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Development of a Radiographic Union Score for Determining Osteotomy Union Rates in Long Bones of the Foot

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ABSTRACT

Determining the status of bone healing after osteotomy can be challenging and has implications ranging from clinical decision-making to standardization of research outcomes without the use of computed tomography. To date, no method has been validated for determining osseous healing of an osteotomy site of the long bones of the foot. The purpose of the present study was to develop a radiographic union scoring system that would enhance the diagnostic healing assessment. We adapted existing orthopedic scales that had been validated for healing in the leg for application in the long bones of the foot. One hundred cases were evaluated by 6 blinded assessors to test the inter- and intrarater reliability of the subjective healing assessment compared with the proposed scoring system. The radiographs were classified by postoperative period: ≤4, 5 to 12, and >12 weeks. The proposed scale had a high interrater reliability but was burdensome. Using a priori item reduction protocols, the scale was limited to the 5 items with the best internal consistency, which significantly reduced the burden. The result was excellent interrater reliability ($\alpha = 0.87$) among all assessors compared with acceptable reliability ($\alpha = 0.66$) for the subjective osteotomy healing assessment. The intrarater reliability during the subsequent retest phase demonstrated similar relationships, with low agreement ($r = 0.38$) for subjective healing. Each of the items included in the final scoring scale had moderate to good agreement across all assessors ($r = 0.51$ to 0.63). The reliability of this system appeared superior to the subjective assessment of osseous healing alone, even in the absence of clinical correlates after an osteotomy in the foot.

A common difficulty in foot and ankle surgical practice is determining when to advance patient care after surgical osteotomy or traumatic osseous injury (1–7). Practitioners rely on clinical assessment, postoperative interval, radiographic appearance, and, occasionally, advanced imaging modalities to help guide protocols for the advancement of activity after osteotomy or fracture fixation of the long bones of the foot and ankle (8–10). This can be challenging, because the evaluation of patients after surgery varies by individual in terms of postoperative pain and clinical appearance, making it subjective and inconsistent. Practitioners rely on the radiographic assessment to provide a more objective outlook regarding patient healing status and to guide clinical advancement. However, radiographic artifacts, technique, implants, and osseous overlap can interfere with the radiographic evaluation and contribute to inappropriate clinical decisions (4,5,7,11,12).

Several orthopedic scoring systems have been developed and validated in recent years in an effort to improve the reliability of radiographic interpretation within the hips and long bones of the leg (radiographic union scale, radiographic union scale for hip, and

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Reviewer:_____

1: Overall General Impression

According to your general impression, would you consider the osteotomy healed?

[ ]Healed [ ]Not Healed

2. Scoring

Cortex Assessment			
Cortex Bridging: Consolidation and evidence of new bone formation between or around the cortex	No Cortical Bridging = 0	Some Cortical Bridging = 1	Complete Cortical Bridging = 2
Medial Cortex Bridging			
Lateral Cortex Bridging			
Dorsal Cortex Bridging			
Plantar Cortex Bridging			
Cortical Osteotomy Line: Disappearance of the cortical osteotomy line			
Medial Cortex			
Lateral Cortex			
Dorsal Cortex			
Plantar Cortex			
Trabecular/Cancellous Assessment			
Defined by decreasing visibility of the osteotomy line as new trabecular/cancellous bone is formed Osteotomy Line	Osteotomy Line Fully Visible = 0	Osteotomy Line Partially Visible = 1	Osteotomy Line Not Visible = 2
Trabecular/cancellous consolidation defined by evidence of new bone formation along osteotomy lines in trabecular/cancellous region of bone Amount of Consolidation	No Consolidation = 0	Some Consolidation = 1	Complete Consolidation = 2

3. Callus Formation

Was callus formation present? [ ]Yes [ ]No

4. Fixation

Was there lucency present around the hardware? [ ]Yes [ ]No

5. Image Quality

Is the quality of the image acceptable? [ ]Yes [ ]No

Did the quality of the image inhibit your assessment? [ ]Yes [ ]No

Did placement/position of hardware inhibit your assessment? [ ]Yes [ ]No

Fig. 1. The osteotomy assessment tool was adapted using a modified Delphi approach and based on previously validated radiographic osseous union scores for the long bones of the leg and hip (radiographic union score, radiographic union scale for hip, and radiographic union scale for tibial fractures) (6,13,15).

radiographic union scale for tibial fractures) (6,13–15). Through comprehensive testing, these scoring systems have been validated within their respective populations and have become a valuable decision support tool that enhances recognition of osseous healing. By implementing a unified method, the accuracy and reliability of the scoring systems have allowed orthopedic surgeons to make more appropriate clinical decisions regarding the advancement of care. Despite the obvious benefits of such a scoring system in the proximal leg, no scales for grading radiographic osseous union after elective osteotomy of the long bones involving the foot or ankle have been validated (2,8,16). The absence of such an instrument has exposed much podiatric data to potential classification, interpretation, and measurement bias. Inconsistency in determining healing versus not healing of an osteotomy will lead to misinformed decision-making, which could increase the likelihood of adverse outcomes. As such, little consistency can be found in the postoperative protocols for lower extremity cases. Radiographs of the foot and ankle are greatly subject to interference, severe overlap, and varied angles; thus, an established scoring system would be beneficial to help assess for osseous healing in an organized manner. Studies have shown that generic guidelines of 6 to 8 weeks for osseous union of the bones of the foot are not reliable; thus, accurate radiographic assessment is paramount (17).

The primary aim of the present study was to develop a radiographic healing scoring system of the long bones in the foot after elective osteotomy. We assessed only the long bones of the foot and not the ankle at this time. Our objective was to validate an instrument that would be reliable, reproducible, and sensitive to change for application in both clinical and research settings. We hypothesized that the final instrument would have greater accuracy than the standard physician assessment alone in determining osseous healing after elective osteotomy of the long bones in the foot. The development of a radiographic union scoring system for osteotomy of the long bones of the foot will permit more objective and consistent radiographic and clinical assessment. This will be valuable in developing validated research data and establishing the standard of care for treatment protocols after osteotomy of the long bones of the foot.

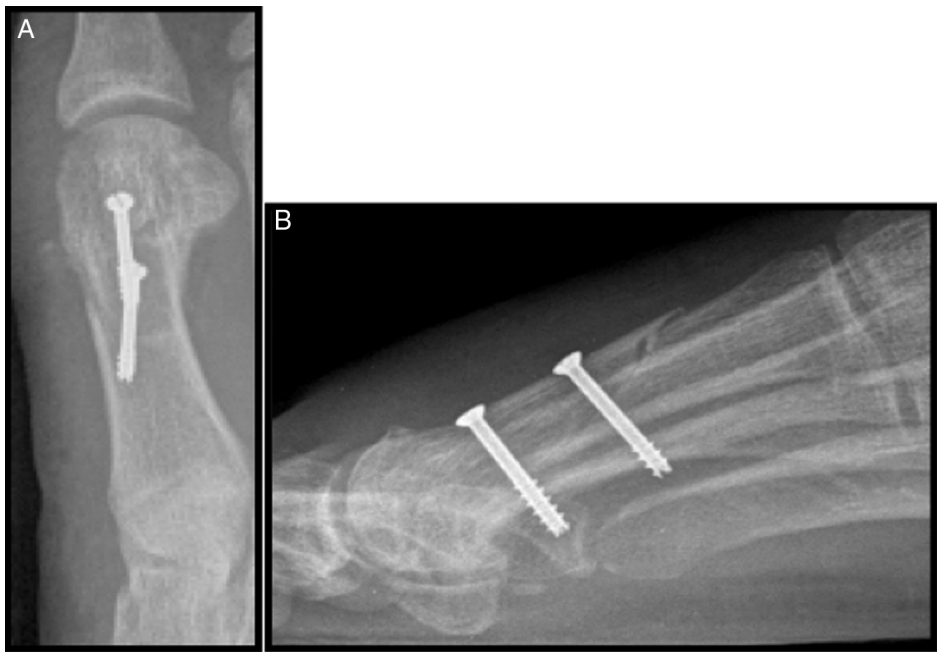

Fig. 2. Example of a de-identified patient case, which consisted of an anteroposterior (*A*) and a lateral (*B*) radiograph.