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Classification of open tibia fractures: the rationale for a new classification system

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Abstract Open tibial shaft fractures are one of the most common long bone injuries encountered. Current existing classifications are designed to characterize the nature of the injury and guide clinical decision making. However, despite these advancements, there are areas in our current classification system that can be improved to not only make reliability more producible but also create prognostic factors that can help guide treatment.

Keywords: open fracture, tibial shaft fracture, fracture classification

1. Introduction

Tibial shaft fractures are the most commonly fractured long bone, with an estimated annual incidence of 21.5 per 100,000 population.[1] Owing to the subcutaneous nature of the tibia, open tibial fractures are the most common type of open fractures, accounting for 11.2% of all open fractures.[2] Open tibial shaft fractures can be associated with significant soft-tissue injury, and numerous classification systems exist to describe these injuries. The goals of classification systems used in orthopaedics are to characterize the nature of the injury and guide clinical decision making.[3] A successful classification system must have a high degree of interobserver reliability, indicating good repeatability of findings, accuracy in distinguishing various presentations or severity of the condition, and correlation with treatment strategy and observed outcomes. The role of patient-specific factors such as medical comorbidities has currently remained separate from fracture classifications; however, their role may have an evolving impact on patient outcomes.

2. History of Current Classification Systems

The most commonly referenced classification for open fractures is the Gustilo–Anderson classification. In 1976, Gustilo and Anderson[4] published a retrospective review of 673 open fractures of the tibia in 602 patients to determine the impact of primary versus secondary closure, use of primary internal fixation, and routine use of antibiotics in the treatment algorithm of open tibia fractures. They then prospectively followed additional 350 patients, categorizing open fractures into 3 types based on wound size, level of contamination, and osseous injury as follows: type I: an open fracture with a wound less than 1 cm long and clean; type II: an open fracture with a laceration greater than 1 cm long without extensive soft-tissue stripping; and type III: an open segmental fracture, an open fracture with extensive soft-tissue damage, or a traumatic amputation. Special categories in type III were high-velocity ballistic injuries, any open fracture caused by a farm injury, and any open fracture with accompanying vascular injury requiring repair.[4] Type III fractures made up over 60% of open fractures and proved to have the most variability in severity and prognosis with infection rates ranging from 9.9% to 44%, suggesting that a single classification was insufficiently specific. Despite advances in antibiotic therapy, debridement, and fixation strategies, the numbers remain largely unchanged.[5] Gustilo et al[6] further subclassified type III open fractures into IIIA: open fractures with adequate soft-tissue coverage of a fractured bone despite extensive soft-tissue laceration or flaps or high-energy trauma regardless of the size of the wound; IIIB: open fractures with extensive soft-tissue injury loss with periosteal stripping and bone exposure, which are usually associated with massive contamination; and IIIC: open fractures associated with arterial injury requiring repair. A progressively worsening prognosis was seen within these subtypes as IIIA injuries had a 4.4% infection rate with no amputations, IIIB injuries had a 52% infection rate with 16% leading to amputation, and IIIC injuries had a 42% infection rate with a 42% amputation rate. Over time, there have been numerous attempts to modify the Gustilo classification. Most notably, Trabulsy et al[7] in 1994 introduced the concept of wounds being 1 to 10 cm long for type II injuries and "usually" >10 cm for all type III injuries, which has since propagated in the literature although many publications omit the "usually" descriptor included in their original work.

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Around the same time Gustilo's classification system was developed, Tscherne and Oestern proposed a classification for soft tissues. Their classification system was composed of the amount of contamination ranging from minimal to severe. Furthermore, soft-tissue stripping was labeled as contusions. Similar to Gustilo-Anderson, this classification system is unable to fully describe the spectrum of injuries that a type III fracture is associated with.[8]

The Ganga Hospital Open Injury Severity Score (GHS) was developed by Rajasekaran et al[9] in 2006 for predicting salvage versus amputation in open type IIIB injuries in response to the varied presentation of type III B injuries, lack of proper management guidelines, and lack of a comprehensive scale to determine salvage versus amputation in severely injured limbs. The injury is graded from 1 to 5 in 3 categories: covering tissue (skin and fascia), skeleton (bones and joints), and functional tissues (muscles, tendons, nerve units). Comorbidities which may influence treatment and outcome are given 2 points each, and the final score is the summation of the individual scores. A high sensitivity and specificity for amputation was documented when a score of 14 was used as the threshold score for amputation.[9] The primary focus of the score has been that of a decision-making tool in limb salvage versus amputation, more than a true classification system aiming to offer generalized management. Furthermore, it overlooks the type I and type II injuries.

In 2010, the Orthopaedic Trauma Association (OTA) Open Fracture Study Group (OFSG) published their classification system for open fractures of the upper extremity, lower extremity, and pelvis developed from literature review of 34 risk factors and a panel consensus opinion. It stratifies injury severity in 5 categories including skin injury, muscle injury, arterial injury, bone loss, and wound contamination.[10] Scores ranging from 1 to 3 are given in each category, with a maximum summative score of 15 representing the most severe injury. Studies have shown this classification system to have good prognostic value because it correlates with the type of definitive closure, the development of a 90-day wound complication, the occurrence of a nonunion, and the need for amputation.[11] Furthermore, its categorization has been beneficial for maintaining data for research purposes.

3. Limitations of Current Classifications

The development of an all-encompassing classification system for open tibial shaft fractures remains challenging because of difficulties in accurately characterizing bone, soft-tissue, and vascular injuries and how they relate to patient outcomes. Of the several classifications for open tibial shafts proposed, the Gustilo–Anderson classification remains the most widely used.[4,6,7,9,11] Despite its popularity, it suffers from a few well-studied shortcomings such as poor-to-moderate interobserver reliability often attributed to imprecise definitions of injury characteristics.[12] There is also a lack of mutual exclusivity between types given that many injuries possess features of different classification types, such as an open tibial shaft with a wound less than 1 cm but with "moderate" soft-tissue damage.

The OTA/OFC classification tried to address some of these shortcomings of the Gustilo–Anderson classification. As we know, open fracture severity can have both bony and soft-tissue components. Skin defects can be small but also difficult or not able to approximate. Bony injury can range from minimal to segmental bone loss. Muscle loss can be localized and have significant damage that can worsen over several days. Finally, Bi et al[13] demonstrated that vascular injuries compromise wound healing potential in their associated angiosome. This classification system, albeit a significant improvement, has some subjectivity in descriptors such as "extensive degloving," "muscle loss," and "muscle function."[10] This system has been shown to be superior to the Gustilo–Anderson system in relation to the detail of the description of open fractures and its prognostic value with moderate-to-excellent interobserver reliability, although other comparative series have shown it to be similar to those of the Gustilo–Anderson system.[14,15]

Finally, the GHS draws direct parallels between the type of injury, patient comorbidities, and surgical treatment, which, in theory, is an ideal characteristic for a classification system. However, its utility is limited to patients with the most severe trauma, limiting its use as a true classification system to offer guidance in all open tibial shaft fractures.

4. What is Missing: Essential Factors to Consider in a New Classification

Despite the multitude of studies that evaluate various issues related to open fractures, the number of studies that systematically identify and evaluate factors that categorize open fracture severity, treatment complexity, and predict outcomes remains limited. A new system with clear objective descriptors defining each type should reflect current health care standards such as functional outcomes, patient-reported outcomes, quality-adjusted life years, and functional return more so than infection alone. Factors to consider in a new classification system can be divided into fracture characteristics, injury characteristics, and patient characteristics.

4.1. Fracture Characteristics

Location of open fractures is often overlooked. The generalizability of the OTA/OA classification to all open fractures can be challenging to interpret. An open fracture with segmental bone loss of the radius has significantly different implications than that of the tibia.[16]

Although current classifications have mainly focused on fracture characteristics with descriptors of bone and soft injuries, there remains the need for further development. While type III injuries make up nearly 60% of open tibial shaft fractures, there remains a large amount of variability within subcategories regarding prognoses. Regarding vascular injury, type IIIC injuries are defined as those requiring vascular repair and are associated with the worse prognosis of type III injuries. However, it has been demonstrated that open tibial shaft fractures with arterial injuries that do not undergo repair due to preserved distal vascular supply have significantly higher rates of wound healing complications, flap coverage needs, time to definitive coverage, amputation, and infections.[13]

The full extent of deep soft-tissue injury and its viability is often underestimated and may not correlate with the size of the skin defect. Type IIIB injuries are described as having a wound size >10 cm with extensive soft-tissue injury requiring a free tissue or rotational flap. However, computed tomography (CT) scans of type I and II open tibial shaft fractures have demonstrated evidence of air in subcutaneous tissues and anterior and deep posterior compartments >5 cm away from the fracture and wound site in 69% of fractures.[17] Wounds are usually located anteromedially because the tibia is subcutaneous. Thus, a 1-cm anteromedial wound may present as a true type I fracture because of limited soft-tissue coverage, but a 1-cm anterolateral or posterolateral wound may have significantly more soft-tissue stripping. Utilization of CT scans can hopefully provide a new means of defining the zone of injury.

Fracture morphology is discussed in current classifications, with the Gustilo–Anderson classification describing fracture comminution as “minimal,” “moderate,” and “severe” in type I, II, and III fractures, respectively.[6] The OTA-OSFG classification also subgroups fractures as those with no bone loss, some bone loss or devascularization requiring excision with some cortical opposition, and segmental bone loss.[10] Defining a critical size defect can be challenging. A critical size defect is treated much differently in a wound that is closed primarily and heals versus a defect that requires a flap.[18,19] However, the amount or extent of comminution and bone loss remains difficult to define to guide treatment.

4.2. Injury Characteristics

Current classification systems lack a true definition of injury mechanisms, despite evidence of similar-appearing injuries with different mechanisms having vastly different outcomes. Soft-tissue and bony injuries are dependent on the amount of energy transferred to the limb at the time of impact, which varies when considering a fall from standing to a fall from a height where the mass may be comparable but the squared value of the velocity increases. Road traffic accidents are the most common mechanism of injury, accounting for more than half of all open tibial shaft fractures, and the remainder caused by falls, sports-related injuries, and direct trauma. Nearly 60% of all open tibial shaft fractures are classified as type III, although there remain large variations within this classification.[2] Clinical series involving closed and open treatment of tibia fractures have demonstrated increased complication rates and prolonged union times associated with high-energy injuries.[20,21] Animal studies have demonstrated that the addition of a crush injury to the soft tissue in addition to a tibial shaft fracture results in prolonged union times and increased risk of skin necrosis.[22]

Furthermore, gunshot and blast injuries pose an additional consideration. The Gustilo–Anderson[23] classifications mention ballistic fractures within the group of open injuries, referring to close-range gunshot injuries or high-velocity injury, but they do not mention the more common low-velocity gunshot wounds (GSWs). Literature regarding the risks of infection associated with low-energy ballistic fractures is limited, and treatment standards for debridement and antibiotics remain controversial.[24,25] Low-velocity GSW tibia fractures have a historically low rate of infection and nonunions, with the reoperation rate similar to that of closed tibial shaft fractures and significantly lower than open tibia fractures.[26,27] However, a more recent study has demonstrated that these injuries behave as an intermediary between closed and open fractures.[28]

4.3. Patient Characteristics

Studies investigating outcomes in open tibial shaft fractures have focused mostly on intrinsic injury characteristics and extrinsic variables such as antibiotic prophylaxis, time to debridement, and soft-tissue management. However, the effect of nonmodifiable intrinsic patient characteristics may affect clinical outcomes beyond the control of the surgeon even when appropriately treated.

Patient comorbidities have been shown to play a significant role in outcomes after management of open tibial shaft fractures. Congestive heart failure, bleeding disorders, obesity, diabetes, hypertension, chronic obstructive pulmonary disease, psychiatric illness, and smoking are all linked to higher rates of infection and lower rates of fracture union.[29–31] Increased age has also been found to have higher rates of infection, nonunion, amputation, medical complications, and mortality and longer times to union after open tibial shaft fractures.[32,33] The management of open fractures in the elderly is complex with respect to poor soft tissues and slower wound healing.[34,35] Tibial shaft fractures in the elderly are more likely to be open, reported as high as 51.5% of the time due to the decreased tensile strength of the skin, and occur most commonly after simple ground-level falls likely secondary to the fragile, elderly soft tissue.[36] Steele et al[33] also demonstrated poor outcomes for return to mobility and preinjury residential status in patients older than 75 years with 75% reporting reduced mobility by one grade and 16% reduced by 2 grades at an average of 2 years of follow-up.

Interestingly, rates of amputation in elderly patients sustaining type III open fractures have been found to be much lower (5%–14%) when compared with younger patients, where rates as high as 25% have been reported.[33,37] Similarly, risk of morality has been shown to be higher in patients sustaining open tibial shaft fractures when compared with closed; however, this increased risk is not seen in elderly patients.[38,39] This may be due to overestimating the severity of open fractures in the elderly based on current classifications, compared with the severity of injury and force needed to produce similar injuries in a younger patient with more robust skin and soft tissue, as evidenced by higher Injury Severity Scores seen in younger patients.[40]

5. Conclusions

Classifications of orthopaedic injuries have 2 main functions: (1) accurately characterizing the nature of a problem to guide treatment decision making, ultimately improving outcomes, and (2) establishing an expected outcome for the natural history of an injury, forming a basis for uniform reporting of results for various surgical and nonsurgical treatments.

The Gustilo–Anderson classification has stood the test of time, although not without its flaws. The original classification system looked only at infection as an outcome, but it has since been recognized that functional outcomes such as patient-reported outcome measures, quality-adjusted life years, and functional return are greater measures of success. There is a need for a new classification system of open tibial shaft fractures that incorporates not only fracture characteristics but also patient and injury characteristics to more appropriately guide treatment and manage patient expectations after these injuries.

References

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. *Injury*. 2006;37:691–697.
2. Court-Brown CM, Bugler KE, Clement ND, et al. The epidemiology of open fractures in adults. A 15-year review. *Injury*. 2012;43:891–897.
3. Garbuz DS, Masri BA, Esdaile J, et al. Classification systems in orthopaedics. *J Am Acad Orthop Surg*. 2002;10:290–297.
4. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am*. 1976;58:453–458.
5. Castillo IA, Heiner JA, Meremikwu RI, et al. Where are we in 2022? A summary of 11,000 open tibia fractures over 4 decades. *J Orthop Trauma*. 2023;37:e326–e334.
6. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma*. 1984;24:742–746.

7. Trabulsy PP, Kerley SM, Hoffman WY. A prospective study of early soft tissue coverage of grade IIIB tibial fractures. *J Trauma*. 1994;36:661–668.
8. Agrawal A. Unified classification of open fractures: based on Gustilo and OTA classification schemes. *Injury*. 2018;49:1526–1531.
9. Rajasekaran S, Naresh Babu J, Dheenadhayalan J, et al. A score for predicting salvage and outcome in Gustilo type-IIIA and type-IIIB open tibial fractures. *J Bone Joint Surg Br*. 2006;88:1351–1360.
10. Orthopaedic Trauma Association Open Fracture Study Group. A new classification scheme for open fractures. *J Orthop Trauma*. 2010;24: 457–464.
11. Garner MR, Warner SJ, Heiner JA, et al. Evaluation of the orthopaedic trauma association open fracture classification (OTA-OFC) as an outcome prediction tool in open tibial shaft fractures. *Arch Orthop Trauma Surg*. 2022;142:3599–3603.
12. Brumback RJ, Jones AL. 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 Am*. 1994;76: 1162–1166.
13. Bi AS, Fisher ND, Parola R, et al. Arterial injury portends worse soft tissue outcomes and delayed coverage in open tibial fractures. *J Orthop Trauma*. 2022;36:535–543.
14. Ghoshal A, Enninghorst N, Sisak K, et al. An interobserver reliability comparison between the Orthopaedic Trauma Association's open fracture classification and the Gustilo and Anderson classification. *Bone Joint J*. 2018;100-B:242–246.
15. Agel J, Evans AR, Marsh JL, et al. The OTA open fracture classification: a study of reliability and agreement. *J Orthop Trauma*. 2013;27:379–384; discussion 384–385.
16. Putnam SM, Dunahoe J, Agel J, et al. Clinical correlation of the orthopaedic trauma association open fracture classification with wound closure and soft-tissue complications in open upper extremity fractures. *J Orthop Trauma*. 2021;35:e184–e188.
17. Suzuki T, Nakayama Y, Matsui K, et al. Prevalence and distribution of air in the leg on preoperative multidetector high-resolution computed tomography in closed and low-grade open tibial shaft fractures. *J Orthop Surg (Hong Kong)*. 2019;27:2309499019825585.
18. Haines NM, Lack WD, Seymour RB, et al. Defining the lower limit of a "critical bone defect" in open diaphyseal tibial fractures. *J Orthop Trauma*. 2016;30:e158–e163.
19. Mauffrey C, Barlow BT, Smith W. Management of segmental bone defects. *J Am Acad Orthop Surg*. 2015;23:143–153.
20. Hooper GJ, Keddell RG, Penny ID. Conservative management or closed nailing for tibial shaft fractures. A randomised prospective trial. *J Bone Joint Surg Br*. 1991;73:83–85.
21. Johner R, Wruhs O. Classification of tibial shaft fractures and correlation with results after rigid internal fixation. *Clin Orthop Relat Res*. 1983;178: 7–25.
22. Edwards P. The effect of crush injury to the skin on healing of fracture of the shaft of the tibia in dogs. *Acta Orthop Scand*. 1965;36:89–94.
23. Gustilo RB. Use of antimicrobials in the management of open fractures. *Arch Surg*. 1979;114:805–808.
24. Dougherty PJ, Vaidya R, Silverton CD, et al. Joint and long-bone gunshot injuries. *Instr Course Lect*. 2010;59:465–479.
25. Simpson BM, Wilson RH, Grant RE. Antibiotic therapy in gunshot wound injuries. *Clin Orthop Relat Res*. 2003;408:82–85.
26. Nguyen MP, Savakus JC, O'Donnell JA, et al. Infection rates and treatment of low-velocity extremity gunshot injuries. *J Orthop Trauma*. 2017;31:326–329.
27. Su CA, Nguyen MP, O'Donnell JA, et al. Outcomes of tibia shaft fractures caused by low energy gunshot wounds. *Injury*. 2018;49:1348–1352.
28. Prather JC, Montgomery T, Cone B, et al. Civilian ballistic tibia shaft fractures compared with blunt tibia shaft fractures: open or closed? *J Orthop Trauma*. 2021;35:143–148.
29. Saiz AM Jr., Stwalley D, Wolinsky P, et al. Patient comorbidities associated with acute infection after open tibial fractures. *J Am Acad Orthop Surg Glob Res Rev*. 2022;6:e22.00196.
30. Enninghorst N, McDougall D, Hunt JJ, et al. Open tibia fractures: timely debridement leaves injury severity as the only determinant of poor outcome. *J Trauma*. 2011;70:352–356; discussion 356–357.
31. Yokoyama K, Uchino M, Nakamura K, et al. Risk factors for deep infection in secondary intramedullary nailing after external fixation for open tibial fractures. *Injury*. 2006;37:554–560.
32. Yusof NM, Khalid KA, Zulkifly AH, et al. Factors associated with the outcome of open tibial fractures. *Malays J Med Sci*. 2013;20:47–53.
33. Steele J, Pedersen JB, Jay S, et al. Gustilo-Anderson type III tibial fractures have poor functional outcomes in patients over 75 years. *J Clin Orthop Trauma*. 2020;11(suppl 1):S71–S75.
34. Gould L, Abadir P, Brem H, et al. Chronic wound repair and healing in older adults: current status and future research. *J Am Geriatr Soc*. 2015;63:427–438.
35. Gosain A, DiPietro LA. Aging and wound healing. *World J Surg*. 2004;28: 321–326.
36. Court-Brown CM, Biant LC, Clement ND, et al. Open fractures in the elderly. The importance of skin ageing. *Injury*. 2015;46:189–194.
37. Dagum AB, Best AK, Schemitsch EH, et al. Salvage after severe lower-extremity trauma: are the outcomes worth the means? *Plast Reconstr Surg*. 1999;103:1212–1220.
38. Weber CD, Hildebrand F, Kobbe P, et al. Epidemiology of open tibia fractures in a population-based database: update on current risk factors and clinical implications. *Eur J Trauma Emerg Surg*. 2019;45:445–453.
39. Cox G, Jones S, Nikolaou VS, et al. Elderly tibial shaft fractures: open fractures are not associated with increased mortality rates. *Injury*. 2010;41:620–623.
40. Anandasivam NS, Russo GS, Swallow MS, et al. Tibial shaft fracture: a large-scale study defining the injured population and associated injuries. *J Clin Orthop Trauma*. 2017;8:225–231.