

Determination of Radiographic Healing: An Assessment of Consistency Using RUST and Modified RUST in Metadiaphyseal Fractures

Jody Litrenta, MD¹; Paul Tornetta III, MD¹; Mohit Bhandari, MD, MSc, PhD²; Clifford B. Jones, MD³; Samir Mehta, MD⁴; Robert O'Toole, MD⁵; Robert Ostrum, MD⁶; Stephen Kottmeier, MD⁷; Kenneth Egol, MD⁸; William Ricci, MD⁹; Emil Schemitsch, MD¹⁰; Daniel Horwitz, MD¹¹;

¹Boston University Medical Center, Boston, Massachusetts, USA;

²McMaster University, Hamilton, Ontario, Canada;

³Orthopaedic Associates of Grand Rapids, Grand Rapids, Michigan, USA;

⁴University of Pennsylvania, Philadelphia, Pennsylvania, USA;

⁵University of Maryland Medical Center, Baltimore, Maryland, USA;

⁶Carolinas Medical Center, Charlotte, North Carolina, USA;

⁷Stony Brook Medical Center, East Setauket, New York, USA;

⁸NYU Langone Medical Center, New York, New York, USA;

⁹Washington University, St. Louis, Missouri, USA;

¹⁰St. Michael's Hospital, Toronto, Ontario, Canada;

¹¹Geisinger Health System, Danville, Pennsylvania, USA

Background/Purpose: There are many criteria that contribute to fracture healing, yet no definition of radiographic union exists. Cortical continuity, elimination of the fracture line, and the number of bridging cortices have all been used, without clear consensus. Recently, the Radiographic Union Scale for Tibia fractures (RUST) was developed to score the healing of diaphyseal tibia fractures after intramedullary nailing. This score has reported reliability and validity; however, there is no value that defines union. Furthermore, it has not been validated for metaphyseal fractures or those treated with plate fixation. The purpose of our study was to determine the reliability of this method in quantifying healing and to define a value for radiographic union in a large series of metaphyseal tibia and femur fractures treated with plates or intramedullary nails.

Methods: Metadiaphyseal healing was evaluated using two prospective methods: *Part 1:* 12 orthopaedic trauma surgeons evaluated a series of radiographs of 27 distal femur fractures treated with either plate or retrograde nail fixation at various stages of healing in random order using a modified RUST score. Each cortex on the AP and lateral radiograph was scored as: 1 = no callus, 2 = callus present, 3 = bridging callus, 4 = remodeled, fracture not visible. For each radiographic set, the grader indicated if the fracture was radiographically healed or not. *Part 2:* We reviewed the radiographic results of two multicenter randomized trials comparing plate versus nail fixation of 81 distal femur (37 plate, 44 nail) and 46 proximal tibia (22 plate, 24 nail) fractures. Radiographs were scored at 3, 6, and 12 months using the modified RUST score above. At each time point investigators indicated if the fracture was healed or not. *Evaluations:* The intraclass correlation coefficient (ICC) was determined for each cortex, the modified RUST score, the standard RUST score (by collapsing "callus present" and "bridging callus"), and the assignment of union for the part 1 data. The RUST and modified RUST that defined "union" were determined for both parts of the study and the ICC was determined for part 1.

- The FDA has not cleared this drug and/or medical device for the use described in this presentation (i.e., the drug or medical device is being discussed for an "off label" use). For full information, refer to page 600.

Results: ICC: The modified RUST score demonstrated higher ICC than the standard RUST (0.68 vs. 0.63). Better ICC was seen in nails than plates for both modified and standard RUST (0.74 and 0.67 vs. 0.59 and 0.53). The modified RUST had substantial agreement for plates and nails while RUST had moderate agreement. *Union:* There was no difference in scoring between distal femur and proximal tibia for part 2 data so it is reported together. The average RUST and modified RUST score at union for nails was higher than plates ($P < 0.01$) (Table 1). The ICC for union was 0.53 (nails: 0.58; plates: 0.51), which indicates moderate agreement. However, union may best be defined by the percentage of reviewers assigning it at various scores as seen in Table 2.

Table 1. Average RUST and Modified RUST Values Considered United

	Part 1		Part 2		Combined (Part 1 + 2)	
	RUST	Modified	RUST	Modified	RUST	Modified
All	8.3 ± 1.8	11.1 ± 2.6	9.1 ± 1.7	12.3 ± 2.5	8.5 ± 1.8	11.4 ± 2.6
Nail	8.9 ± 1.5	12.2 ± 2.1	9.2 ± 1.7	12.4 ± 2.6	9.0 ± 1.6	12.3 ± 2.3
Plate	7.9 ± 1.8	10.4 ± 2.6	8.9 ± 1.7	12.2 ± 2.4	8.2 ± 1.8	10.8 ± 2.7

Table 2. Percentage of Reviewers Assigning Union (Part 1 Data)

Score	RUST			Modified RUST		
	8	9	10	9	10	13
% United	42%	76%	94%	16%	58%	91%

Conclusion: The ICC for the modified RUST is slightly higher than for RUST in metadiaphyseal fractures and had substantial agreement. The average RUST and modified RUST at union was 8.5 and 11.4. The ICC for the assessment of union was 0.53, which is moderate agreement. A minimum threshold for union of 9 for RUST and 10 for modified RUST may be reasonable as the majority of reviewers assigned union at that point. Definite union would be 10 and 13 with over 90% of reviewers assigning union. These are the first data-driven estimates of union for these scores.