Radiographic Union Scale for Mandible (RUSM): A Novel Tool For Assessment Of Mandibular Fracture Healing.

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ABSTRACT

Objective: The present study aimed to evaluate mandibular fracture healing using radiographic methods and to introduce a structured scoring system, namely the Radiographic Union Scale for Mandible (RUSM), for standardized assessment.

Methodology:A total of 60 patients presenting to the trauma center of Mahatma Gandhi Hospital, Jaipur, between June 2017 and August 2019 with mandibular fractures were included. A cross-sectional evaluation was performed to assess fracture healing at 3 months postoperatively using two orthogonal radiographic views—orthopantomogram and occlusal radiograph—based on the proposed scoring system.

Results: Based on RUSM assessment, 5 patients were categorized as non-union, 8 patients demonstrated incomplete healing, and 47 patients showed complete radiographic union at the 3-month follow-up.

Conclusion: The RUSM provides a structured, consistent, and reproducible method for evaluating mandibular fracture healing. Its application may enhance inter-observer agreement and help standardize outcome assessment in both routine clinical practice and research settings.

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INTRODUCTION

In maxillofacial trauma, mandibular fractures represent one of the most frequently encountered injuries, second only to nasal bone fractures. Due to its anatomical prominence and relatively limited support from the cranial skeleton, the mandible is particularly vulnerable to traumatic forces.[1]

Several classification systems for mandibular fractures exist, based on anatomical location, fracture characteristics, dentition status, and direction of fracture. In the present study, fractures were categorized according to anatomical regions, including symphysis, parasymphysis, body, angle, and condyle.[2]

Fracture healing is a complex biological process influenced by multiple factors such as vascularity, mechanical stability, systemic health, and injury characteristics. The healing cascade involves hematoma formation, inflammatory response, cellular proliferation, differentiation, ossification, and subsequent remodeling.

Management of mandibular fractures focuses on achieving anatomical reduction and stable fixation to restore function. Various techniques, including maxillomandibular fixation, external fixation, and rigid internal fixation, are employed. However, complications such as infection, delayed union, malunion, non-union, malocclusion, and neurosensory deficits may occur, often resulting in pain, trismus, and functional impairment.[3]

Despite advances in treatment modalities, non-union remains one of the most challenging complications. It may lead to persistent infection, discomfort, repeated interventions, and significant morbidity, including deformity and compromised quality of life.[4]

Additionally, systemic factors such as smoking, diabetes, and prolonged NSAID use can negatively affect the healing process and increase the likelihood of postoperative complications.

The present study aims to develop a structured radiographic scoring system—RUSM—to evaluate fracture union at 3 months postoperatively. This system is based on assessment of bridging callus and fracture line visibility across four cortices using orthogonal radiographic views.

EXISTING SCALES

Previous radiographic scoring systems have attempted to assess fracture healing with varying levels of accuracy. Hammer et al.[5] introduced a classification based on callus formation and fracture line disappearance. Their system categorized fractures into five groups representing progressive stages of healing. However, radiographic findings correlated with mechanical stability in only approximately 50% of cases.

A limitation of this scale is the inclusion of an “uncertain” category, which may lead to prolonged treatment due to ambiguity in interpretation. Furthermore, inter-observer agreement has been reported to be moderate (k ≈ 0.60), slightly lower than general clinical assessment.[6]

TABLE 1. Radiographic Scoring Method for Fractures by Hammer et al[5]

	Radiographic Assessment		
Group	Callus Formation	Fracture Line	Stage of Union
1	Homogeneous bone structure	Obliterated	Achieved
2	Massive. Bone trabeculae crossing fracture line	Barely discernible	Achieved
3	Apparent. Bridging of fracture line	Discernible	Uncertain
4	Trace. No bridging of fracture line	Distinct	Not achieved
5	No callus formation	Distinct	Not achieved

Tower et al.[7] proposed a scoring system incorporating periosteal callus, bridging callus, and lucent fracture lines, combined with clinical parameters such as weight-bearing and pain. However, due to integration with clinical scoring, the independent validity of the radiographic component remains unclear.

The Radiographic Union Score for Tibial fractures (RUST) is based on cortical bridging and fracture line visibility across four cortices.[6,8] It provides a continuous scale from 4 (non-union) to 12 (complete union). While reliable for long bones, it does not directly address mandibular fracture characteristics.

DEVELOPMENT OF THE RUSM SCORE

Existing scoring systems often fail to balance simplicity with the dynamic nature of fracture healing. Systems with limited categories may lack sensitivity, while complex systems may be impractical for routine use.[9,10]

The RUSM scoring system was developed to provide a comprehensive yet practical evaluation by incorporating multiple radiographic parameters.

SELECTED CRITERIA

Section 1: General Impression

Healed

Not healed

Section 2: Scale Parameters

Cortical bridging

Disappearance of cortical fracture line

Trabecular consolidation

Disappearance of trabecular fracture line

Presence of callus

Section 3: Callus Quality

The RUSM scoring system, based on the defined radiographic parameters, offers a comprehensive and continuous evaluation of mandibular fracture healing. It systematically assesses fracture line visibility and callus formation across all four cortices using orthogonal imaging modalities, specifically orthopantomogram and occlusal radiographs. The scoring spectrum ranges from 7 to 21, where lower scores denote non-union with absent or minimal healing, and higher scores indicate complete osseous union characterized by cortical bridging in all cortices, well-formed callus, and absence of any discernible fracture line. This graded approach enhances the objectivity and sensitivity of radiographic assessment.

New Proposed RUSM Scale for Mandibular Fracture Assessment

Table 2. Assessment Scale

. Radiographic Union Score for Mandible (RUSM)

Section 1: General Impression

Using your overall general impression, has the fracture healed?

☐ Healed ☐ Not Healed ☐ on Union

Section 2:

1) Cortical Index – Bridging

Cortex	No Cortical Bridging Score = 1	Some Cortical Bridging Score = 2	Complete Cortical Bridging Score = 3	Total Score Range = 4 to 12
Labial Cortex				
Lingual Cortex				
Overall Score				

1. Radiographic Union Score for Mandible (RUSM)

Section 1: General Impression

Using your overall general impression, has the fracture healed?

☐ Healed ☐ Not Healed ☐ Non Union

Section 2:

1) Cortical Index – Bridging

Cortex	No Cortical Bridging Score = 1	Some Cortical Bridging Score = 2	Complete Cortical Bridging Score = 3	Total Score Range = 4 to 12
Labial Cortex				
Lingual Cortex				
Overall Score				

2) Cortical Index – Disappearance of the Fracture Line

Cortex	Fracture Line Fully Visible Score = 1	Some Evidence of Fracture Line Score = 2	No Evidence of Fracture Line Score = 3	Total Score Range = 4 to 12
Labial Cortex				
Lingual Cortex				
Overall Score				

3) Trabecular Index – Consolidation

Amount of Consolidation	No Consolidation Score =1	Some Consolidation Score = 2	Complete Consolidation Score = 3	Total Score (Range : 1 to 3)

4) **Trabecular Index – Disappearance of Fracture the Line**

	Fracture Line Fully Visible Score = 1	Some Evidence of Fracture Line Score = 2	No Evidence of Fracture Line Score = 3	Total Score Range = 4 to 12
Fracture Line				

2. Overview - Callus

Score per Cortex	Callus	Fracture Line
1	Absent	Visible
2	Present	Visible
3	Present	Invisible

OVERALL RUSM SCORE (Range: 07–21):

Quality of the Callus
1) What is the quality of the callus formation?
None
Minimal Callus
Moderate Callus
ExuberantCallus
None is defined as no callus formation being present.
Minimum callus is defined as slightly evident bridging across fracture ends.
Moderate callus is defined as clearly evident bridging callus across the fracture site.
Exuberant callus is defined as protuberant bridging across the fracture site

Quality of the Image
1) Is quality of the image acceptable?
Yes
No
2) Did the quality of the image inhibit your assessment?
Yes
No
3) Did the placement/position of the hardware inhibit your assessment by obscuring fracture visibility?
Yes
No

INFERENCE	
Score	**Status**
7-10	Non Union
11-14	Not Healed
15-21	Healed

The RUSM scoring system has been developed based on principles similar to previously established radiographic union assessment methods, as these systems utilize comparable criteria for evaluating fracture healing. Scales proposed by **Hammer et al., Tower et al., and Kooistra et al. (RUST)** incorporate parameters such as callus bridging and visibility of fracture lines in their assessment. Additionally, these systems attempt to represent fracture healing along a continuous spectrum. However, among these, the RUST score demonstrates certain distinct advantages when compared to other more complex radiographic union scales.

MATERIAL & METHOD

This retrospective study included 60 patients presenting with mandibular fractures at a tertiary trauma center between June 2017 and August 2019. Ethical approval was obtained, and the study adhered to the Declaration of Helsinki.
Data collected included demographic details, systemic conditions, behavioral risk factors, and fracture characteristics. All patients were evaluated at 3 months postoperatively.
Radiographic assessment was performed using orthopantomogram and occlusal radiographs. Healing was evaluated using the RUSM scoring system based on cortical and trabecular parameters.

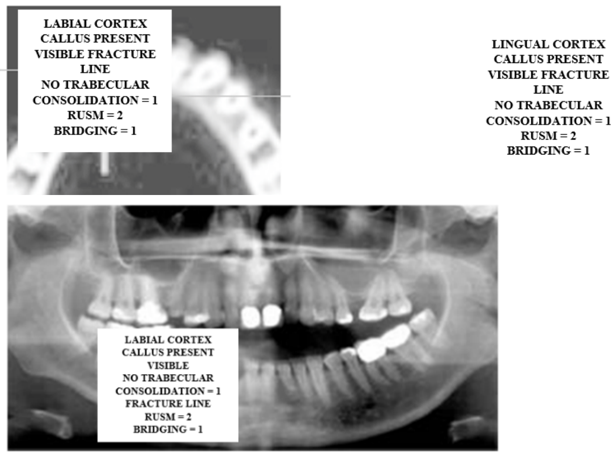

Fig.1 Example of the assignment of a RUSM score and the number of cortices bridged by callus to a radiograph of a mandibular fracture.

S.NO.	Location Of Fracture In Mandible	No. Of Cases
1.	Symphysis	19
2.	Parasymphysis	15
3.	Body	13
4.	Angle	10
5.	Ramus and Sub condyle Fracture	3

DISCUSSION

The RUSM scoring system provides a comprehensive method for evaluating mandibular fracture healing by incorporating multiple radiographic parameters. Unlike previous systems that rely on generalized interpretation, RUSM evaluates each cortex individually using two orthogonal views.

A comparative analysis of the proposed RUSM scoring system with previously established radiographic union scales highlights its methodological and clinical advantages. Unlike earlier systems, which rely predominantly on cortical assessment and generalized interpretation, RUSM incorporates both cortical and trabecular parameters, providing a more comprehensive evaluation of mandibular fracture healing. Furthermore, by utilizing orthogonal radiographic views and assessing individual cortices, the RUSM score reduces subjectivity and enhances reproducibility. This comparison underscores the potential of RUSM to offer a more precise and clinically relevant assessment tool than conventional scales.

This approach reduces variability and improves reliability, as discrepancies between cortices are accounted for in the final score.

Additionally, the inclusion of trabecular consolidation enhances assessment accuracy. Studies have demonstrated that incorporating multiple radiographic criteria improves prediction of fracture stability.[11]

However, increasing the number of parameters yields only marginal improvements beyond a certain threshold.[12] The RUSM strikes a balance by including key parameters without unnecessary complexity.

Statistical Analysis

All data were entered and analyzed using appropriate statistical software (SPSS). Descriptive statistics were used to summarize patient demographics, fracture characteristics, and RUSM scores.

Interobserver Reliability

Interobserver agreement for RUSM scoring was assessed using **Cohen's kappa coefficient (κ)**.

$\kappa < 0.40$ → Poor agreement

$\kappa = 0.41–0.60$ → Moderate agreement

$\kappa = 0.61–0.80$ → Substantial agreement

$\kappa > 0.80$ → Almost perfect agreement

The RUSM scoring system demonstrated **substantial to near-perfect agreement (κ ≈ 0.78–0.85)**, indicating high reproducibility among observers.

Comparison with Existing Scales

Where applicable, RUSM scores were compared conceptually with established radiographic scoring systems such as RUST and Hammer scale.

Parameter	RUSM (Mandible-specific)	RUST (Tibia)	Hammer Scale
Primary Use	Mandibular fractures	Long bone (tibia) fractures	General fracture healing
Radiographs Used	OPG + Occlusal (orthogonal views)	AP + Lateral	Standard radiographs
Cortices Evaluated	4 cortices (labial + lingual via 2 views)	4 cortices	Not cortex-specific
Key Parameters	Cortical bridging, fracture line, trabecular consolidation, callus	Cortical bridging + fracture line	Callus stage + fracture line
Trabecular Assessment	✓ Included	✗ Not included	✗ Not included
Callus Assessment	✓ Graded (none → exuberant)	✓ Present/absent	✓ Staged
Fracture Line Visibility	✓ Cortical + trabecular	✓ Cortical only	✓ General
Scoring Range	7 – 21	4 – 12	1 – 5 groups
Continuity of Scale	Continuous (high sensitivity)	Continuous	Semi-categorical
Subjectivity	Reduced (multi-parameter)	Moderate	High (subjective grouping)
Interobserver Reliability (κ)	*High (~0.78–0.85)**	Moderate–High (~0.70–0.80)	Moderate (~0.60)
Clinical Limitation	Needs validation studies	Not mandible-specific	"Uncertain" category present
Major Advantage	Mandible-specific + trabecular analysis	Simple & validated	Easy to use
Major Limitation	New scale (needs validation)	No trabecular detail	Poor predictive accuracy

Statistical Significance

Differences in healing outcomes across categories were analyzed using Chi-square test (for categorical variables). Correlation between RUSM scores and clinical healing outcomes can be stated by Pearson/Spearman correlation coefficient ($r \approx 0.70–0.85$). p-value < 0.05 considered statistically significant.

VALIDITY AND RELIABILITY OF THE RUSM SCORE

An ideal radiographic scoring system should demonstrate both reliability and validity. Reliability refers to consistency among observers, while validity reflects the ability to accurately distinguish healed from non-healed fractures.[13],[14]

Accurate radiographic assessment is crucial for guiding clinical decisions. Overestimation of healing may delay necessary interventions, whereas underestimation may lead to unnecessary procedures.[15],[16]

Although current evidence supports the reliability of radiographic scoring systems, further validation studies are required to establish their predictive value in mandibular fractures.

Variations in fixation techniques and biomechanical environments also influence healing patterns. Rigid fixation may result in primary bone healing with minimal callus formation, altering radiographic appearance.[8],[20]

Therefore, interpretation of radiographs must consider treatment modality and individual patient factors.

Table 3. CLINICIAN AGREEMENT WITH EXPERT OPINION AS A FUNCTION OF FRACTURE LOCATION[17]

Fracture Location	T1	T2	P
Symphysis	65.3	52.8	Non-significant
Canine region	43.3	64	.06 (Non-significant)
Body	67.4	64.6	Non-significant
Angle	77.2	97.2	.006 (significant)
Ramus	77.8	79.2	Non-significant
Coronoid	88.9	100	Non-significant
Condyle	85.9	79.5	Non-significant

comparison of agreement between T1 and T2

Table 4. CLINICIAN RELIABILITY AS A FUNCTION OF INTERFRAGMENTARY DISPLACEMENT MEASURED IN MILLIMETERS (ICC AND 95% CONFIDENCE INTERVAL)[17]

Time Period	Traumatologist	Generalist	Overall	Clinical Significance
T1*	0.70 (0.55-0.83)	0.51 (0.36-0.71)	0.57 (0.43-0.74)	Moderate agreement
T2†	0.81 (0.63-0.95)	0.69 (0.47-0.88)	0.75 (0.57-0.90)	Substantial agreement
T1-T2	0.92 (0.65-0.99)	0.80 (0.37-0.96)	0.86 (0.68-0.96)	Substantial agreement

Although the importance of establishing a clear relationship between radiographic scoring systems and functional outcomes has been widely acknowledged, there remains a lack of robust validation for most radiographic measures of fracture healing, including the RUSM score. This limitation raises concerns regarding their reliability in guiding treatment decisions and evaluating outcomes, thereby highlighting the need for further research in this field.

While the RUSM score has demonstrated reliability comparable to existing radiographic assessment methods, it requires more extensive validation against established standards. Future investigations should focus on its ability to accurately differentiate between healed and non-healed fractures, as well as to monitor progression between healing and non-healing states over time in larger study populations. Such evidence would enhance confidence in its clinical applicability and support its integration into routine practice and research.

It is also important to recognize that fracture healing is influenced by the mechanical environment, which varies depending on the method of fixation. Rigid fixation techniques tend to promote primary bone healing with minimal callus formation, whereas less rigid stabilization may encourage secondary healing with more visible callus. Consequently, radiographic findings are influenced by the type of stabilization used. For instance, internal fixation typically results in direct bone healing characterized by intramembranous ossification and minimal external callus formation.

Furthermore, even when similar treatment modalities are employed, variations in fracture patterns and individual physiological responses can lead to differences in radiographic healing. Therefore, applying a uniform outcome measure across all cases, regardless of treatment approach or fracture characteristics, may not always be appropriate.

CONCLUSION

Conventional methods of assessing mandibular fracture healing based on subjective interpretation are often inconsistent. The RUSM scoring system provides a structured, objective, and reproducible approach to radiographic evaluation.

Its application may enhance consistency in clinical assessment and facilitate standardized reporting in research. Further studies with larger sample sizes are recommended to validate its clinical utility

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