.4 months with ORIF at 7.1 months, IMN at 10.1 months, and frame at 17.2 months, with a significant difference between ORIF and frame (p=0.009). There was no significant difference between implants in rates of delayed union, non-union, amputation or death. Internal fixation provides faster time to union, and so patients may be able to return to function faster.

A limitation of our study was that patients were not randomised to fixation method, and so there is likely some inherent bias in surgeon choice of fixation depending on fracture and soft tissue injury type.

CONCLUSIONS

Our study supports that ORIF has faster healing times, with less time to union compared to frames. It also shows that frames require more operations than internal fixation. There is a trend towards higher superficial infection rates with frames, at 66.7%. No implant was superior to another in terms of limb salvage, or deep infection rates.. This study also shows no difference in outcome depending on time to initial surgery or debridement, which suggests quality and not timing of operation may have the most effect on outcomes.

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