Fracture and Dislocation Classification Compendium - 2007

Orthopaedic Trauma Association Classification, Database and Outcomes Committee

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Summary: The purpose of this new classification compendium is to republish the Orthopaedic Trauma Association's (OTA) classification. The OTA classification was originally published in a compendium of the Journal of Orthopaedic Trauma in 1996. It adopted *The Comprehensive Classification of the Long Bones* developed by Müller and colleagues and classified the remaining bones. In this compendium, the introductory chapter reviews new scientific information about classifying fractures that has been published in the last 11 years. The classification is presented in a revised format that is easier to follow. The OTA and AO classification will now have a unified alpha-numeric code eliminating the differences that have existed between the 2 codes. The code was significantly revised for the clavicle and scapula, foot and hand, and patella. Dislocations have been expanded on an anatomic basis and for most joints will be coded separately. This publication should stimulate new developments and interest in a unified language to code and classify fractures. Further improvements in classification will result in better patient care and clinical research.

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THE RATIONALE FOR REPUBLISHING

The Orthopaedic Trauma Association (OTA) fracture classification was published in a compendium of the Journal of Orthopaedic Trauma (JOT) in 1996.[1] It adopted *The Comprehensive Classification of Fractures of the Long Bones* developed by Müller and collaborators,[2] classified bones that had not been previously classified and revised the alpha-numeric code developed by the Müller group. In their introduction to the 1996 compendium, the Coding and Classification Committee noted that the goal of the comprehensive classification was to classify fractures in a uniform and consistent fashion to allow standardization of research and communication.[1] The committee observed that the current state of fracture classification was ineffective for these purposes with multiple diverse systems used in different parts of the skeleton for various purposes, thwarting any possibility of a standardized language and accumulation of uniform data. Their intent was for the new classification to be a flexible, evolving classification system in which changes would be made based on comment, criticism and appropriate clinical research. In this way the classification could continue to optimally serve the needs of orthopedic traumatologists for both clinical practice and research.

Since the compendium was published in 1996, the classification has resided on the OTA website and has been regularly used in trauma databases in North American Trauma Centers. It is the official classification of the OTA and of the JOT. In these ways it has developed wide acceptance and has dramatically improved the way information about fractures is communicated, stored, and used to advance knowledge through clinical research. In some anatomic areas this classification has largely supplanted all others, achieving one of the original intents.

Unfortunately, the OTA classification has not achieved some of its originally stated goals. It has not been modified since 1996 and therefore it has not been the flexible, evolving classification envisioned when it was published. It also has not become a truly universal language of communication because multiple other anatomically specific classifications still exist and are part of commonly used fracture language, and for some areas of the skeleton they are still preferred.

Since 1996, considerable new scientific information has been published about fracture classification in general and the OTA system in particular. Factors leading to poor reliability and reproducibility of fracture classifications have been intensively studied. These studies have led to important new information on how clinicians interpret images of fractures on radiographs and the process by which fractures are classified. Unfortunately, difficulties with classification reliability have led to some loss of enthusiasm with the classification process. It is now widely recognized that, to ensure that any classification is suitably reliable, it must undergo an intense and rigorous scientific scrutiny. The effort required is considerable, and this difficult process has either been ignored or avoided in favor of popular and widely used classifications.

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Material presented in this Compendium is based on the *Comprehensive Classification of Fractures of Long Bones,* by M.E. Müller, J. Nazarian, P. Koch and J. Schatzker, Springer-Verlag, Berlin, 1990. The Orthopaedic Trauma Association is indebted to Professor Maurice Müller for allowing the Association to use the system.

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The purpose of this new classification compendium is to republish the OTA classification. There are many reasons to do this. It will further a cohesive collaboration between the OTA Classification, Database and Outcomes Committee and the Arbeitsgemeinschaft für Osteosynthesefragen Classification Task Force (AO/CTF) group and will publish the unified coding agreed upon by the two groups (Fig. 1). This will further the original goal of developing an internationally recognized uniform means to communicate about and perform clinical research on fractures and dislocations. This introductory chapter discusses the advantages and disadvantages of the uniform classification as it has existed for the past 10 years, reviews new scientific information on fracture classification, highlights the successes that have been realized, summarizes the drawbacks to systematic classification of fractures, and describes the process the OTA Classification, Database and Outcomes Committee has gone through to modify the existing classification and adopt a new uniform alpha-numeric code as proposed by the AO/CTF group.

FUNDAMENTALS OF FRACTURE CLASSIFICATION

Classification is the process by which related groups are organized based on similarities and differences.[3] It condenses the language necessary to convey information among individuals with a similar understanding of the classification. A broad and diverse topic such as fractures lends itself well to the classification process. We all classify fractures as part of our standard description of an injury. In describing a fracture, we identify a bone, define a region in the bone, and routinely describe displacement and comminution and location of fracture lines with respect to relevant anatomy. In these ways we are verbally classifying the fracture as we describe it. Formal classification of fractures systematizes this descriptive process and replaces words with categories and numbers or letters that convey the same information. Fracture classification allows information about fractures to be stored in a way that facilitates comparisons among different groups or among similar groups treated differently.

A good fracture classification fulfills some fundamental objectives. It should provide a reliable and reproducible means of communication. Different observers (reliability) or the same observer on repeated viewings (reproducibility) presented with the same material (for example, a radiograph) must agree on the classification of a fracture a high percentage of the time. If this is not the case, the classification has failed in its fundamental goal—a means to communicate information based on agreed similarities and differences.

There should be clear clinical relevance for the groups within the classification that relate either to treatment guidelines, to prognosis, or to risk for complications. Without clinical relevance there is no good reason to define and separate different groups. To ensure that this relevance is present, prospective clinical research is necessary. Generally speaking, the hierarchy of a classification should proceed from less severe (as defined by energy of injury, difficulty of treatment, or patient outcome) to more severe, because classification is the fundamental way to convey information about injury severity. Another type of hierarchy used in both the OTA and the AO classification organizes fractures within a class from less to more detailed injury descriptions. This enables a rater to utilize the appropriate complexity to suit his or her purposes. This characteristic is relatively unique to this classification but its utility has not been widely employed in the past 11 years. Most good fracture classifications are organized with these hierarchies. Ideally, a classification should be all-inclusive (all fractures within reason in a given region should be included) and mutually exclusive (a given fracture should fit in only one category). Finally, a classification should be logical, comprehensible, and should not contain an unmanageable number of categories, a problem that ensures poor reliability.[4]

Many different characteristics of fractures have been used as the basis of fracture classification systems. Most classifications, such as the OTA classification, are based on the anatomic location and the morphology of the fracture.[1] These features can simply be observed or formal measurements may be necessary. Most commonly the observations and measurements are made on radiographs but in some circumstances information obtained on physical exam, history or intra-operative findings is considered as part of the classification process. Other features of a fracture, such as the mechanism of injury or associated injuries, may be used in determining how the fracture should be classified.[5] Unless the information necessary to classify a fracture and how this information is assessed are precisely defined, observers will use the classification in different ways and reliability will suffer.

To serve the purposes of populating large trauma databases, such as those used at many major trauma centers, and to provide a space efficient shorthand across languages, a standardized alpha-numeric code for all fractures is necessary and has always been a part of this system, another relatively unique feature. Site-specific classifications must be replaced with a systematic, orderly classification system that encompasses fractures of the entire skeleton. This is absolutely necessary for multi center collaboration, retrospective comparison of results, international communication and for ease of accomplishing the task of recording information about all fractures in a trauma database. Although site-specific research is possible without a comprehensive classification, the more one system is used consistently for all purposes, the closer we come to a uniform universal language for fracture care. We believe that this is a goal that continues to be worth pursuing and is one of the fundamental advances of the comprehensive classifications of Müller at al[2] and the OTA classification.[1]

ADVANTAGES OF A COMPREHENSIVE CLASSIFICATION OF FRACTURES

The publication of the English edition of *The Comprehensive Classification of Fractures of Long Bones* by Müller at al in 1990 and the subsequent publication of the OTA classification in the 1996 JOT compendium were landmark advances in fracture classification compared to the state of the art that was current at that time.[1,2] Before these publications, a systematic classification of fractures throughout the skeleton was not available. Eponyms were rampant—Colles fracture is an example used to designate diverse patterns of distal radius fractures variably including intra-articular and extra-articular patterns, partial and total articular comminution, and variable amounts of angulation and displacement. Trauma databases were essentially not possible. Classifications were developed by individual investigators to suit their own purposes and were widely disseminated not only in publications but in book chapters and other non scientific works. There was no uniform language that related to injury severity. Some of the terminology of these classifications has now become commonplace, such as partial and total articular fractures.

The vision of Müller and colleagues and the collaboration of the OTA dramatically changed the field of fracture classification.[1,2] These widely adopted classifications are now used internationally and have partially achieved a universal language for fracture communication. They are all-inclusive with all bones and all fractures included, and each category, with only a very few exceptions, is mutually exclusive. They include common criteria (extra-articular, partial articular, total articular) throughout the skeleton, which makes it possible for even relatively inexperienced practitioners to achieve the basics of using the classification at the type and group level. However, experience has shown that this should not be pushed to an extreme because certain areas of the skeleton are amenable and others are not. For this reason, in some anatomic areas in this revision we have used criteria that are anatomically specific and clinically relevant.

Another advantage of the comprehensive classifications is that there are clear definitions of the various groups and subgroups. For example, the localization within a long bone is defined by the rule of squares to define the three areas in the bone (proximal, shaft, distal).[2] This may appear simplistic, but most other commonly used classifications do not adequately define the fracture types or groups or even what fractures belong in the classification. For example, the Schatzker classification is of proximal tibia fractures but fails to define how a proximal tibia fracture should be distinguished from a shaft fracture.[6] Therefore, not only is there uncertainty within the groups but exactly which fractures are chosen to be classified and which ones are not is not clearly communicated. Investigators are free to use the classification in whatever way suits their purpose.

There have also been criticisms of the comprehensive classification systems and areas in which the original goals have not been achieved. With 27 subgroups in each of the areas, it is easy to conclude that it is too complex and overwhelming for the average user. As the complexity increases observer reliability decreases. Although these concerns are valid, one of the advantages of the design of this classification is that it lends itself to use of as much or as little of the increasing complexity of the types, groups, and subgroups as is needed for a given purpose or a given user. For example, research projects may require more detail, whereas routine database entries may have less detail. Another problem is that many of the criteria that distinguish among groups and subgroups may be of unknown or little clinical significance, rendering the complexity of the classification of minimal value. Further clinical research is necessary to refine groups into those that have maximal clinical significance for either treatment techniques, risks of complications, or clinical outcomes.

FRACTURE CLASSIFICATION: ISSUES WITH OBSERVER RELIABILITY

The importance of careful scrutiny of the observer reliability of fracture classifications became increasingly apparent in the early 1990s and remains a major issue for fracture classification. The language and assumptions we use to group fractures was seriously questioned, and the lessons learned continue to be of utmost importance today. In a 1993 publication in the Journal of Bone and Joint Surgery, Siebenrock and Gerber assessed the observer reliability of the Neer classification of proximal humerus fractures.[7] This important classification was and still is one of the most commonly used classifications in fracture care. It fulfills many of the goals of a good classification because it provides a way to communicate critically important information about proximal humerus fractures. Decisions on treatment and determinants of outcome are based on categories determined by defining the relationships between four typical fracture parts of the proximal humerus. Unfortunately this important work demonstrated that the observer reliability of this classification was much poorer than expected. This data created a wave of controversy, with many surgeons criticizing the data and the methods. However, further publications on the Neer and many other fracture classifications have demonstrated that the use of categorical classifications is generally not highly reliable, and that these problems must be acknowledged and the issues that lead to them carefully studied.[8–12] The fact that reliability is far less than perfect in many common fracture classifications is no longer a disputed issue.

The reasons for poor reliability have been extensively investigated, and together these investigations constitute a significant body of work produced over the past 10-14 years. Investigators have studied the effect on classification reliability of clinician experience,[8–11] complex imaging studies,[8,12–15] traced lines on radiographs,[16] multiple radiographic views,[10,17] number of categories,[8,18–22] binary decision making,[23] ability to measure displacements,[24,25] and to determine basic fracture assessments (comminuted or not; displaced or not).[24] These investigations have demonstrated that even under the most ideal conditions with experienced clinicians, clear group definitions, and excellent imaging studies, observer disagreement still occurs. It can be decreased but not eliminated.

There are many reasons for observer disagreement in classifying fractures. Some of them can be improved through validated development of a classification and determining categories but others present limitations to the degree that observer reliability can be achieved with categorical classifications. Observers have inherent biases based on their personal experiences that lead them to different conclusions on the basis of the same information. Even without this bias they make errors such as failing to see a fracture line that others agree is present.[26] These problems are inevitable and cannot be overcome. Another fundamental issue is that fracture classification is in many ways an assessment of injury severity. Classifying a fracture and therefore its severity places it within a specific category whereas in reality fracture severity occurs on a continuous spectrum.[21,27,28] Some injuries are on the border between one category and another, making observer disagreement inevitable.

Despite these issues, observer reliability is better in some circumstances than in others and for some classifications than for others. Not surprisingly most studies have shown that experienced clinicians usually classify fractures more reliably than less experienced clinicians, although the effect is variable in different studies.[9–11] Reliability can be improved by modifications of existing classifications or during the development of new classifications by a systematic methodological approach.[29]

Through these methods, problems that are now known to increase observer error and disagreement can be readily identified and minimized as much as possible. Categories within a classification should be as discrete as possible because less discrete categories lead to wide gray zones and thus increase observer disagreement. For example, if a category is defined by asking if a fracture line enters the articular surface, a clear judgment can be made. However, if the category is defined by the presence or absence of fracture comminution, this less clear assessment (how is comminuted defined?) increases the chances for disagreement.[24] Similarly, subjective assessments perform poorly, such as a category defined by a high energy mechanism especially without definition of what this phrase means.[24] To the extent possible, categories should be uniquely defined. As an example, assessing whether the physis is either involved with a fracture or is not is a more uniquely defined assessment than whether the fracture is angulated or not. The latter leaves room for various interpretations of angulation. If measurements are used to define categories the degree of error in measuring must be considered and minimized. For example, the degree of displacement of the articular surface in millimeters has been shown to have high observer error, which means that this commonly used assessment is a poor way to define categories.[24,30] Some measurements are impossible to make. A category defined as greater or less than 1 centimeter of displacement between fragments (eg, the greater tuberosity from the rest of the humerus) requests an observer to measure something on radiographs that are often exposed in a plane that makes this measurement impossible, relegating the assignment of a fracture category to a guess unless multiple, carefully exposed radiographs in various degrees of rotation are evaluated.[17] Moreover, categories are sometimes defined according to a pre-defined cut-off regarding a continuous diagnostic parameter. For example, the obliquity of diaphyseal fractures is reduced to a dichotomous variable ($< 30°$ vs $\geq 30°$) in the comprehensive long bone classification. Any such cut-off values ideally should be chosen so that they are reliably measured and clinically important, but this may not be the case.

The Comprehensive Classification developed by Müller at al and modified and adopted by the OTA has not been immune to these problems with observer reliability.[1,2] Studies in the distal radius, distal tibia, proximal tibia, proximal femur[8,18–22] and elsewhere have demonstrated that the observer reliability of the system falls off significantly between the type and group level and again at the group to subgroup level. It has generally been conceded that for the purposes of clinical research it has excellent reliability only at the type level.[20,21]

NEW INITIATIVES IN CLASSIFICATION OVER 10 YEARS

There have been initiatives in fracture assessment designed to improve classification rather than merely to define problems.[25] The rank order method has been used in studies in other clinical areas where categorical classification has proved to be difficult.[27] To avoid problems with classification, Buckwalter et al assessed residents' clinical performance by having faculty rank them in relation to each other and then correlated the rankings with in-training exam scores.[31] They found high levels of faculty agreement for relative ranks of resident performance indicating that the rank order method was an excellent substitute for classification. As problems with categorical classification of fractures became apparent, rank order methods have been applied to fractures. This method avoids the problem with reliability that occurs when a continuous variable, such as fracture severity, is arbitrarily assigned to categories. Instead, a number of fractures are ranked in relation to each other by experienced clinicians for severity or for any variable of interest. DeCoster et al and Williams et al have demonstrated that the rank order method to assess fracture severity leads to high levels of observer agreement in the relative rank between cases.[27,28] This indicates that observers agree on the relative order of injury severity but when asked to assign categories they have much greater disagreement. In both of these studies, the rank order method was used to predict clinical outcomes.[27,28] Unfortunately, this method is only amenable to use within a defined series of patients because the results cannot be transposed out of the series. It therefore has applicability only for research purposes where it can be used as a more reliable way to assign relative severity than classification. Nork et al have recently used this method to assess injury severity in a series of bicondylar tibial plateau fractures and have applied the results to determine factors that predict outcome after treatment.[32]

Considering the problems with previous classifications another new initiative in fracture classification has been developed by the AO/CTF group, which has been working on several site-specific projects to develop new classifications using a systematic methodology in three phases.[33] The first development phase involves clinical experts developing proposals for the classification system, as well as defining the classification process. This phase is related solely to diagnostics and defines a common language with which surgeons should be able to identify and classify fractures similarly. Successive pilot agreement studies are conducted to ensure that clinical experts can do this, and if they cannot, the proposed system and classification process is appropriately changed and reevaluated. Such a systematic process has been applied for the development of a pediatric long bone classification with very encouraging results.[34] An innovative approach using latent class modeling for the analysis of classification data has been proposed, particularly when an acceptable reference standard classification process is lacking.[35] The second phase involves a multicenter agreement study to ensure that future users with less clinical experience can also classify fractures similarly. Depending on the results, some modifications toward improvement of the system may still be proposed.[36,37] This creates the basis for a reliable classification tool to be used in the context of prospective clinical studies for evaluation of fracture treatment options and outcomes in a third validation phase.

The AO/CTF group and the OTA's Classification, Database and Outcomes Committee are collaborating in the development, validation, and promotion of clinically relevant and widely accepted classification systems. Internationally recognized classification review groups for different body sites are being created as an important step forward. Modifications of new and existing systems should be evidence-based, ie, proposed and supported on the basis of solid validation data.

The AO/CTF group has also integrated approved classification systems into a software named AO COIAC (AO Comprehensive Injury Automatic Classifier) to support teaching and to facilitate diagnosis and coding of injuries. A skeleton interface provides access to one of several area-specific

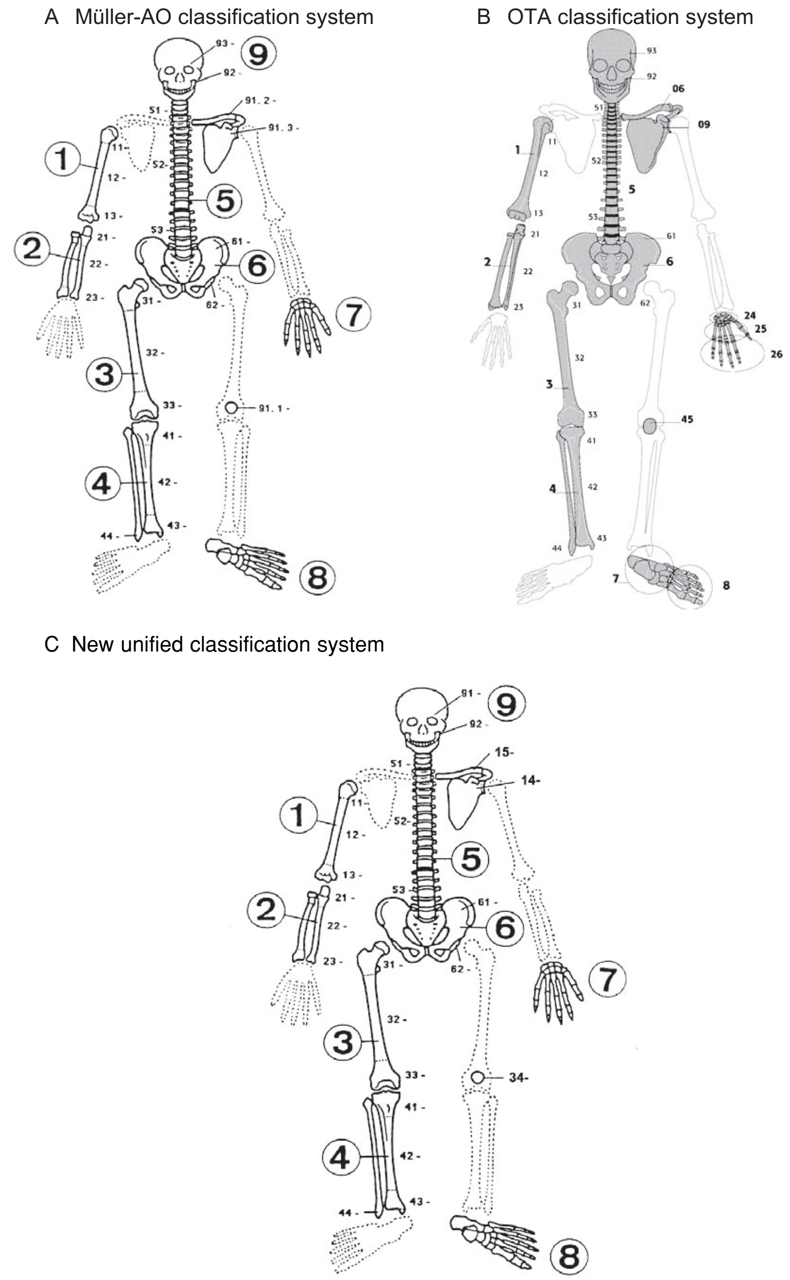

FIGURE 1. Designation of bone location

classification modules. Drawing fracture lines or clicking with the mouse on standard bone drawings aids the classification process for the user, with successive drop-down menus and classification options. Data can be saved in a relational database and exported for further analyses and presentations, or printed for the patient's files. For each injury the classification data can be collected by several different surgeons and/or at different times, hence supporting research and validation efforts.[33] The group's initial publications have been on a pediatric long bone classification.[34]

THE PROCESS OF REVISING THE COMPENDIUM

At the time of the original publication of the OTA classification the committee classified additional bones that were not included in the original Comprehensive Classification proposed by Müller et al.[1,2] This led the committee to make some changes in the overall numeric code which over the past 10 years resulted in two somewhat different codes, one used by the AO and one by the OTA. For example, in the original AO system clavicle was 91.2 and in the OTA system it was 06, patella 91.1 AO and 34 OTA, and the wrist and hand were 7 in AO and 24, 25 and 26 for OTA. In early 2006 the AO/CTF group proposed a new unified numbering scheme to replace both of the previous versions. This proposal was considered and then accepted by the Classification, Database and Outcomes Committee of the OTA. Now clavicle (15), scapula (14), patella (34), hand (7), and foot (8) will be the same for both groups. Through this agreement there is now one universal alpha-numeric code that promotes the concept of a universal language for fractures. The original AO and OTA numbering schemes and the new unified numbering scheme are reproduced in Figure 1 A-C. The body of this compendium uses the new unified alpha-numeric code. There are no changes to the long bone sections (humerus, radius and ulna, femur, and tibia) originally published by Müller et al,[2] which further promotes a unified fracture code accepted universally by both groups.

In addition to accepting and incorporating the unified numbering format, other revisions of the OTA classification were produced with the help of member volunteers from the organization. Members participating were asked to independently review assigned sections of the classification and to make suggestions for improvement in language, descriptions, style and format. All suggestions were collated anatomically and then reviewed by the Classification, Database and Outcomes Committee at a full day meeting. Committee members submitted additional suggestions. All suggestions from the member volunteers and committee members were individually considered. Extra consideration was given to suggestions that were received from multiple individuals.

After discussion, if the committee unanimously agreed that suggested revisions were improvements, they were adopted and included in this volume. The major change that is immediately apparent relates to format, where many members suggested and the committee agreed that all groups (A,B,C) should be presented on the same page rather than split as in the 1996 publication. The long bone sections 1–4 were not changed. The advantages of addressing difficulties with language and categories identified in these areas by OTA members and the committee were offset by the important goal of furthering a unified international fracture language. The sections other than long bone (14, 15, 5–8) were updated. We have made extensive revisions to the foot and carpus. Metacarpal and metatarsal and phalanges are now exactly aligned in both the foot and the hand. Dislocations were expanded on an anatomic basis and designated with a zero code in the second digit. Dislocations will be coded separately (other than in the pelvis, forearm, and talus), and this section has been completely revised.

A new part of the classification, the pediatric long bone classification, has been incorporated directly from the work of the AO/CTF group and is the result of their meticulous scientific effort. We sincerely hope that future republications of the OTA classification will be able to incorporate additional changes resulting from this type of rigorous scientific method and will therefore need to depend less on committee review.

SUMMARY

Since the original publication of the OTA Fracture Classification in the 1996 JOT Compendium, there has been important progress in fracture classification. We are farther along toward the goal of a universally accepted fracture language, but more progress remains to be made. New knowledge has helped us to understand how classifications work, or sometimes do not work. Much of this new knowledge has been enlightening; some of it has highlighted areas in which additional work is necessary. Advances in fracture care are possible only through an organized grouping of the pathology presented by the myriad of fracture patterns and associated injuries. Republication of the OTA classification in this compendium combined with advances in fracture classification software and scientific methodology by the AO/CTF group, will serve to further this goal. We hope to reinvigorate interest in the language we use to communicate and record information about fractures and dislocations, because it is only through this language that we can collectively learn from our experiences to provide better care for future fracture patients. We encourage those interested in fracture care to utilize this classification and to participate in further classification improvements that will lead to the publishing of yet another improved version 10 years from now.

Listing of references can be found on page S133.

Introductory Message from the AO Classification Supervisory Committee

The AO Classification Supervisory Committee welcomes the opportunity to participate with the Orthopaedic Trauma Association (OTA) in the revision of the Compendium on Fracture Classification. The original cooperative effort on this Compendium was started to standardize the classification system for fractures based upon the work of Maurice Müller through the Comprehensive Classification of Fractures. The collaboration of AO with the OTA ensured that this system has a basic worldwide readership and distribution. This opportunity to attempt to standardize the terminology for fractures and classifications has now led to a revision of the Compendium to deal with any potential change. Two major events have occurred. First, a truly validated classification for pediatric fractures is now available. This classification has gone through two critical stages of internal validation and evaluation and has now been published in pediatric peer-reviewed journals. This is a major landmark in the classification literature and development, in that a classification system has now been validated by accepted methodology. The OTA and the AO Classification Supervisory Committee are continuing this work by developing a validated scapular fracture classification. This has just begun its first stages of validation. Consequently, it will not appear in this edition of the Compendium but when it has been completed, probably within the next year or year and a half, it will be available as a supplement. The OTA and AO are firm in their conviction that all new classifications must be developed on the basis of broad, internationally recognized expertise and that appropriate validation and verification by the accepted methodology should be carried out before publication and use. It is also hoped that over the next year or two, there will be an attempt to validate the comprehensive classification.

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