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Determination of Radiographic Healing using the RUST Score and the Modified RUST in Femoral Shaft Fractures Treated with Intramedullary Nailing

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Abstract: ***Objectives: To determine and compare the reliability of both the Radiographic Union Scale for Tibial Fractures (RUST) and modified RUST when applied to assess bone healing in femoral shaft fractures treated with intramedullary nailing from January 2013 to December 2017 at a Level III Trauma Center in a tertiary government hospital. Methods: Eight observers were assigned randomly, namely two fellow orthopaedic consultants and six orthopaedic residents, to assess the femoral shaft x-rays of patients treated with intramedullary nailing using the Radiographic union scale for tibial fractures (RUST) and the newly created modified RUST. Two sets of x-rays in the anteroposterior and lateral views for their respective follow up periods, eighty six (86) sets in total, were used. These 86 sets of radiographs were primarily assessed by the raters within the 2nd week of August 2020 and final assessment was done within the 2nd week of September 2020. Results: Assessments of eighty six sets of radiographs showed that there is an excellent and essentially perfect agreement between all observers with the use of RUST and mRUST at 0.92 ICC (95% CI; 0.88-0.94) and 0.93 ICC (0.90-0.95), respectively and as stated by Portney et. al. (2009), an ICC of 0.90 to 0.99 is acceptable for use as a clinical measure. Conclusion: This study showed that the Radiographic Union Scale for Tibial Fractures (RUST) and the modified RUST possesses a high intra-observer and inter-observer agreement and variability that can both be clinically used as a tool for assessment of radiographic healing of fractures of the femoral shaft treated with intramedullary nailing. These two scoring systems also have nearly identical high reliability and reproducibility when their use is compared.***

Keywords: RUST Score, mRUST Score, Interobserver reliability, Intraobserver reliability, femoral fractures, intramedullary nailing, SIGN nails, Reliability

Disclosure

The cases used in this study were supported by a grant from a third party company, the Surgical Implant Generation Network (SIGN) Fracture Care International, a humanitarian-aid organization from Washington, U.S.A. The author has not received and will not be receiving any benefits in the future for professional or personal use from any commercial party particularly SIGN Fracture Care International.

1. Introduction

One of the most dramatic complications of traumatic femoral shaft fractures are non-union. The treatment for non-union itself usually warrants repeat surgery or rarely non-operative means can be utilized. One major problem, however, is the difficulty to diagnose non-union itself. Aside from the difficulty to diagnose non-union per se, the peculiarity of each single bone from each other adds to the difficulty in coming up with a common diagnostic measuring tool for non-union for all types of bone. Fortunately, for tibial shaft fractures, when they are treated with intramedullary nailing, they can be assessed by the Radiographic Union Score for tibial fractures or commonly called RUST which was created by Whelan, et.al (2010). Recently, a research conducted and published by the author last 2018, proved that this scoring system, RUST score, can also be used in femoral shaft fractures treated with intramedullary nailing and with excellent inter-observer and intraobserver agreement. More recently, Litrenta et.al. (2015), devised a modification to the said RUST score and applied it to assess fracture healing in the metaphyseal areas particularly the distal femur and the proximal tibia, with note of a better agreement between observers.

The RUST utilizes a scoring process wherein its system can be useful to most, if not all, of the long bones that are treated with intramedullary nailing. The RUST is based on callus formation and visibility of fracture line at 4 cortices observed on AP and lateral radiographs (Figure 1).

Lowest score of 4 means there is no radiographic signs of healing and highest score of 12 which indicates a radiographically healed fracture. One (1) point is given for each cortex in every radiograph if it displays no callus appearance and if fracture lines are still visible. Two (2)points are given for each cortex if it displays callus formation however with visible fracture lines. Three (3) points are given for each cortex if there is presence of callus and with no fracture line visible.

The modified RUST scoring system is identical with the RUST scoring system, however, the category for callus is further subdivided into two parts. Two (2) points are given to cortices which show the presence of callus but with no signs of bridging between cortices and with a visible fracture line. Three (3) points are given to cortices which show the bridging callus between cortices and with a visible fracture line. Consequently, if bridging callus is present and there is no visible fracture line, then a score of four (4) is assigned.

In this study, we utilized two radiographic scoring systems, namely the RUST or Radiographic Union Score for Tibial Fractures and the modified RUST in assessing bone healing of femoral shaft fractures operatively managed with intramedullary nailing. We evaluated the inter-rater and

intra-rater agreement of each scoring system and ultimately compare which scoring system gives a better reliability or agreement between observers.

A previous study by the author showed an excellent agreement between the observers when using the RUST score in assessing bone healing in femoral shaft fractures. The current modification to the said scoring system yet has showed promise and better agreement between observers and still has not been used to score the shaft component of the femoral shaft.

2. Objectives

General Objectives:
To determine and compare the reliability of both the Radiographic Union Scale for Tibial Fractures (RUST) and modified RUST score when applied to assess bone healing in femoral shaft fractures treated with intramedullary nailing from January 2013 to December 2017 at a Level III Trauma Center

Specific Objectives:
1) To determine the RUST Score of femoral shaft fractures treated with intramedullary nailing of the femur from January 2013 to December 2017 at a tertiary government hospital
2) To determine the modified RUST Score of femoral shaft fractures treated with intramedullary nailing of the femur from January 2013 to December 2017 at a tertiary government hospital
3) To determine inter-observer variability of RUST scores of femoral shaft fractures treated with intramedullary nailing of the femur from January 2013 to December 2017 at a tertiary government hospital among selected observers
4) To determine inter-observer variability of modified RUST scores of femoral shaft fractures treated with intramedullary nailing of the femur from January 2013 to December 2017 at a tertiary government hospital among selected observers
5) To determine intra-observer variability of RUST scores of femoral shaft fractures treated with intramedullary nailing of the femur from January 2013 to December 2017 at a tertiary government hospital among selected observers
6) To determine intra-observer variability of modified RUST scores of femoral shaft fractures treated with intramedullary nailing of the femur from January 2013 to December 2017 at a tertiary government hospital among selected observers
7) To compare the reliability of both the RUST and modified RUST scores when applied to assess bone healing in femoral shaft fractures treated with intramedullary nailing from January 2013 to December 2017

3. Methodology

This study was designed to determine the reliability of Radiographic Union Score for Tibia Fractures (RUST) and the modified Radiographic Union Score for Tibia fractures (mRUST) when used in randomly selected patients who have undergone intramedullary nailing of the femur from January 2013 to December 2017 in a tertiary government hospital.

Study Design
A Descriptive Cross-Sectional Study

Study Setting
This study was conducted in a tertiary government hospital

Study Period
This study was conducted from July to September 2020

Study Population
All patients admitted at a tertiary government hospital with fracture of the femoral shaft and have undergone intramedullary SIGN nailing of the femur. In total, fifty (50) patients were found to have undergone intramedullary SIGN nailing of the femur with adequately documented follow up-radiographs.

Twenty-five (25) radiographs were taken on the 3rd to 6th weeks, twelve (12) radiographs were taken on the 6th to 8th weeks, twelve (12) radiographs were taken on the 8th to 10th weeks, five (5) radiographs were taken on the 10th to 12th weeks, twenty-seven (27) radiographs were taken on the 12th to 52nd weeks and five (5) radiographs were taken on more than 52 weeks (also shown on Table 1).

Table 1: Number of available follow-up radiographs of femurs treated with intramedullary SIGN nailing from January 2013 to December 2017

Follow-up Period	Number of radiographs available
3-6 weeks	25
6-8 weeks	12
8-10 weeks	12
10-12 weeks	5
>12-52 weeks	27
>52 weeks	5
Total:	**86**

Inclusion Criteria
Radiographs were included if the succeeding criteria were found: 1) Radiographic pictures were retrievable from the Online SIGN Surgical Database, 2) Patient was admitted in our institution (a tertiary government hospital) from January 2013 to December 2017.

Exclusion Criteria
Radiographs were excluded if any of the succeeding criteria were met: 1) Fractures not located on the femoral shaft (from five centimeters below the lesser trochanter and more proximally, and fractures six centimeter from the knee joint and distally), 2) Patients having follow-up radiographs of fractures taken less than three weeks, 3) Presence of a cast or brace on the thigh as seen on radiographs

Sample Size
A total of eighty-six (86) sets of radiographs of fifty (50) patients was employed in this study. According to Doros, G., and Lew, R. (2010), when using a confidence level of 0.05 and an expected Intraclass correlation coefficient (ICC) of 0.6 to 0.7, we would need a minimum of 50 samples to

determine precise agreement between observers. Thus, all eighty-six (86) sets of radiographs would be used in this study.A high degree of significance level was employed (set at 0.05) since the result of this study has important significance. Table 1 shows the distribution of available radiographs with their respective follow-up dates.

Description of the Study Procedure

Eight observers were assigned, namely, two Fellow Orthopaedic Consultants and six (6) Orthopaedic Residents from a tertiary government hospital to assess the radiographs using the RUST and mRUST scoring system. Two radiographs in the Anteroposterior (AP) and Lateral Views for each follow-up period, eighty six (86) sets in total were used for this study. These eighty six (86) sets of x-rays were. Another assessment was done on the 2nd week of September 2020 by the same observers but with reorganized order and numbering of the selected and assessed radiographs. All the radiographs were evaluated in an office set-up with negligible noise and sufficient lighting i.e. at the Orthopaedics room of a tertiary government hospital using a single laptop with maximum brightness. Intra-observer and inter-observer agreement were assessed by the statistical tool as follows.

Statistical Tool

Data was analyzed using SPSS Version 25. The RUST and mRUST scores were analyzed with Intra-class correlation coefficient to obtain the inter-observer and intra-observer reliability. Portney LG & Watkins MP (2000) had proposed a level of acceptability as clinical measure as shown on the table below (Table 2) with 0.90 to 0.99 as measure acceptable for clinical measures, good ICC at 0.75 to 0.89 and poor to moderate with 0.50 to 0.74 ICC. Additionally, Landis and Koch (1977) stated that we defined 0–0.2 as slight agreement, 0.21–0.40 as fair agreement, 0.41–0.60 as moderate, 0.61–0.8 as substantial, and values above .0.81 to be essentially perfect agreement for the ICC evaluations. 95% Confidence interval was used.

Table 2: Level of acceptability as clinical measure by Portney LG & Watkins MP (2000)

ICC	Fleiss (1986)	P&W (2009)
0.99	Excellent	Clinical Measures
0.96		
0.90		
0.89		Good
0.80		
0.75		
0.50-74	Good	Poor to moderate

4. Results

From eighty-six (86) femur radiographs available, all were included to be utilized for evaluation of consistency and repeatability of RUST and mRUST when used as a scoring tool for union in femoral shaft fractures treated with intramedullary nailing. The following are the results of this study:

Table 3: RUST Intraclass Correlation Coefficients (95% Confidence Interval)

Rater	Intra-Observer ICC 95% CI		Initial Assessment	Final Assessment	Total ICC 95% CI	
Consultant 1	0.91 *(0.86-0.94)*	0.88 (mean)	0.66 *(0.38-0.80)*	0.58 *(0.32-0.73)*	0.84 *(0.76-0.89)*	**0.92 (0.88-0.94)**
Consultant 2	0.84 *(0.75-0.89)*					
Resident 1	0.84 *(0.75-0.89)*	0.77 (mean)	0.81 *(0.68-0.88)*	0.79 *(0.66-0.87)*	0.89 *(0.84-0.93)*	
Resident 2	0.55 *(0.07-0.76)*					
Resident 3	0.89 *(0.82-0.93)*					
Resident 4	0.66 *(0.48-0.78)*					
Resident 5	0.89 *(0.48-0.78)*					
Resident 6	0.80 *(0.66-0.882)*					

Table 3shows all the RUST Intraclass Correlation Coefficients (ICC) with a 95% CI computed using SPSS Version 25. The highest intraobserver ICC was noted on consultant 1 with an ICC of 0.91 and is interpreted as excellent according to Fleiss' (1986). The lowest ICC was exhibited by resident 2 with an ICC of 0.55 and is interpreted as poor agreement by Portney and Watkins. Both assessments from the consultants and residents showed a decrease in their ICC upon final assessment, from 0.66 to 0.58 among consultants and 0.81 to 0.79 among residents. As shown in table 3above, all the sixteen (16) ratings using RUST of eighty six (86) radiographs summed up into an ICC of 0.92*(0.92-0.94)* which is interpreted as "excellent" according to Fleiss' (1986) standards and as "acceptable as clinical measure" according to Portney et. al (2009), and ultimately as essentially perfect according to Landis and Koch.

Table 4: mRUST Intraclass Correlation Coefficients (95% Confidence Interval)

Rater	Intra-Observer ICC 95% CI		Initial Assessment	Final Assessment	Total ICC 95% CI	
Consultant 1	0.68 *(0.52-0.79)*	0.65 (mean)	0.72 *(0.38-0.80)*	0.94 *(0.91-0.96)*	0.83 *(0.77-0.88)*	0.93 (0.90-0.95)
Consultant 2	0.63 *(0.43-0.76)*					
Resident 1	0.85 *(0.78-0.90)*	0.81 (mean)	0.83 *(0.72-0.89)*	0.83 *(0.71-0.89)*	0.91 *(0.84-0.93)*	
Resident 2	0.71 *(0.75-0.84)*					
Resident 3	0.92 *(0.88-0.95)*					
Resident 4	0.71 *(0.55-0.81)*					
Resident 5	0.90 *(0.84-0.93)*					
Resident 6	0.77 *(0.36-0.89)*					

Table 4 above displays all the ICCs calculated from mRUST scores of all assessments. Notably, the highest mRUST Intra class ICC was obtained by resident 3 and 5 respectively, 0.92 and 0.90 which are interpreted as excellent and essentially perfect agreement. As compared to RUST scores discussed earlier, initial assessments were improved to higher ICCs when final assessment was done especially among the two consultants but no improvement among the residents but with an equal ICC on the re-assessment. In total, agreement was noted to be better among residents at 0.91 ICC at 95% CI (confidence interval) and only 0.83 ICC for the consultants. Nevertheless, an ICC of 0.83 would still be interpreted as above substantial or essentially perfect agreement. Ultimately, ICC of mRUST is minimally better than RUST when used in femoral shaft fractures with the following values: 0.93 and 0.92 respectively.

5. Discussion, Conclusion and Recommendations

5.1 Discussion

Non-union is still one of the major complications in orthopaedic trauma care. Majority of the difficulty encountered in the management of this complication is the establishment of a definite diagnosis of non-union. Without a proper diagnosis of non-union, orthopedic surgeons are boggled whether there is need for further treatment of these fractures. Recently, criteria for long bone union has been described by Whelan, et.al (2010) and was further modified by Litrenta, et.al (2015), namely the RUST and modified RUST. These scoring systems are generally applied for tibial fractures and recently modified for the use in metaphyseal fractures of the distal femur and proximal tibia. The use of these scoring systems in the femoral shaft has not been done not until the author's previous study (Francisco, et. al., [2018]) using RUST scoring in femoral shaft fractures treated with IM nails which showed clinically acceptable agreement.

As noted by Whelan (2010), total agreement was substantial (ICC, 0.86; 95% CI, 0.79-0.91) for RUST when it was applied on Fractures on the tibial shaft and was shown to increase in relation to the raters' clinical experience. A further modification of RUST was done by Litrenta, et.al. (2015), namely the mRUST, which also showed a substantial agreement and reproducibility of this scoring tool with a substantial ICC of 0.68 as compared to 0.63 in standard RUST.

Currently there are still no universally accepted radiographic union scoring criteria for femoral shaft fractures. In this study, we used and compared the Radiographic Union Scoring for tibial fractures (RUST) and modified Radiographic union scoring for tibial fractures (mRUST) as a measure to assess bone healing in femoral shaft fractures managed operatively with intramedullary nailing. We were able to retrieve and rate eighty six follow up x-rays of patients who underwent intramedullary nailing of the femoral shaft.

As obviated by the results of this study, there is an excellent and essentially perfect agreement between all observers with the use of RUST and mRUST at 0.92 ICC (95% CI; 0.88-0.94) and 0.93 ICC (0.90-0.95), respectively. As stated by Portney et. al. (2009), an ICC of 0.90 to 0.99 is acceptable when used as a clinical measure. This means that the usage of RUST and mRUST scoring in femoral shaft fractures managed with an intramedullary nail is highly reliable and reproducible. Total ICC in this study is excellent (0.75-0.99) as interpreted byFleiss (1986).

This study noted that there is very minimal difference between the reliability of the RUST and mRUST scoring system which was also shown by the study conducted by Litrenta, et.al (2015).

5.2 Conclusions

This study showed that the Radiographic Union Scale for Tibial Fractures (RUST) and the modified RUST possesses a high intra-observer and inter-observer agreement and variability that can both be clinically used as a tool for assessment of radiographic healing of fractures of the femoral shaft treated with intramedullary nailing. These two scoring systems also have nearly identical high reliability and reproducibility when their use is compared.

5.3 Recommendations

The author suggests the use of this tool in more research to back-up its use in the clinics. Some researches making new criteria for bony union of femoral fractures is also highly recommended. With eight observers in this study, a better and wider pool of observers and more radiographs for rating are also recommended to further support these types of studies. Correlation with functional outcome studies are also highly suggested.

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Appendix

Appendix A: Sample RUST Form used.

Radiographic Union Scale of Tibial Fractures (RUST) scoring Sheet

Name of Rater: _____ Date: _____

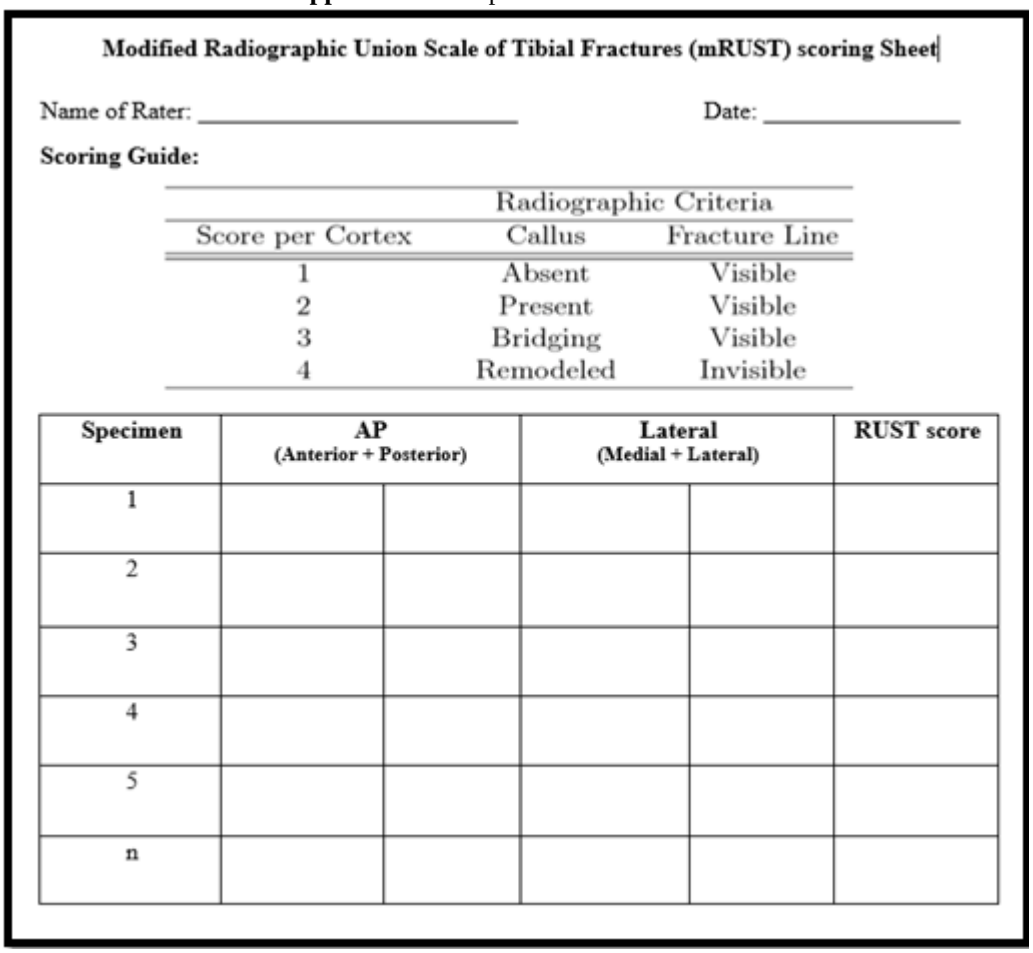
Scoring Guide:

Score per cortex	Radiographic criteria	
	Callus	Fracture line
1	Absent	Visible
2	Visible	Visible
3	Visible	Nonvisible

Copied from Ahmed et. al. (2014)

Specimen	AP (Anterior + Posterior)		Lateral (Medial + Lateral)		RUST score
1					
2					
3					
4					
5					
n					

Appendix B: Sample mRUST Form used



Modified Radiographic Union Scale of Tibial Fractures (mRUST) scoring Sheet

Name of Rater: _____ Date: _____

Scoring Guide:

	Radiographic Criteria	
Score per Cortex	Callus	Fracture Line
1	Absent	Visible
2	Present	Visible
3	Bridging	Visible
4	Remodeled	Invisible

Specimen	AP (Anterior + Posterior)		Lateral (Medial + Lateral)		RUST score
1					
2					
3					
4					
5					
n					

Table 1: Number of available follow-up radiographs of femurs treated with intramedullary SIGN nailing from January 2013 to December 2017

Follow-up Period	Number of radiographs available
3-6 weeks	25
6-8 weeks	12
8-10 weeks	12
10-12 weeks	5
>12-52 weeks	27
>52 weeks	5
Total:	**86**

Table 2: Level of acceptability as clinical measure by Portney LG & Watkins MP (2000)

ICC	Fleiss (1986)	P&W (2009)
0.99	Excellent	Clinical Measures
0.96		
0.90		
0.89		Good
0.80		
0.75		
0.50-74	Good	Poor to moderate

Table 3: RUST Intraclass Correlation Coefficients (95% Confidence Interval)

Rater	Intra-Observer ICC 95% CI		Initial Assessment	Final Assessment	Total ICC 95% CI	
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Consultant 2	0.84 (0.75-0.89)					
Resident 1	0.84 (0.75-0.89)	0.77 (mean)	0.81 (0.68-0.88)	0.79 (0.66-0.87)	0.89 (0.84-0.93)	
Resident 2	0.55 (0.07-0.76)					
Resident 3	0.89 (0.82-0.93)					
Resident 4	0.66 (0.48-0.78)					
Resident 5	0.89 (0.48-0.78)					
Resident 6	0.80 (0.66-0.882)					

Table 4: mRUST Intraclass Correlation Coefficients (95% Confidence Interval)

Rater	Intra-Observer ICC 95% CI		Initial Assessment	Final Assessment	Total ICC 95% CI	
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Consultant 2	0.63 *(0.43-0.76)*					
Resident 1	0.85 *(0.78-0.90)*	0.81 (mean)	0.83 *(0.72-0.89)*	0.83 *(0.71-0.89)*	0.91 *(0.84-0.93)*	
Resident 2	0.71 *(0.75-0.84)*					
Resident 3	0.92 *(0.88-0.95)*					
Resident 4	0.71 *(0.55-0.81)*					
Resident 5	0.90 *(0.84-0.93)*					
Resident 6	0.77 *(0.36-0.89)*					

Table 5: Overall mean RUST score, Overall mean mRUST Score

Radiograph	Mean RUST Score overall	Mean mRUST Score Overall
1	10	14
2	6	7
3	8	12
4	6	7
5	9	14
6	7	9
7	6	9
8	9	12
9	7	8
10	9	12
11	8	12
12	8	9
13	7	10
14	10	13
15	7	9
16	7	10
17	10	15
18	6	8
19	6	8
20	5	6
21	8	10
22	6	7
23	10	13
24	10	13
25	12	15
26	7	8
27	6	8
28	11	16
29	8	9
30	11	15
31	8	10
32	7	8
33	10	15
34	12	15
35	9	11
36	8	11
37	5	6
38	9	12
39	7	8
40	8	10
41	9	12
42	8	11
43	8	10
44	12	16
45	7	9
46	7	9
47	7	10
48	8	10
49	7	9
50	8	9
51	8	11
52	10	14
53	8	10

54	10	12
55	7	9
56	10	13
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76	10	14
77	9	12
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83	6	8
84	12	15
85	9	12
86	12	16

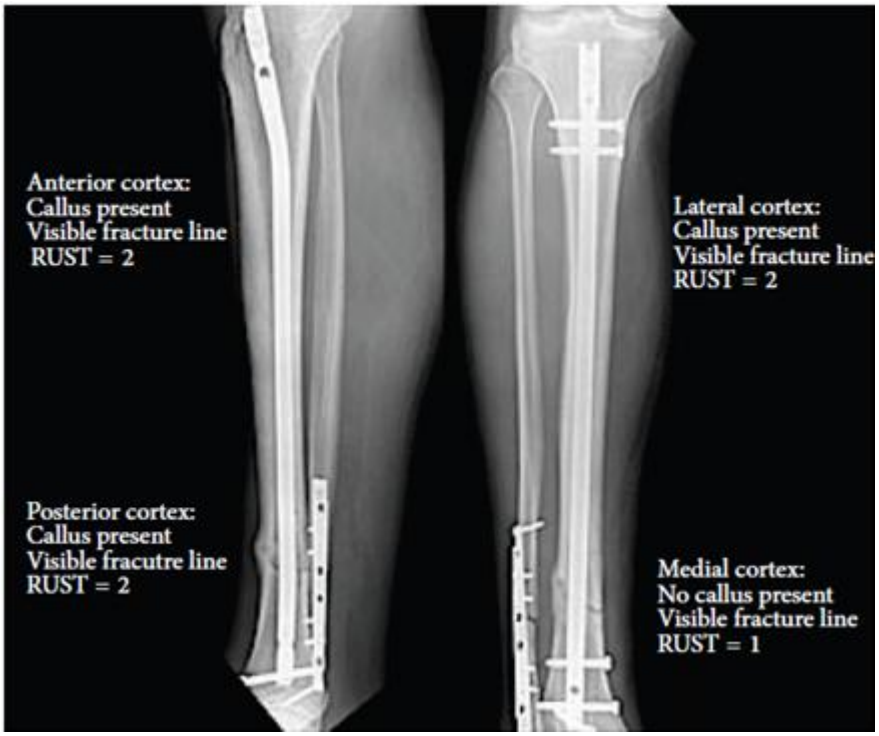

Figure 1: Assignment of the RUST in a patient with distal tibial shaft fracture at 3 months postoperatively. Overall RUST = 7. *Copied from Whelan et. al. (2010)*