

# THE RELIABILITY OF THE PRE-OPERATIVE CLASSIFICATION OF OPEN TIBIAL FRACTURES IN CHILDREN A PROPOSAL FOR A NEW CLASSIFICATION

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The purpose of this observational study was to evaluate the accuracy of Gustilo's classification of open tibial fractures in children. Pre- and post-debridement (using the parameters of Gustilo's classification) wound gradings in 27 children with a mean age of 10 years (3 to 15 years) who had sustained an open tibial fracture were compared. Pre-operative Polaroid photographs of the wound were taken of all these patients in the accident and emergency department.

In every case, the fracture was treated with prophylactic intravenous antibiotic administration, wound debridement and lavage. Following wound exploration in the operating theater, the wound was classified using Gustilo's parameters again ; this was different from the initial grading. We compared post-debridement classification according to Gustilo to the new classification which we propose. The latter classification is a peroperative assessment of the extent of soft tissue damage and it addresses bone stability. According to this classification, the majority of open tibial fractures were stable, requiring no skin graft or flap and had a good outcome. Only five patients were treated by initial external fixation of the tibia ; the remainder were treated by cast immobilization. Wounds were treated as appropriate.

The clinical outcome study included the assessment of wound and fracture healing and the incidence of complications. The mean period for follow-up was 8 months (6 to 24 months). There were no cases of nonunion or deep wound infection and the wounds healed in all these patients.

We conclude that Gustilo's classification is not specific and does not reflect the extent of soft tissue and skeletal damage. Factors such as the degree of soft tissue damage and periosteal stripping that are

noticed following wound debridement and velocity of injury are far more important than the wound size. Our proposed peroperative classification covers the extent of soft tissue injury and skeletal stability, thus predicting the outcome more than the Gustilo classification.

**Keywords :** open fracture ; children ; classification ; reliability.

**Mots-clés :** fracture ouverte ; enfant ; classification ; fiabilité.

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## INTRODUCTION

Classification of open fractures is important because it allows comparison of results in scientific publications, but more importantly because it gives the surgeon guidelines for prognosis and permits us to make some statements about methods of treatment. Throughout the world, the wound classification system of Gustilo and Anderson (7) and the subsequent modification by Gustilo, Gruinger, and Davis (6, 8, 9) is the most widely accepted and quoted.

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There is however a wide variation in the interpretation and use of the Gustilo-Anderson classification and generally there is too much emphasis on wound size (3). The critical factors in their classification system are (1) the degree of soft tissue injuries, and (2) the degree of contamination. A devastating crush injury of the leg necessitating amputation may be associated with only a small skin wound. The size of skin wound is therefore a poor guide to the classification. Additionally the classification does not take into consideration the size of the patient. Children have a smaller surface area, yet the grading of the wound size has not been modified for this age group.

The aim of the current paper is to evaluate the wound classification in children and to correlate the initial classification with post-debridement classification, the fracture morbidity and the outcome.

### MATERIAL AND METHODS

We have reviewed 27 children (15 boys and 12 girls) aged 3-15 years (mean age of 10 years) years who sustained an open tibial fracture between 1992 and 1998. In the same period 360 children under the age of 16 sus-

tained closed fractures of the tibia, therefore open injuries accounted for 6.3% of tibial fractures treated at Bradford Royal Infirmary. Open fractures caused by bullet injuries were excluded. The injury was caused by car accidents in 25 patients, a kick by a horse in one patient and a fall in another. The right side was involved in 12 and the left in 15. Two patients had an associated head injury and one had an ipsilateral femoral fracture.

All wounds were graded according to the system of Gustilo-Anderson. We recorded the pre- and post-debridement grading of the fracture using the parameters of Gustilo. Polaroid photographic assessment of the wound in all these patients was made in the accident and emergency department. The majority of these fractures were classified as Gustilo grade I on initial inspection. However after wound exploration in the operating theater, the periosteum in these cases was found to be stripped; according to Gustilo's classification this resulted in upgrading to grade III (a, b). Unsurprisingly there is discrepancy when applying Gustilo's classification prior to and after, wound exploration in the operating theater. We also applied our proposed classification, which is performed after the wound exploration (table I).

The fracture patterns were assessed, the commonest injury being a transverse or oblique fracture at the junction between the middle and lower thirds of the tibia. In four patients, the fracture was situated in the distal third of the tibia, in two patients between the upper and the

Table 1. — Proposed new classification of open tibial fractures following the debridement of the wound (this classification is used in table IV)

Type	Wound size	Level of contamination	Soft tissue injury	Bony injury (stable-S, unstable-US)
I (a)	a wound requiring no skin graft or flap	Minimal	Intact periosteum. Minimal to moderate muscle damage	No comminution (S)
I (b)	a wound requiring skin graft or flap	Moderate to severe	Intact periosteum. Minimal to moderate muscle damage	No comminution (US)
II (a)	a wound requiring no skin graft or flap	Minimal to moderate	Stripped periosteum. Minimal to moderate muscle damage	No to minimal comminution (S)
II (b)	a wound requiring skin graft or flap	Moderate to severe	Stripped periosteum. Minimal to moderate muscle damage	Minimal to moderate comminution (US), Segmental fracture
III	A wound requiring skin graft or flap	Severe	Stripped periosteum. muscular, neurovascular injury	Unstable comminuted and/or segmental with or without bone loss

Table II. — A comparison between pre and post-debridement classification using the Gustilo classification parameters

Pre-operative grading	Post-debridement grading	New classification
I (13)	I (1) II (5) III-a (1) III-b (6)	I (a) I (a) I (a) 5 patients with II (a) and 1 patient with II (b)
II (6)	III-a (3) III-b (3)	3 patients with II (a) 2 patients with type II (a) & 1 patient with II (b)
III-a (3)	III-b (3)	II (a), 3 patients
III-b (5)	III-b (5)	II (b) 5 patients

Table III. — Grading of the fracture in patients who required a fasciocutaneous flap

Pre-operative grade	Postoperative classification using the Gustilo parameters	New classification
II (2)	III-b	II (b)
III-b	III-b	II (b)

middle third. In one patient, the fracture affected the mid-shaft of the tibia. The fibula was intact in three cases and the tibial fracture was segmental in one patient.

All patients were managed by early intravenous prophylactic antibiotic administration and primary aggressive debridement and wound toilet with lavage within 6 hours of injury. The soft tissue injury was treated in collaboration with the plastic surgeon (tables I, II, III); 30% of the wounds required plastic surgical attendance.

The decision concerning the type of stabilization of the fracture was made according to the surgeon's preference. Primary external fixation was used in five patients, in three because of unstable fracture configuration (segmental or comminuted), and in a further two to assist soft tissue management. The remainder (22 cases) were treated with above-knee plaster-of-Paris splintage with a window over the wound. Change of above-knee plaster to a below-knee tibial cast brace (Miami cast) was carried out when the tibial fracture felt stable (upon telescoping and varus valgus stress) and when a radiograph of the fracture showed evidence of callus formation (usually from 5 to 8 weeks after injury). In the group treated by external fixation, the fixator was removed in 6-11 weeks after the operation. A below-knee walking cast was then applied until radiological fracture union.

One patient in our series was treated by skeletal traction for an ipsilateral femoral fracture and plaster slab immobilization for his tibial fracture.

## RESULTS

In order to correlate the pre- and post-operative wound debridement with outcome measures, we studied the following factors: the number of theatre visits for wound or fracture attention following the initial debridement, the number of clinic visits following discharge from the hospital, the wound healing, the duration of fracture healing and complications. Following primary debridement and skeletal stabilization, the mean number of subsequent theatre visits was 2 (range 1 to 3 visits) for post-debridement grade I and II and a mean 3 visits (range 1 to 5 visits) for post-debridement Gustilo Grade III a& b. Mean duration of in-patient hospitalization was 6 days (range 1 to 9 days) for post-debridement grades I & II and 9.4 days (3 to 25 days) for Gustilo grades III (a & b). The mean number of clinic follow-ups was 3 for post-debridement grades I & II. The number of clinic

Table IV. — Average time to clinical and radiological union

Pre-operative Gustilo classification	Post-debridement classification according to the Gustilo system	New classification	Weeks
I	I	I (a)	7
I	II	I (a)	8 (7-9)
I	III-a	II (a)	11 (8-13)
I	III-b	II (b)	13 (9-16)
II	III-a	II (a)	10 (7-11)
II	III-b	II (b)	17.6 (8-32)
III-a	III-a	II (a)	12 (8-19)
III-b	III-b	II (b)	21 (13-30)

Table V. — Pre- and post-debridement grading in relation to the complications

Pre-operative Gustilo grading	Post-debridement grade according to Gustilo system	New grading	Complication
III-b	III-b	II(b)	Delayed union
II	III-b	II(b)	Delayed union
II	III-b	II (b)	Malunion
III-b	III-b	II (b)	Compartment syndrome

follow-up visits on the other hand was 5 (1 to 11 visits) for post-debridement Gustilo grades III a & b.

The mean period of follow-up was 8 months (6 to 24 months). The fracture was considered united when clinical and radiological signs of healing were noticed. Mean time to healing was as in table IV. There were no instances of limb length inequality or joint stiffness at discharge; the wounds were all healed at discharge (apart from eight patients with post-debridement Gustilo grades III a & b which took a mean 16 days to heal (range from 10 to 25 days). The following complications were encountered (table V) :

1. One case of compartment syndrome was encountered and was released / decompressed in the standard manner. This patient's pre- and post-debridement grading of the wound was IIIB ; the fracture was treated by external fixation.
2. In five cases the tibial fracture became displaced in the plaster, requiring external fixation to maintain the position in two patients, internal fixation using Kirshner wire and screw fixation

in one, and re-manipulation with further plaster cast immobilization for the remaining two.

3. One patient required corrective osteotomy 15 months after the injury to correct 15° varus malunion. This particular 12-year-old boy sustained a grade IIIB (post-debridement) open tibial fracture, the pre-operative grade in this particular patient was II. The tibia was fixed initially using an Orthofix unilateral frame and the skin defect was closed using partial split skin graft. Malunion resulted from problems encountered with the fixator and delayed healing of this short oblique comminuted fracture. Within two weeks of injury, the patient developed severe pin tract infection requiring reseating of one set of pins ; the fixator was dynamized 5 weeks following injury. Because of delayed healing, the fixator was kept for three months.
4. Two cases of delayed union (requiring 6 months to heal) were encountered, post-operative gradings were grade IIIB fractures, while the preoperative grade in one of them was II. Both these patients were initially treated in external fixator frames. Neither required further intervention.

Problems of surgical treatment :

1. One patient presented with painful cheloid scar formation of split skin graft, which settled spontaneously.
2. Four cases of pin tract infection. These were treated with antibiotics and pin toilet. In one case reseating of one set of pins was required and the reduction of the fracture was lost.

## DISCUSSION

Several issues surrounding the management of open tibial fractures in children remain unresolved and controversial. The issues of main concern revolve around the management of the bony injury, whether to definitively fix, either internally or externally, or whether to treat conservatively in a cast. Other issues of perhaps less concern, but which add confusion to the subject, include the question of the Gustilo grading of fractures in general and the question of how much remodeling we might expect in a child (and consequently how much deformity we can consider acceptable).

The imperfection of the Gustilo grading system, with its liability to interobserver error, has previously been discussed in the literature (1, 4). Besides, the degree of soft tissue injury is not always related to the size of the wound. A very large wound caused by a sharp object such as a knife may have minimal associated soft tissue crush and therefore may carry a very good prognosis. The size of the wound in children on the other hand is underestimated because of their relatively smaller body surface area compared to adults. According to the Gustilo-Anderson classification, in grade III open fractures the size of the wound should be more than 10 cm long or the periosteum should be disrupted. In our cases nevertheless the periosteum was stripped in those where the classification was accordingly upgraded using Gustilo's parameters.

The discrepancy in literature is obvious in respect of our observations. Although the majority of cases in published papers on open tibial fractures in children are considered to be grade II (5, 10), yet Buckley *et al.*, who reviewed 41 children with open

tibial fractures, found that the incidence of compartment syndrome, vascular injury, infection and delayed union were similar to those reported for open fractures in adults. The incidence of delayed union following open fractures of tibia is reported to be as high as 14% in Buckley's series (2), presumably because the Gustilo-Anderson classification in these series has been applied pre-operatively relying on wound size. When the parameters of the Gustilo classification are used after the wound exploration in operating theaters, the grading system was often upgraded ; this we believe has tended to make our series seem to contain more 'severe' injuries than other series in the literature.

The current new classification proposed has in this series addressed the concerns. According to this classification, and in order to avoid the fallacies encountered with Gustilo's pre-operative classification, the extent of soft tissue injury, including the stripping of the periosteum and the fracture stability, is assessed after wound exploration in the operating theater. In this proposed classification, it is important to highlight in the documentation the fracture stability ; this ultimately affects the methods for immobilization whether it is a plaster cast or instrumented fixation. In this series and because of a lack of pediatric external fixator at some stage in our hospital, we had to treat some of our severe open tibial fractures using plaster cast in the presence of soft tissue cover. A satisfactory result was however obtained with plaster cast immobilization. This I believe is because of the rapid soft tissue and bone remodeling potential in the pediatric age group as compared to adult and elderly patients.

As the relevance of the size of the wound is the degree of contamination and the need for plastic soft tissue cover, the current proposed classification has not included the length of the wound in centimeters. Instead the classification addresses the degree of contamination and whether or not the wound requires soft tissue cover.

## CONCLUSION

The outcome analysis relying entirely on the size of wound is not a realistic reflection of the grade of soft tissue injury in open fractures, and it is no

wonder that the outcome measures following the management of a particular grade of open long bone fracture vary in the literature. Post-debridement classification of open tibial fractures in children is a better indicator of the outcome. Factors such as the velocity of injury perhaps play a major role in inflicting the overall degree of soft tissue injury, periosteal stripping and the configuration of the fracture, particularly from the standpoint of the amount of displacement and comminution evident. Another classification system using Tscherne's system which addresses the impact of injury on soft tissue perhaps predicts the outcome of long bone fracture better than the Gustilo classification which merely relies on the size of the wound (11). Tscherne's classification is however used for closed rather than open tibial fractures. The current proposed classification is perhaps an alternative for the Gustilo classification. The amount of soft tissue, skeletal injury and degree of contamination addressed in the current classification assists in the prediction of the outcome and the choice of treatment.

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#### **REFERENCES**

1. Brumback R. J., Jones A. L. Interobserver agreement in the classification of open fractures of the tibia. The results of a survey of two hundred and forty five orthopaedic surgeons. *J. Bone Joint Surg.*, 1995, 77-B, 1291-1296.
2. Buckley S. L., Smith G., Sponseller P. D. Open fractures of the tibia in children. *Acta. Orthop. Scand.*, 1976, 47, 448-451.
3. Chapman M. W. Open fractures in : *Fractures in Adults*, Rockwood and Green (eds.) Lippincott, Philadelphia, 4<sup>th</sup> edition, 1992, pp.223-264.
4. Gustilo R. B. Current concepts in the management of open fractures. *Instr. Course Lect.*, AAOS, 1987, 36, 359-366.
5. Gustilo R. B., Anderson J. T. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones : Retrospective and prospective analysis. *J. Bone Joint Surg.*, 1976, 58-A, 453-458.
6. Gustilo R. B., Gruninger R. P. Davis T. Classification of type III (severe) open fractures relative to treatment and results. *Orthopaedics* 1987, 10,1781-1788.
7. Gustilo R. B., Simpson, L., Nixon R., Ruiz A., Indeck W. Analysis of 511 open fractures. *Clin. Orthop*, 1969, 66, 148-154.
8. Horn B. D., Retting M. E. Interobserver reliability in the Gustilo and Anderson classification of open fractures. *J. Orthop. Trauma*, 1993,7, 357-360.
9. Irwin A., Gibson P., Ashcroft P. Open fractures of the tibia in children. *Injury*, 1995, 26,21-24.
10. Song K. M., Sangeorzan B., Benirschke S., Browne R. Open fractures of the tibia in children. *J. Pediatr. Orthop.*, 1996, 16, 635-639.
11. Tscherne H., Cotzen L. *Fractures with soft tissue injuries*. Berlin, Springer-Verlag, 1984.

#### **SAMENVATTING**

*A. A. FARAJ. De betrouwbaarheid van de preoperatieve classificatie van open tibia fracturen bij kinderen.*

Het doel van deze klinische studie was de evaluatie van de bruikbaarheid van de Gustifio classificatie bij de beoordeling van open tibia fracturen bij kinderen. Bij middel van de parameters van de Gustilo classificatie, werd bij 27 kinderen slachtoffer van een open tibia fractuur met een gemiddelde leeftijd van 10 jaar (3 tot 15 jaar) een gradering van het letsel uitgevoerd op de spoed-gevallenafdeling vóór wonddebridement, systematisch aangevuld met preoperatieve Polaroidbeelden. De routine aanpak bestond in preventieve intraveneuze antibiotica therapie, wonde debridement en lavage. Na de heelkundige exploratie in de operatiekamer werd het letsel opnieuw geklasseerd volgens de Gustilo parameters : de classificatie was duidelijk verschillend van de initiële uitgevoerd op de spoed. Daarom werd een nieuwe classificatie opgesteld gebaseerd op de peroperatoire vindingen en de ernst van de weekdeeltsels en op de stabiliteit van de breuk. In deze nieuwe classificatie waren de meeste open tibiafracturen in kinderen stabiel, vroegen geen huident of huidflap, en heelden met een gunstig resultaat. Slechts in vijf gevallen was uitwendige fixatie nodig : in de overige gevallen was gipsimmobilisatie, mits de nodige aandacht voor de wonde, voldoende. De klinische evaluatie van het resultaat was gebaseerd op de beoordeling van het uitzicht van de wonde, het verloop van de fractuurheling en het voorkomen van verwikkelingen. De gemiddelde opvolgstermijn bedroeg 8 maanden (6 tot 24 maanden). Er waren geen gevallen van pseudarthrosis of diepe wondinfectie en de wonden genazen in alle gevallen. Wij menen te moeten besluiten dat de Gustilo classificatie geen juist beeld geeft van de ernst van de

weekdeel- en botletsels. De afmetingen van de wonde zijn veel minder belangrijk dan het snelheidsimpact van het trauma en de uitgebreidheid van de weekdeelkwetsuur en periostale loslating, zoals vastgesteld bij het heelkundig wondtoilet. Onze classificatie opgesteld tijdens het operatief debridement, en gebaseerd op botstabiliteit en uitbreiding van weekdeelletsels geeft een beter uitkomstbeeld dan de Gustilo classificatie.

### RÉSUMÉ

*A. A. FARAJ. Étude de la fiabilité de la classification préopératoire des fractures ouvertes du tibia chez l'enfant. Proposition d'une nouvelle classification.*

Ce travail a été réalisé pour évaluer la fiabilité de la classification de Gustilo pour les fractures ouvertes du tibia chez l'enfant. L'auteur a comparé chez 27 enfants âgés en moyenne de 10 ans (3 à 15 ans) qui présentaient une fracture ouverte du tibia, les classifications des plaies avant et après débridement, sur base des éléments de la classification de Gustilo. Toutes les plaies ont été photographiées à l'arrivée aux urgences. Le traitement a associé dans tous les cas une antibiothérapie systémique à titre préventif et le débridement-lavage de la plaie. Pour chaque cas, la classification a été revue sur base des critères de Gustilo après exploration de la plaie en salle d'opération ; la nouvelle classification était souvent dif-

férente de la classification initiale. L'auteur propose une nouvelle classification, qu'il compare à la classification de Gustilo réalisée après débridement. La nouvelle classification consiste en une évaluation peropératoire de l'étendue des dégâts des tissus mous, et elle prend en compte la stabilité osseuse. Avec cette classification, la majorité des fractures ouvertes du tibia étaient stables, ne requéraient ni greffe ni lambeau cutané, et ont eu une bonne évolution. Cinq patients seulement ont été traités au départ par fixation externe, les autres ont été traités par immobilisation plâtrée. Le traitement des plaies a été individualisé. L'étude du résultat final a pris en compte la cicatrisation de la plaie et la consolidation osseuse ainsi que l'incidence des complications. Le suivi moyen était de 8 mois (6 à 24 mois). Il n'y a eu aucune pseudarthrose et aucune infection profonde, et toutes les plaies ont guéri correctement.

L'auteur conclut que la classification de Gustilo manque de spécificité et ne reflète pas l'étendue des dégâts osseux et des tissus mous. Certains facteurs comme l'importance des lésions des tissus mous et le décollement périosté, que l'on ne peut apprécier qu'après débridement de la plaie, ainsi que le niveau d'énergie du traumatisme, sont beaucoup plus importants que la dimension de la plaie. La classification peropératoire proposée prend en compte les lésions des tissus mous et la stabilité osseuse ; elle a une meilleure valeur prédictive que la classification de Gustilo.