ORIGINAL PAPER
PŮVODNÍ PRÁCE

The Effect of Plaster of Paris on Reliabilities of RUST and mRUST Scoring Systems

Vliv sádrového obvazu na spolehlivost RUST a mRUST skórovacích systémů

M. KUMBARACI[1], A. TURGUT[1], S. HANCIOGLU[1], H. GUNAY[2], U. ALTUNDAG[1], E. EGELI[1]

[1] Tepecik Training and Research Hospital, Izmir, Turkey
[2] Egean University Faculty of Medicine Hospital, Izmir, Turkey

ABSTRACT

PURPOSE OF THE STUDY

The aim of our study is to investigate the reliabilities of the radiographic union score for tibial fracture (RUST) and modified RUST scoring systems in the evaluation of fracture healing in adult tibia fractures treated with intramedullary nailing and pediatric tibia fractures treated with closed reduction and cast immobilization and to compare the reliabilities between two groups.

MATERIAL AND METHODS

Between January 2016 and January 2020, the informations of patients (ages of 4–10) with tibia fractures treated with closed reduction and casting and patients (aged 18–65 years) with tibia fractures treated with intramedullary nailing were analyzed retrospectively. Forty-seven good quality AP and lateral radiographs (represent different healing stages) each for pediatric and adult fracture groups were selected and were included in two PPTs separately. The radiographs were assessed twice with an interval of three weeks by an observer group consisting of four senior orthopedic surgeons and four orthopedic residents, and fractures were evaluated according to the RUST and mRUST scoring systems.

RESULTS

The inter-observer agreement of RUST and mRUST were ‘perfect’ in adult tibia fractures and ‘substantial’ in pediatric tibia fractures in both evaluations. However, in deciding fracture consolidation, inter-observer agreement was found to be ‘perfect’ in pediatric tibia fractures, while it was ‘substantial’ in adult fractures in both assessments. The mean intra-observer reliability of RUST system in adult tibia fractures was 0.860 (0.674–0.968) and 0.818 (0.693–0.909) in pediatric tibia fractures, respectively. The mean intra-observer agreement of mRUST system was 0.842(0.745–0.979) in adult fractures and 0.857 (0.756–0.932) in pediatric fractures, respectively. The mean intra-observer reliability of decision on union was 0.842 (0.638–1.000) in adult fractures and 0.785 (0.611–0.977) in pediatric fractures, respectively.

DISCUSSION

The decision of union in tibia shaft fractures is based on repeated clinical and radiological evaluations but there are no universally accepted guidelines to evaluate radiographic union. It has been shown in previous studies that the RUST and mRUST scoring systems can be used safely in the evaluation of fracture healing in adult patients with tibia fracture treated with intra-medullary nailing. To our knowledge, there are no studies investigating the reliability of RUST and mRUST systems in conservatively treated pediatric tibial fractures. We hypothesized that the plaster of Paris makes it difficult to assess fracture union on direct radiographs and reduce the reliabilities of these scoring systems in pediatric tibial fractures.

CONCLUSIONS

Our study showed that both RUST and mRUST scoring systems are useful tools that can be used safely assessing fracture healing in both pediatric and adult tibia fractures. The presence of a plaster of Paris on the extremity did not adversely affect the inter-observer and intra-observer agreement of the RUST and mRUST scoring systems.

Key words: pediatric tibia fracture, radiographic union score for tibial fracture (RUST), modified RUST, radiographic union, reliability.

INTRODUCTION

Tibia fractures are one of the most common long bone fractures in adults and childhood (9, 16). These fractures are usually treated with intramedullary nailing or plate osteosynthesis in adults and in children, the most preferred and cost effective treatment of uncomplicated tibial shaft fractures is closed reduction and cast immobilization (9, 10, 20). Determination of union in tibial shaft fractures is based on clinical and radiological assessment. However, in children because the affected extremity is in a plaster cast it is not possible to make a clinical diagnosis with evaluating the local pain and possible pathological movement at the fracture side. Therefore, radiographic evaluation appears to be the sole decision maker. Presence and amount of callus, loss of visibility of the fracture line and cortical continuity are radiologic parameters used in the evaluation of fracture union but there is no universal criteria for the determination of fracture union in long bones (8). Whelan et al. developed the “Radiographic Union Score for Tibial Fracture (RUST)” scoring system to assess union in

Fig. 1. Evaluation of adult tibia fractures treated with intramedullary nail fixation according to RUST scoring system (Total RUST score: 7).

adult tibial fractures treated with intramedullary nailing (22). In this scoring system, by giving a numerical value to each cortex at the fracture line, fracture union is evaluated according to the presence of callus and the visibility of the fracture line. Although this scoring system does not provide an exact score for defining fracture union, it aids in standardization in radiographic evaluation of tibial fractures. The reliability of RUST system has been evaluated in a few studies and demonstrated excellent aggreement (3, 12, 13, 17, 22). It is noteworthy that in most of these studies, patient x-rays were examined in chronological order. Litrenta et al. developed the modified RUST (mRUST) system and in this scoring system, different from RUST, they qualified the amount of callus and subdivide the callus formation into 'present' or 'bridging' (13). We hypothesized that intra- and inter-observer reliabilities of these scoring systems would reduce for pediatric tibia shaft fractures because the presence of the plaster of Paris on the extremity should make the evaluation difficult.

To our knowledge, this is the first study analyzing the reliability of these scoring systems in conservatively treated pediatric tibia fractures. The aim of our study was to investigate the reliabilities of RUST and mRUST scoring systems in the evaluation of fracture healing in adult tibia fractures treated with intramedullary nailing and pediatric tibia fractures treated with closed reduction and cast immobilization and to compare the reliabilities between two groups.

MATERIAL AND METHODS

This study was approved by the local ethical committee. Between January 2016 and January 2020, the informations of patients (ages of 4–10) with tibia fractures treated with closed reduction and casting and patients (aged 18–65 years) with tibia fractures treated with intramedullary nailing were analyzed retrospectively. Ninety-two pediatric and 82 adult patients who met the criteria were found. Exclusion criteria were; communited and segmenter fractures, pathological fractures, osteoporotic fractures, and patients with previous fractures of the same tibia. Consequently, radiographs of 32 pediatric and 29 adult tibial fractures were included in the study. An orthopaedic resident, who did not participate in the study as an observer, prepared two separate Microsoft® Office PowerPoint presentations (PPTs). Forty-seven good quality AP and lateral radiographs (represent different healing stages) each for pediatric and adult fracture groups were selected and were included in two PPTs separately. The observer groups consisted of four senior orthopaedic surgeons experienced in orthopaedic trauma (group 1) and four residents who were training more than three years in orthopaedics (group 2). Before the individual evaluations, observers came together to discuss how to implement the RUST and mRUST scoring systems and they reached a consensus at the end of the meeting. There after tables of these scoring systems were given to observers and they were asked individually to evaluate the fractures' healing according to RUST and mRUST systems and also asked whether the fractures have healed or not. The observers did not have information about the ages, fracture times and clinical status of patients. After three weeks, order of the PPT slides was randomly changed and the observers were asked to assess the radiographs again in a different numerical order.

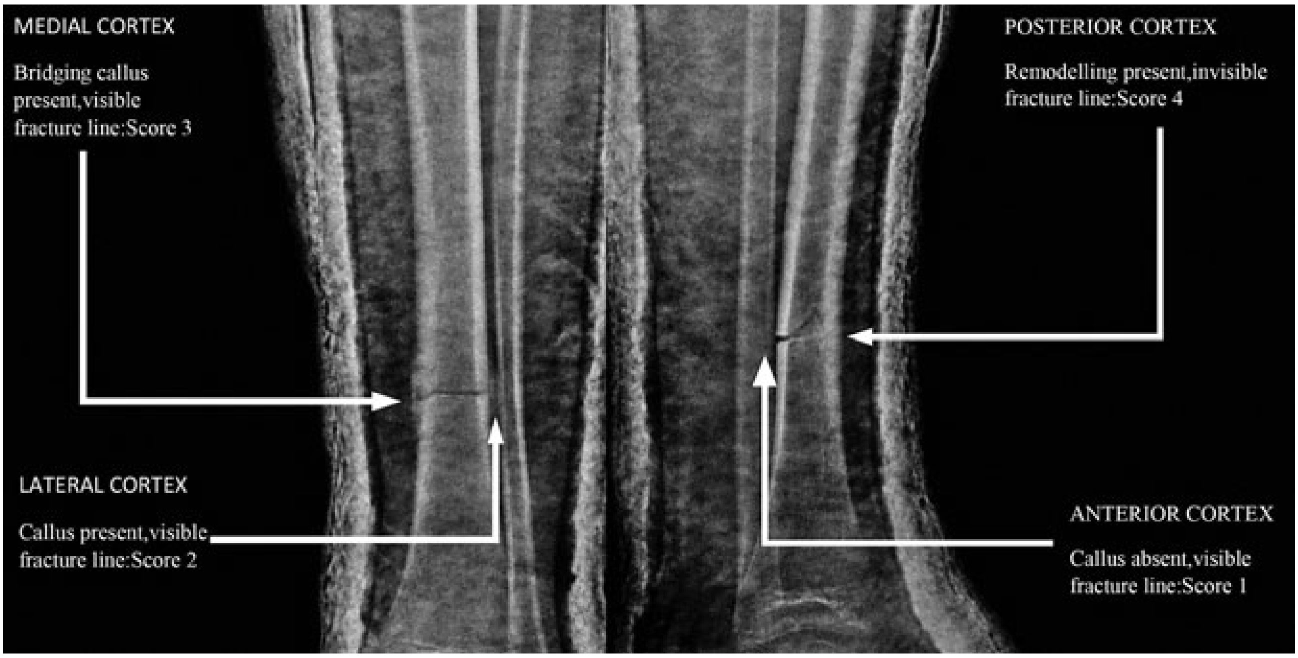

Fig. 2. Evaluation of pediatric tibia fracture treated with closed reduction and casting according to the mRUST scoring system (Total mRUST score: 10).

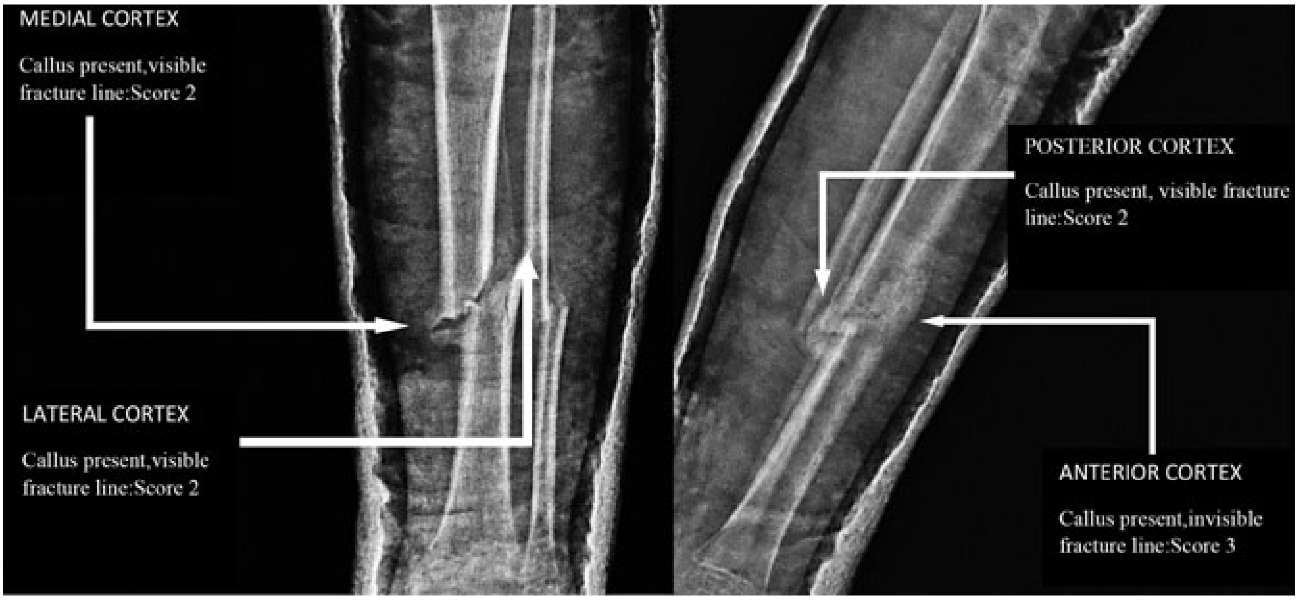

Fig. 3. An example of pediatric tibia fracture treated with casting, evaluated by RUST scoring system (Total RUST score:9).

Radiographic union score for tibial fracture (RUST)

RUST scoring system evaluates fracture union by examining four cortices on AP and lateral radiographs. On AP radiographs, medial and lateral cortices and on the lateral radiographs, anterior and posterior cortices are given score of 1, 2 and 3 (1=no callus, visible fracture line, 2=callus present, visible fracture line, 3=visible callus, no fracture line) according to the degree of union and the sum of the each cortex scores gives RUST ranging from 4–12 (Table 1) (22).

Table 1. Radiographic union score for tibial fracture (RUST)

	Radiographic evaluation	
Score for each cortex*	Callus formation	Fracture line
1	absent	visible
2	present	visible
3	present	invisible

* Medial, lateral, anterior and posterior cortices are given score of 1, 2 and 3 according to the degree of union and the sum of the each cortex scores gives RUST ranging from 4–12 (22).

Table 2. Modified radiographic union score for tibial fracture (mRUST)

	Radiographic evaluation	
Score for each cortex*	Callus formation	Fracture line
1	absent	visible
2	present	visible
3	bridging callus	visible
4	remodeled	invisible

* A score is given each cortices according to the degree of union and the sum of the each cortex scores gives mRUST ranging from 4–16 (13).

Modified RUST (mRUST)

In the mRUST scoring system, different from RUST, callus formation is evaluated separately as 'present' or 'bridging' and each cortex is given a score from 1 to 4 according to the degree of union (1= no callus, 2=callus present, 3=bridging callus, 4=remodeled, fracture line not visible). The mRUST is the sum of the scores for each cortex, ranging from 4 to 16 (Table 2) (13).

Statistical analyses

Statistical analyses were carried out using the IBM Statistical Statistical Package for Social Sciences (SPSS) for Windows, version 24.0 (IBM Corp., Armonk, New York, USA). Intra-class Correlation Coefficient (ICC) values were calculated for the evaluation of intra-observer reliability. Fleiss kappa values other than ICC were calculated for the evaluation of inter-observer reliability, because there were more than two observers. ICC and Fleiss kappa values were evaluated as; 0–0.2, slight agreement; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.8, substantial; and >0.81 as perfect agreement (6, 11).

RESULTS

The inter-observer agreement of RUST and mRUST were 'perfect' in adult tibia fractures and 'substantial' in pediatric tibia fractures in both evaluations (Table 3). However, in deciding fracture healing, inter-observer agreement was found to be 'perfect' in pediatric tibia fractures, while it was 'substantial' in adult fractures in both assessments. The inter-observer reliability values of RUST and mRUST systems were similar in both pediatric and adult tibial fractures (Table 3). The inter-observer reliability of RUST and mRUST systems in the evaluation of healing in adult and pediatric tibia fractures were similar between the two different experience groups (Table 4). It was found that increasing experience in the profession did not increase reliability in both RUST and mRUST systems. The mean intra-observer reliability of RUST system in adult tibia fractures was 0.860 (0.674-0.968) and 0.818 (0.693-0.909) in pediatric

Table 3. Inter-observer reliability of RUST and mRUST scoring systems in the evaluation of healing of pediatric and adult tibia fractures treated with plaster of paris and intramedullary nails, respectively

	RUST Fleiss kappa (95% CI)	mRUST Fleiss kappa (95% CI)	Decision on union ICC (95% CI)
First evaluation in pediatric fractures	0.785 (0,706–0.857)	0.793 (0.716–0.862)	0.847 (0.771–0.905)
First evaluation in adult fractures	0.904 (0.855–0.940)	0.910 (0.865–0.944)	0.786 (0.679–0.867)
Second evaluation in pediatric fractures	0.748 (0.622–0.844)	0.750 (0.662–0.831)	0.844 (0.720–0.913)
Second evaluation in adult fractures	0.845 (0.768–0.904)	0,865 (0.797–0.916)	0.751(0.627–0.846)

CI: Confidence interval, ICC: Intraclass Correlation Coefficient
RUST: Radiographic union score for tibial fracture, , mRUST: Modified radiographic union score for tibial fracture

Table 4. Inter-observer reliability of RUST and mRUST scoring systems among the experience groups in the evaluation of healing of pediatric and adult tibia fractures treated with plaster of paris and intramedullary nails, respectively

		RUST Fleiss kappa (95% CI)	mRUST Fleiss kappa (95% CI)	Decision on union ICC (95% CI)
First experience group	**First evaluation in pediatric fractures**	0.801 (0,712–0.872)	0.774 (0.677–0.854)	0.739 (0.592–0.843)
	First evaluation in adult fractures	0.668 (0.480–0.799)	0.728 (0.574–0.836)	0.510 (0.233–0.704)
	Second evaluation in pediatric fractures	0.691 (0.573–0.795)	0.738 (0.630–0.828)	0.782 (0.574–0.836)
	Second evaluation in adult fractures	0.749 (0.607–0.848)	0,777 (0.651–0.865)	0.489 (0.201–0.692)
Second experience group	**First evaluation in pediatric fractures**	0.796 (0,707–0.869)	0.836 (0.759–0.896)	0.860 (0.781–0.915)
	First evaluation in adult fractures	0.925 (0.883–0.955)	0.923 (0.880–0.954)	0.779 (0.654–0.867)
	Second evaluation in pediatric fractures	0.380 (0.029–0.626)	0.796 (0.706–0.869)	0.376 (0.023–0.623)
	Second evaluation in adult fractures	0.667 (0.478–0.799)	0,696 (0.524–0.817)	0.653 (0.457-0.791)

CI: confidence interval, ICC: Intraclass Correlation Coefficient
RUST: Radiographic union score for tibial fracture, mRUST: Modified radiographic union score for tibial fracture

Table 5. Intra-observer reliability of RUST and mRUST scoring systems among the experience groups in the evaluation of healing of pediatric and adult tibia fractures treated with plaster of Paris and intramedullary nails, respectively

		RUST ICC (95% CI)	mRUST ICC (95% CI)	Decision on union ICC (95% CI)
First experience group pediatric	**Observer 1**	0.861 (0,763–0.920)	0.932 (0.880–0.961)	0.817 (0.694–0.894)
	Observer 2	0.693 (0.508–0.816)	0.800 (0.667–0.883)	0.754 (0.558–0.863)
	Observer 3	0.783 (0.642–0.873)	0.806 (0.676–0.887)	0.611 (0.301–0.783)
	Observer 4	0.765 (0.578–0.869)	0,756 (0.562–0.864)	0.681 (0.490–0.810)
First experience group adult	**Observer 1**	0.968 (0,942–0.982)	0.979 (0.962–0.988)	0.638 (0.350–0.798)
	Observer 2	0.935 (0.883–0.964)	0.941 (0.893–0.967)	1.000 (1.000–1.000)
	Observer 3	0.930 (0.874–0.961)	0.938 (0.888–0.965)	0.744 (0.540–0.857)
	Observer 4	0.936 (0.886–0.965)	0,978 (0.960–0.988)	1.000 (1.000–1.000)
Second experience group pediatric	**Observer 5**	0.873 (0,772–0.929)	0.919 (0.854–0.955)	0.977 (0.659–0.987)
	Observer 6	0.888 (0.807–0.936)	0.867 (0.762–0.926)	0.868 (0.763–0.927)
	Observer 7	0.909 (0.843–0.948)	0.912 (0.843–0.951)	0.765 (0.579–0.869)
	Observer 8	0.775 (0.596–0.875)	0,867 (0.761–0.926)	0.813 (0.663–0.896)
Second experience group Adult	**Observer 5**	0.871 (0,769–0.928)	0.910 (0.838–0.950)	0.821 (0.679–0.900)
	Observer 6	0.821 (0.679–0.900)	0.837 (0.707–0.909)	0.912 (0.841–0.951)
	Observer 7	0.748 (0.548–0.860)	0.904 (0.828–0.947)	0.756 (0.561–0.864)
	Observer 8	0.674 (0.416–0.819)	0,745 (0.542–0.858)	0.868 (0.763–0.927)

CI: confidence interval, ICC: Intraclass Correlation Coefficient
RUST: Radiographic union score for tibial fracture, mRUST: Modified radiographic union score for tibial fracture

tibia fractures, respectively. The mean intra-observer agreement of mRUST system was 0.842 (0.745–0.979) in adult fractures and 0.857 (0.756-0.932) in pediatric fractures, respectively. The mean intra-observer reliability of decision on union was 0.842 (0.638–1.000) in adult fractures and 0.785 (0.611–0.977) in pediatric fractures, respectively (Table 5).

DISCUSSION

The most important findings of present study were that; the RUST and mRUST scores were found to be reliable in both pediatric tibia fractures treated with plaster cast and adult tibia fractures treated with intramedullary nailing. Both inter-observer and intra-observer reliabilities were high in decision making on union.

In the decision of bone healing, patient-based clinically objective criteria and radiographic results should be evaluated together. Sarmiento determined the criteria for fracture union as; the absence of pain with loading in the fracture area, no pathological movement in the fracture line and the appearance of callus formation on radiographs in the fracture line (18). Numerous scoring systems have been used to radiologically evaluate the fracture healing with examining callus formation and the visibility of the fracture line, but no consensus has been achieved (1, 2, 5, 8, 10, 12, 21). In addition, physical examination may be confusing in some adult patients and it cannot be performed in pediatric fractures treated with plaster cast.

Whelan et al. developed the RUST scoring system and they tried to standardize evaluation of bone healing in the setting of tibial fractures treated with intramedullary nailing and in their study they found the inter-observer agreement and the intra-observer agreement as ‘perfect’ (ICC = 0.86 and ICC = 0.88, respectively) (22). They suggested that RUST scoring can be used in all types of tibia fractures, however, they stated that this scoring system should be compared with clinical evaluations in future studies. Cekic et al. investigated the reliability of the RUST system and its correlation with clinical results. They observed that the RUST scores matched directly with the clinical conditions of the patients. They did not find high pain scores or low functional scores in patients with high RUST scores (3). In this study, the RUST score was found to be 10 or above in 27 of 41 patients. This finding indicates that, in this retrospective study, the majority of the fracture had united or were about to union. It may not be appropriate to clearly evaluate the consistence of the RUST system and functional assessment in this kind of study in which patients were not homogeneously distributed. Also, radiographic evaluation was done by the same physician and inter-observer agreement was not investigated.

Litrenta et al. developed the modified RUST system and in their study, they evaluated this system in patients with distal metaphyseal femur fractures treated with intramedullary nailing or plates. In this scoring system, the amount of callus was evaluated more specifically and defined as ‘bridging’ or ‘nonbridging’. They found that both the standard RUST and the mRUST scoring systems showed substantial agreement in the evaluation of healing in metaphyseal fractures and also stated that mRUST was slightly more reliable than the standart RUST. In addition, they tried to determine a point to make a union decision by using RUST and mRUST scores (13). Due to the lack of standardized objective and gold standard criteria used to evaluate union during the healing period in direct radiographs, in our study, we did not try to find a cut-off value for RUST and mRUST that states the exact degree of union

Ross et al. created a nonunion prediction model by using demographic data, soft tissue injuries, fracture classifications and radiological evaluations at sixth weeks of patients with tibia fractures treated with intramedullary nailing (17). It was found that patients with fracture healing at the end of the treatment had higher RUST scores at the sixth week compared to patients without union. As a result, they stated that infection and lower RUST scores were significantly associated with nonunion (17). Fowler et al. reported that, in their evaluation of tibia fractures at postoperative third month, standard RUST scores and property of fracture (open or closed) were the most important predictive factors for tibial nonunion (17,7). Whelan et al. suggested that an optimal use of the RUST score would be in conjuction with follow-up radiographs and evaluation in preassigned intervals (22).

Cooke et al. created a femoral diaphyseal model in murines and they investigated the compatibility of RUST and mRUST scores with the structural and biomechanical properties of the bone. They also tried to determine whether biomechanical properties correlated with a subjective determination of a healed fracture. They scanned the femora with micro-computed tomography and they calculated callus volume, mineralization and bone mineral density. They also measured the biomechanical properties of healing bone. They showed that both RUST and mRUST scores were positively correlated with callus strength, stiffnes and rigidity and they suggested that RUST and mRUST scoring systems are useful tools for determinating the healing and estimating the bone union (4).

Litrenta et al. osteotomized sheeps' tibiae and then applied osteosynthesis with intramedullary nails. They evaluated fracture healing with radiographs and then investigated fracture stiffness biomechanically. In their study, all reviewers agreed that a score of 10 and 14 for standard RUST and a mRUST, respectively represented radiographic union. Biomechanically united tibiae had an average mRUST score of 14.1 and RUST score of 10.3. Although human and animal bone properties are different from each other, in the light of these biomechanical studies, especially in pediatric tibia fractures it might be decided whether the treatment with plaster will be discontinued by considering these RUST and mRUST scores(14). However, the visibility of the fracture area is mandotary in decision making.

In some fracture types, problems may be encountered in the evaluation of radiographs according to the RUST and mRUST scoring systems. In long oblique fractures, the overlapping of fracture fragments on lateral radiographs makes the evaluations difficult. In these images, it is difficult to evaluate both the fracture lines and callus and it may cause inconsistency among the observers. The callus may not be clearly evaluated in transverse fractures with well reduced. In addition, it was seen that there was a difference of opinion about 2 and 3 points in the RUST and mRUST scoring. There were disagreements as to which callus formation should qualify as bridging callus. At the end of the meeting, consensus was reached.

Evaluation of union in pediatric tibial fractures treated with casting should be done together with radiographic assessment and physical examination. However, since the affected limb is in a cast, the tenderness and pathological movement in the fracture line cannot be evaluated. This adds more value to the radiological evaluation. Although nonunion in pediatric tibia fractures is not as common as in adult tibia fractures, delayed unions and nonunions might be seen in up to 25% in open tibial fractures (15). Therefore, monitoring the progression of fracture healing is very important for the success of treatment. Inadequate evaluation of fracture healing may cause unnecessary immobilization of the extremity, activity limitation, children staying away from normal life and school and local osteopenia in the affected extremity. On the contrary, thinking that the fracture has healed accidentally may lead to unnecessary removal of the plaster and financial losses by applying new plastering. Our hypothesis was that the presence of plaster of Paris should have a negative effect on the reliability of RUST and mRUST scoring systems. However, our study results showed that we could not prove our hypothesis. RUST and mRUST systems are seeming to be useful tools in this monitoring. If the RUST or mRUST score at each control is written on the follow-up form of the patients, the progress in recovery can be observed more clearly.

Our study has some strengths and limitations. This is first study to evaluate the healing of pediatric tibia fractures treated with cast immobilization using RUST and mRUST systems. In our study, the functional status of the patients and the pain scores were not evaluated, it seems difficult to completely distinguish the healed fractures from the nonunions. Radiographs in the study were selected from transverse and oblique fractures, comminuted and segmental fractures were not included in the study. Future studies including these fractures can provide more information on the reliability of these systems. In addition, the cut-off value for decision making on union was not investigated in our study, since the presence of union in fractures in different healing stages in human bones could not be demonstrated by biomechanical studies.

CONCLUSIONS

As a result, we found that we were wrong with our hypothesis. We thought that plaster and cotton would negatively affect the reliabilities of the RUST and mRUST systems in the evaluation of union in pediatric tibia fractures. However, when compared with adult tibia fractures treated with an intramedullary nail, it was found that the presence of a plaster of Paris on the extremity did not adversely affect the inter-observer and intra-observer agreement of the RUST and mRUST scoring systems. Additionally, increased experience was not found to be a positive factor on the reliability of these systems.

References

1. Bhandari M, Guyatt GH, Swiontkowski MF, Tornetta P 3rd, Sprague S, Schemitsch EH. A lack of consensus in the assessment of fracture healing among orthopaedic surgeons. J Orthop Trauma. 2002;16:562–566.
2. Brinker MR, Bailey DE, Jr. Fracture healing in tibia fractures with an associated vascular injury. J Trauma. 1997;42:11–19.
3. Cekic E , Alıcı A , Yeşil M. Reliability of the radiographic union score for tibial fractures. Acta Orthop Traumatol Turc. 2014;48:533–540.
4. Cooke ME, Hussein AI, Lybrand KE, Wulff A, Simmons E, Choi JH, Litrenta J, Ricci WM, Nascone JW, O'Toole RV, Morgan EF, Gerstenfeld LC, Tornetta P 3rd. Correlation between RUST assessments of fracture healing to structural and biomechanical properties. J Orthop Res. 2018;36:945–953.
5. Craig JG, Jacobson JA, Moed BR. Ultrasound of fracture and bone healing. Radiol Clin North Am. 1999;37:737–751.
6. Fleiss JL. Statistical methods for rates and proportions. 2nd ed., John Wiley & Sons, New York, 1981.
7. Fowler J, Dubina AG, Castillo RC, Boulton CL, Nascone JW, Sciadini MF, et al. Prediction of tibial nonunions at 3 months after intramedullary nailing. Presented at the Annual Meeting of the Orthopaedic Trauma Association, October 2014.
8. Hammer RR, Hammerby S, Lindholm B. Accuracy of radiologic assessment of tibial shaft fracture union in humans. Clin Orthop Relat Res. 1985;199:233–238.
9. Hogue GD, Wilkins KE, Kim IS. Management of Pediatric Tibial Shaft Fractures. J Am Acad Orthop Surg. 2019;27:769–778.
10. Kooistra BW , Dijkman BG, Busse JW, Sprague S, Schemitsch EH, Bhandari M. The radiographic union scale in tibial fractures: reliability and validity. J Orthop Trauma 2010;24(Suppl 1):S81–86.
11. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33:159–174).
12. Leow JM, Clement ND, Tawonsawatruk T, Simpson CJ, Simpson AHRW. The radiographic union scale in tibial (RUST) fractures: reliability of the outcome measure at an independent centre. Bone Joint Res. 2016;5:116–121.
13. Litrenta J, Tornetta P 3rd, Mehta S, Jones C, O Toole RV, Bhandari M, Kottmeier S, Ostrum R, Egol K, Ricci W, Schemitsch E, Horwitz D. Determination of radiographic healing: an assessment of consistency using RUST and modified RUST in metadiaphyseal fractures. J OrthopTrauma. 2015;29:516–520.
14. Litrenta J , Tornetta P 3rd, Ricci W, Sanders RW, O Toole RV, Nascone JW, Faber H, Wilson D. In vivo correlation of radiographic scoring (radiographic union scale for tibia fractures) and biomechanical data in a sheep osteotomy model: can we define union radiographically? Orthop Trauma. 2017;31:127–130.
15. Martin J Herman , Melissa A Martinek, Joshua M Abzug. Complications of tibial eminence and diaphyseal fractures in children: prevention and treatment. Instr Course Lect. 2015;64:471–482.
16. Raducha JE, Swarup I, Schachne JM, Cruz AI Jr, Fabricant PD. tibial shaft fractures in children and adolescents. JBJS Rev. 2019;7:e4.
17. Ross KA, O'Halloran K, Castillo RC, Coale M, Fowler J, Nascone JW , Sciadini MF, LeBrun CT, Manson TT, Carlini AR, Jolissaint JE, O'Toole RV. Prediction of tibial nonunion at the 6-week time point. Injury. 2018;49:2075–2082.
18. Sarmiento A, Sobol PA, Sew Hoy AL, Ross SD, Racette WL, Tarr RR. Prefabricated functional braces for the treatment of fractures of the tibial diaphysis. J Bone Joint Surg Am. 1984;66:1328–1339.
19. Schnarkowski P, Re´die J, Peterfy CG, Weidenmaier W, Mutschler W, Arand M, Reiser MF. Tibial shaft fractures: assessment of fracture healing with computed tomography. J Comput Assist Tomogr. 1995;19:777–781.
20. Schwarz O , Majerníček M, Chomiak J. [Treatment of Fractures of the Distal Third of Tibia Diaphysis by MIPO Technique]. Acta Chir Orthop Traumatol Cech. 2020;87:114–119.
21. Tower SS, Beals RK, Duwelius PJ. Resonant frequency analysis of the tibia as a measure of fracture healing. J Orthop Trauma. 1993;7:552–557.
22. Whelan DB, Bhandari M, Stephen D, Kreder H, McKee MD, Zdero R, Schemitsch EH. Development ofthe radiographic union score for tibial fractures forthe assessment of tibial fracture healing after intramedullary fixation. J Trauma. 2010;68:629–632.

Corresponding author:
Mert Kumbaraci, MD, Orthopaedic Surgeon
Tepecik Training and Research Hospital
Orthopaedic and Traumatology Department
35110 Yenisehir-Izmir, Turkey
E-mail: kumbaracimert@hotmail.com