A New Classification Scheme for Open Fractures

Orthopaedic Trauma Association: Open Fracture Study Group

Objectives: The purpose of this study was to propose a new classification system for open fractures developed by the Classification Committee of the Orthopaedic Trauma Association.

Setting: Academic and Level I trauma center.

Patients/Participants: Consecutive patients with open fractures.

Main Outcome Measurements: Open fracture classification scale.

Results: Evaluation of 34 factors identified through systematic literature review and ranking in order of importance by our panel resulted in consensus on five essential categories of open fracture severity assessment: skin injury, muscle injury, arterial injury, contamination, and bone loss. These categories were chosen with particular attention paid to avoiding redundancy with existing tools for assessment of fracture configuration. Evaluation of the system through prospective data collection revealed that the five categories were widely applicable to open fractures, but the subcategories of open fracture characteristics required alteration to reflect clinically important parameters for open fracture severity stratification. Skin injury was best assessed by its potential for approximation rather than laceration length. Muscle injury required quantitative and qualitative assessment of potential for function. The effects of arterial injury were most accurately assessed through distal limb ischemia. The depth and nature of contamination were important indicators of overall contamination significance. Bone loss was best assessed quantitatively.

Conclusions: The proposed Orthopaedic Trauma Association Classification of Open Fractures is a scientifically derived assessment tool for determining the severity of open fractures. This tool will require further testing to establish validity characteristics and determine its clinical use compared with existing open fracture classification systems.

Key Words: open fractures, classifications

INTRODUCTION

Systematically classifying fractures assists clinicians and researchers in communicating information by grouping injuries with similar characteristics and separating dissimilar injuries. Open fractures are a unique subset of fractures because of the exposure of bone to contamination from the environment and the disruption of soft tissue integrity, which increases the risk for infection, delayed union, nonunion, and even amputation. Contamination and injuries to the integumentary, myofascial, neurologic, vascular, and/or skeletal systems are factors that have historically been used to identify open fracture patterns with similar natural histories or to guide injury-specific treatment strategies. Involvement of these diverse structures, however, has made classifying open fractures difficult.

Multiple classification systems have been used for open fractures. Of these, the most widely used has been the system of Gustilo and Anderson. Its simplicity and ability to stratify open fracture severity in a logical order has allowed it to stand the test of time. Despite being broadly applied to most open fractures, the Gustilo system was designed only for open tibial fractures. The definitions of injury characteristics are imprecise, which leaves room for different interpretations of how a fracture should be classified. One important shortcoming of the Gustilo and Anderson system is that it incorporates concepts of treatment into the classification such as the methods for closure of soft tissue injuries. Ideally, the characteristics of the injury should guide treatment rather than treatment determining the classification. This is particularly problematic when concepts of treatment evolve over time, potentially changing how similar injuries are classified. It is not surprising that reliability studies have shown only moderate interobserver agreement for the Gustilo and Anderson classification.

This is the first report on a project undertaken by the Classification Committee of the Orthopaedic Trauma Association to develop a new classification of open fractures. The global objective of this new classification will be to classify open fractures of the upper extremity, lower extremity, and pelvis in adults and children in a clinically relevant way, which will allow better communication for treatment and research. To develop this classification, the committee has undertaken a systematic scientific process. The purpose of this article is to report the methods and results of that process, propose a new classification of open fractures, and to outline the process to further assess the classification with reliability studies in the clinical setting.

PATIENTS AND METHODS

An extensive search of three electronic databases (PubMed, EMBASE, and Web of Science) was performed by a medical librarian to locate references that identify factors...
in the literature that have been used to clinically evaluate open fractures of the upper extremity, lower extremity, and pelvis. The search strategies used for each database are listed in Appendix 2 (see Appendix 2, Supplemental Digital Content, http://links.lww.com/BOT/A29) and include references dating from the inception of each database (PubMed—1949, EMBASE—1988, Web of Science—1955) through June 2008. All identified titles and abstracts were hand-searched to identify salient references specifically citing an injury profiling system or classification of factors to rate the severity of open fractures. The resulting list of publications was reviewed by one author (A.R.E.), and a comprehensive list of factors describing upper extremity, lower extremity, or pelvic open fracture tissue injury or treatment characteristics was compiled (Fig. 1). For each factor, the relative frequency of use within the selected body of literature was determined. This frequency was used as a simplistic measure of literature-based importance of each factor.

This list of factors was sent by e-mail to a seven-member panel of experienced, fellowship-trained orthopaedic traumatologists, each of whom was instructed to independently examine and prioritize each factor for inclusion or exclusion in the new open fracture classification scheme. Each panel member was asked to rank the factors in order of their relative importance (1–34) using their clinical experience and knowledge of the literature. A rank-order mean was calculated for each factor and the mean used as a measurement of relative importance (Fig. 2). In addition, five of seven traumatologists independently rated the relative necessity of inclusion of each factor into a comprehensive open fracture classification system with designations of “must include,” “may include,” and “would not include.” Responses were recorded, and agreement between evaluators was used to distinguish heavily favored, disfavored, and controversial factors (Fig. 3).

The results of this analysis were presented to an open fracture work group for review, discussion, and consensus during a focused 4-hour meeting at the 2008 American Academy of Orthopaedic Surgeons meeting in San Francisco. The work group was a panel of fellowship-trained traumatologists who were members of the Orthopaedic Trauma Association classification committee. The data and a consensus process were used to: 1) identify factors considered essential to the classification of open fractures; 2) determine whether to include controversial factors; 3) clarify the definitions of each factor; 4) determine whether the definitions applied to each factor would be applicable to all anatomic regions; 5) formulate a draft classification; and 6) develop a plan to test the classification on clinical cases.

![FIGURE 1. Comprehensive list of factors describing open fracture tissue injury or treatment characteristics from the literature.](http://www.jorthotrauma.com)
In addition to using data from this process, the panel also worked from a set of general principles in developing a new proposed classification system. First, the classification should be simple rather than complex and should be anatomically all-inclusive. Second, it should be based on injury pathoanatomy rather than treatment principles because treatment should follow the classification rather than the classification following the treatment. Third, it should not include system issues (e.g., time to débridement). Fourth, it should focus on the anatomic characteristics of the injury.

The proposed initial classification was then tested through a process of clinical data collection between June and September 2008. The goal was to determine the feasibility and ease of use of the proposed classification system. After approval from local Institutional Review Boards, data were collected prospectively. The investigators were committee members who were fellowship-trained orthopaedic traumatologists at five Level I trauma centers. On the data sheet, in addition to classifying the fracture, clinicians were asked to evaluate the classification in each subcategory and record any problems or difficulties. The classification was also presented to an independent group of clinicians in Europe at a focused meeting on fracture classification. At a second meeting of the open fracture work group at the 2008 Orthopaedic Trauma Association meeting in Denver, the data and other feedback were reviewed and the classification was revised.

RESULTS

Literature Review

The literature search yielded a total of 9283 references: PubMed, 7313 total; EMBASE, 697 unique (821 total, 123 overlap with PubMed); and Web of Science, 1273 unique (1586 total, 314 overlap with PubMed and EMBASE). In addition to these references, three additional references known...
to the authors but not identified in the search process were selected for inclusion that were not identified through the search strategies used. In total, 21 salient references were identified by hand-searching the titles and abstracts of all references, selecting those that cited an injury profiling system or classification of factors to rate the severity of open fractures (Fig. 1). Thirty-four unique factors identified as clinical indices of open fracture severity were extracted through the review of these publications.

Rank Order Process

The rank order mean for each of the 34 factors was used as a measure of relative importance of the independent clinician rankings. This identified 10 highly favored factors, as presented in Figure 4. Nine of these 10 factors were in the top 10 selected factors for the majority (greater than 50%) of panelists. Mechanism of injury related to soft tissue injury (transsection, avulsion, crush) and the degree of injury sustained by the muscular envelope, muscle viability at operation, and energy of injury were the most commonly selected and most highly ranked factors in the survey. The importance of each of these factors was also ranked as “must include” by all panelists who provided “must/maybe/not” inclusion evaluation. Psychosocial and logistic factors such as patients’ socioeconomic background, preinjury health status, time from injury to operative treatment, and treatment in a community hospital versus trauma center setting were among the least highly ranked factors in the survey.

Consensus Process

To draft a new open fracture classification, the factors identified as most important through the literature review and rank order process were further analyzed with emphasis on identifying individual factors that, in aggregate, would serve optimally to classify open fractures. The discussion and analysis resulted in the creation of categories of tissue injury that included skin, muscle, vascular, and osseous injury. The top-ranking factors identified by rank order process that pertain to these tissue systems include: 1) skin defect; 2) muscle injury; 3) arterial injury; and 4) bone loss. Contamination was an additional high-ranking factor that was not accounted for by the classification categories, and so it was included as an additional category.

Each factor was divided into mild, moderate, and severe subgroups with the objective of achieving parallel construction in the subgrouping. This provided internal consistency across open fracture injury characteristics, allowing one or more increasingly severe injury characteristics to directly influence the overall assessment of injury severity.

Evaluation of Study Methodology

Independent of this consensus process, the original 34 injury-related factors included in this analysis were divided into six categories by one of the authors (A.R.E.) based on how they would likely be grouped if incorporated into a comprehensive classification system: tissue system injury, mechanical characteristics of injury, physiological parameters, psychosocial factors, contamination level, and logistic factors affecting timing of treatment (Fig. 5). The clinician panel was blinded to this categorization before consensus discussions and proposal of the new classification system. Within each category, the factors were listed by rank order mean to identify which factors were ranked as most important through the determination of rank order by each clinician. The highest ranking factors within selected...
categories from the rank order process included skin defect, muscle injury, arterial injury, bone loss, and contamination, all of which were included in the proposed classification system. This demonstrated general agreement between the rank order and consensus processes while maintaining the principles of simplicity, concentration on injury characteristics, and exclusion of system issues as originally set forth by the committee. These results lend further merit and validity to the methodology used to generate this classification system.

Clinical Feasibility Study

Data were collected on a series of 99 open fractures. There were 23 upper extremity fractures, 56 lower extremity fractures, four pelvic fractures, and 13 foot fractures. Three fractures had no fracture code. The age range of these patients was 6 to 85 years. Graphs of the range of severity are presented in Figure 6. Comments on the classification were reviewed and discussed by the Study Group at the 2008 Orthopaedic Trauma Association Meeting in Denver, CO. Based on the comments and data, findings important to the formulation of a more clinically relevant classification system included: 1) skin injury was more accurately reflected by the quantity and quality of skin coverage rather than wound length; 2) muscle injury required qualitative as well as quantitative description to capture the extent of and potential for additional necrosis; 3) effects of arterial injury on open fracture severity were more objectively assessed through the identification of ischemic injury rather than the mode of treatment used for the arterial injury.
injury; 4) depth and nature of contamination were essential to measurement of the magnitude of contamination; and 5) bone loss was a unique and important factor in the determination of open fracture severity that remains otherwise unaccounted for by other classification systems.

The results of this revision are presented as the Orthopaedic Trauma Association Classification for Open Fractures, which is seen in Appendix 3.

**DISCUSSION**

The overall objective of this project is to create an open fracture classification system that focuses on injury characteristics defined by pathoanatomy. The classification should apply to anatomically diverse skeletal injuries in both adult and pediatric patients and have greater observer reliability than current open fracture classification schemes. This study reports on our systematic review of the literature and selection of injury characteristics that define an open fracture’s severity. This was followed by independent ranking of the importance of these characteristics by experienced observers and development of a preliminary classification scheme through consensus based on these data. We then performed a clinical feasibility study and further refined the categories leading to the current Orthopaedic Trauma Association Open Fracture Classification scheme.

There is an important need for a new classification of open fractures. The Gustilo and Anderson classification, along with other lesser-known open fracture classification systems, fails to provide simple, reliable, and reproducible measurements of objective clinical findings that can be used to guide injury assessment and treatment. Existing open fracture classifications that display poor interobserver agreement or excessive complexity provide suboptimal use in clinical practice and research and, as a result, require revision through a systematic process capable of providing a simple, reliable, reproducible, and valid clinical and research tool.

There are significant obstacles and challenges to developing this type of classification for open fractures that also correlates with patient prognosis. The challenges include making determinations of open fracture severity based on relevant objective clinical findings than can be classified in a way that is easy to remember and communicate, also providing meaningful guidance for treatment and prediction of clinical outcome. Additional challenges and obstacles exist in the validation process of any open fracture classification, including potentially elaborate schemes required for the evaluation of inter- or intraobserver reliability and measurement of validity parameters. We hypothesize, however, that a systematic and scientific approach to the creation of an open fracture classification system will yield an objective, relevant, and evidence-based clinical and research tool.

We included in the proposed classification system such as myofascial injury and bone loss as well as through the implications regarding treatment distinct from the implications of fracture pattern. Subgroupings were agreed on that include no bone loss, bone loss, or devascularization requiring excision with some cortical opposition and segmental bone loss. All subgroupings were considered applicable to both adult and pediatric patients.

Compartment syndrome was considered as a potential “add-on” given that its occurrence is often related to injury severity. However, compartment syndrome is a distinct clinical entity with a complex diagnostic and treatment algorithm, which suggests that it should be considered separately from the open fracture injury. Neurologic injury was also felt to be a separate issue not directly related to grading open fracture severity. Periosteal stripping is difficult to quantify in isolation and was thought to be better assessed through parameters included in the proposed classification system such as myofascial injury and bone loss as well as through the assessment of fracture pattern. Fracture pattern, with its own complexity of classification, is accounted for by separate classification systems such as the Orthopaedic Trauma Association Comprehensive Fracture Classification System.29
The timing of when to classify an open injury is important for many reasons. Classifying an open fracture in the emergency room is useful for physician-to-physician communication as well as for deciding management of the initial injury. Accurately assessing the degree of injury to deep tissues such as muscle, neurovascular structures, and bone is not always possible before operative exploration of the zone of injury. Classifying the fracture in later phases of treatment may be valuable for assessing the evolution of injury characteristics through the treatment period but will not enhance initial injury severity assessment or guide early treatment. As a result, the end of the initial débridement was felt to be the most optimal time to apply the classification. Standardizing the timing of classifying the fracture will assist in comparisons between future studies.

In summary, we have described a systematic approach for a new classification of open fractures that with further study hopefully will improve on existing systems. We are currently planning observer reliability studies and further modifications.

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REFERENCES

APPENDIX 1

Study Group Members
Andrew R. Evans, MD, Department of Orthopaedics, UPMC Mercy, Pittsburgh, PA; Julie Agel, MA, ATC, Department of Orthopaedic Surgery and Sports Medicine, Harborview Medical Center, Seattle, WA; Gregory L. DeSilva, MD, Department of Orthopaedic Surgery, University of Arizona, Tucson, AZ; Thomas A. DeCoster, MD, Department of Orthopaedics, University of New Mexico, Albuquerque, NM; Douglas R. Dirschl, MD, Department of Orthopaedics, University of North Carolina, Chapel Hill, NC; Clifford B. Jones, MD, Department of Orthopaedics, University of Michigan, Grand Rapids, MI; James F. Kellam, MD, Department of Orthopaedic Surgery, Carolinas Medical Center, Charlotte, NC; Douglas W. Lundy, MD, Resurgens Orthopaedics, Marietta, GA; J. Lawrence Marsh, MD, Department of Orthopaedic Surgery, University of Iowa Hospitals and Clinics, Iowa City, IA; Debra L. Sietsema, PhD, Department of Orthopaedics, University of Michigan, Grand Rapids, MI; and Milan K. Sen, MD, University of Texas Medical Science Center at Houston, Houston, TX.
APPENDIX 3

Proposed Classification of Open Fractures

Skin
1. Can be approximated
2. Cannot be approximated
3. Extensive degloving

Muscle
1. No muscle in area, no appreciable muscle necrosis, some muscle injury with intact muscle function
2. Loss of muscle but the muscle remains functional, some localized necrosis in the zone of injury that requires excision, intact muscle-tendon unit
3. Dead muscle, loss of muscle function, partial or complete compartment excision, complete disruption of a muscle-tendon unit, muscle defect does not approximate

Arterial
1. No injury

Contamination
1. None or minimal contamination
2. Surface contamination (easily removed not embedded in bone or deep soft tissues)
3. a. imbedded in bone or deep soft tissues
   b. high risk environmental conditions (barnyard, fecal, dirty water etc)

Bone Loss
1. None
2. Bone missing or devascularized but still some contact between proximal and distal fragments

Invited Commentary

The importance of an open fracture classification system cannot be overemphasized. It is essential for providing guidelines for treatment, prognosis, functional outcomes, interphysician communication, and research. In 1959, Veliskakis classified open fractures into three types based on the severity of the wound. Subsequently, the Gustilo-Anderson open fracture classification has been the mainstay for classification of open fractures and is used extensively by trauma and orthopaedic surgeons throughout the world. This system has been extremely useful. However, it is not without some limitations. Initially, when Gustilo-Anderson first described the classification system in 1976, it was focused on long-bone fracture wounds and did not address contamination. Over time, modifications of the classification occurred. Another drawback was demonstrated in the study by Brumback and Jones showing interobserver agreement of 60% among 245 orthopaedic surgeons. This led to the recommendation of definitively classifying open fractures at the time of surgery for treatment of the open fracture wound. The need for improvement and refinement of an open fracture classification system is always the goal of the scientific investigator.

The Orthopaedic Trauma Association has proposed a new classification system for open fractures focusing on the injury characteristics defined by the pathoanatomy of the open fracture. They have methodically and carefully evaluated 34 factors identified through a systematic literature review, and a panel identified five essential categories for assessing the severity of the open fracture. These include skin injury, muscle injury, arterial injury, contamination, and bone loss. Besides focusing on the pathoanatomy of the open fracture wound, it is also all inclusive of open fractures regardless of anatomic site and is applicable to both adult and pediatric patients. There is greater emphasis on interobserver reliability and emphasizes that the end of the initial débridement is the ultimate time to apply the classification. The Orthopaedic Trauma Association authors emphasize that the validity of this classification system will be tested and, in the future, observer reliability studies and further modifications will occur. The Orthopaedic Trauma Association is proposing a new classification system that will hopefully be an improvement on the existing open fracture classification systems.

Michael J. Patzakis, MD
Professor and Chairman,
Department of Orthopaedic,
The Vincent and Julia Meyer Chair,
Keck School of Medicine of USC,
Los Angeles, CA

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Invited Commentary

The effort spent by the authors of this classification system is appreciated. This is a well thought out approach to solving a vexing problem in orthopaedic surgery that has existed far too long. The strengths of this preliminary treatise include a comprehensive content validation process, including thorough literature review, use of clinical experts, group discussions, and feasibility testing. Going forward, however, the authors should address the following questions.

1. During the content validation phase, did the authors conduct interobserver agreement using some version of the kappa coefficient (eg, agreement on which of the 34 factors should be included or not in a simple “yes/no” fashion or agreement on which factors were rated “must include,” “maybe include,” or “don’t include”)? This would provide information about the actual level of agreement with chance factors subtracted out. In their discussion section, the authors mention that they are planning “observer reliability studies,” but this should ideally take place during the development of the survey itself.

2. How many people were involved in the consensus process to identify individual factors that “would serve optimally to classify open fractures” as well as to then divide each factor into the mild, moderate, and severe subgroups? This is not clearly specified but probably should be.

Finally, the statistical qualities of this preliminary classification system (including interobserver agreement, construct validity, and criterion-related validity) are still untested. Although it is still too early to tell what, if any, problems this newer system will exhibit, we all look forward to a future publication with a large representative sample that would yield a report with statistical results.

William G. De Long, Jr, MD
Professor of Orthopaedic Surgery,
Anatomy and Cell Biology,
Temple School of Medicine,
Chief of Orthopaedics SLHN

Jill Stoltzfus, PhD
Director, Research Institute,
St. Luke’s Hospital and Health Network