International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2025: 7.089

The Modified Gustilo-Ganga Multidomain Open Fracture Classification and Severity Score: A Literature-Based Proposal for Unified Descriptive and Prognostic Documentation of Open Extremity Fractures

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Abstract: ***Background**: The Gustilo-Anderson classification is the most widely used system for classifying open fractures, but it has limitations. Its interpretation can vary, and it does not fully assess tissue injury, contamination, vascular problems, bone loss, patient risk, or timing of treatment. The Ganga Hospital Open Injury Severity Score (GHOISS) is a validated tool for predicting outcomes in severe open tibial injuries, but it is not a general descriptive system. Today, orthoplastic care needs clear documentation of vascular status, contamination, timing, and readiness for reconstruction. **Objective**: To suggest a new open fracture classification system, based on the literature, that keeps the simplicity of Gustilo-Anderson, uses the prognostic strengths of GHOISS, and adds modern modifiers for complete documentation of extremity injuries. **Methods**: We reviewed key literature on Gustilo-Anderson, GHOISS, OTA/AO open fracture classification, mangled extremity scores, infection and nonunion risk, vascular injury, timing of antibiotics and debridement, and orthoplastic reconstruction. Based on this, we propose a new classification system and outline a plan for future validation. **Proposal**: The Gustilo-Ganga Open Fracture Classification and Severity Score (GG-OFCSS) records the anatomical site, Gustilo-Anderson grade, Ganga tissue score, and required modifiers for contamination, vascular status, nerve injury, and timing or system readiness. This approach produces a structured classification code rather than a single label. For example: Tibia shaft / GA-IIIB / GHOISS 16 / K2 V0 N1 T2. **Conclusion**: GG-OFCSS aims to integrate descriptive classification and prognostic scoring while retaining the Gustilo-Anderson and GHOISS systems. Prospective multicentre validation is needed to test reliability, infection rates, nonunion rates, flap needs, amputation rates, reoperation rates, and functional outcomes.*

Keywords: open fracture; Gustilo-Anderson; Ganga Hospital Open Injury Severity Score; fracture classification

1. Introduction

Open fractures are complicated injuries that involve unstable bones, contamination, soft-tissue damage, vascular problems, muscle loss, and patient factors. Treatment goals are to prevent infection, restore bone stability, provide lasting soft-tissue coverage, achieve bone healing, maintain limb function, and decide between limb salvage and amputation. Because early management involves many specialities, a classification system should cover more than just the wound. It should include biological severity, reconstructive needs, and treatment planning. The Gustilo-Anderson classification, first introduced in 1976 and updated in 1984 for Type III injuries, is still widely used for trauma communication, research, antibiotic protocols, and surgery decisions [1,2]. Its main strength is simplicity, but this also means some information is lost. One grade cannot clearly distinguish a clean, high-energy fracture with healthy soft tissue from a farm-contaminated fracture with muscle loss, an exposed tibia requiring a free flap, or a limb with vascular repair and ischemia. Known problems include only fair agreement between observers, subjective interpretation, and incomplete coverage of muscle injury, bone loss, contamination, patient risk, and changing tissue health [3-5].

Recent changes in open fracture classification show the need for a new approach. The OTA Open Fracture Classification introduced a system that considers skin injury, muscle injury, arterial injury, contamination, and bone loss as distinct areas [6-8]. The Ganga Hospital Open Injury Severity Score (GHOISS) also developed a tissue-based system for severe open tibial injuries, especially Type IIIB, by separately scoring covering tissues, bone, functional tissues, and other health factors [11-13]. Both systems show that open fracture severity is complex. This paper looks at whether the well-known Gustilo-Anderson system can be combined with the strengths of GHOISGustilo-Anderson and the details in modern orthoplastic care.

This paper presents the Gustilo-Ganga Open Fracture Classification and Severity Score (GG-OFCSS), a system based on the literature and designed as a structured, registry-friendly clinical language rather than a validated outcome prediction tool. The paper also describes a plan to test the system's reliability and its value for future prognostication. This is not a systematic review or meta-analysis. The literature reviewed includes the history of open fracture classification, reliability studies, current scoring systems, orthoplastic standards, timing of treatment, contamination, vascular injury, bone loss, nonunion, infection, and decisions about limb salvage. Sources include PubMed articles, major reviews, BOAST standards, and key works on Gustilo-Anderson, GHOISS, OTA-OFC, MESS/LEAP, antibiotic and debridement timing, irrigation, and early soft-tissue coverage. The proposed system follows five main design principles: (1) keep Gustilo-Anderson as the base language; (2) use GHOISS for tissue severity and prognosis; (3) separate descriptive classification from amputation prediction; (4) add required modifiers for factors that affect treatment and outcomes; and (5) make sure the final code can be used in operative notes, registries, audits, and multicentre studies, and existing Classification and Scoring Systems

Gustilo-Anderson classification

Gustilo and Anderson classified open fractures into Types I, II, and III, with Type III later subdivided into IIIA, IIIB, and IIIC because Type III injuries were too heterogeneous in severity and prognosis [1,2]. This remains the most recognised classification system. The distinction between IIIA and IIIB is clinically important because it separates severe injuries with adequate soft-tissue coverage from injuries requiring soft-tissue reconstruction. Type IIIC identifies open fractures with arterial injury requiring repair.

However, the Gustilo-Anderson classification is often given before full debridement, when it is still unclear how healthy the tissue is or how much bone is exposed. It does not give enough weight to contamination type, muscle death, bone loss, specific nerve injuries, timing of care, or patient risk. Studies show only moderate agreement between users, even with photos and surveys [3,4]. So, while the system is needed, it is not enough on its own.

OTA/AO multidomain classification

The OTA Open Fracture Classification was developed to improve objectivity by grading five pathoanatomic domains: skin injury, muscle injury, arterial injury, contamination, and bone loss [6]. Reliability testing demonstrated improved agreement compared with published Gustilo-Anderson reliability data, with particularly strong reliability for arterial injury and moderate-to-substantial agreement for skin injury, bone loss, and contamination [7]. Subsequent work suggested that OTA-OFC domains may correlate with treatment decisions, supporting a multidomain approach [8].

The conceptual limitatiThe main limitation of OTA-OFC is its limited adoption in daily practice due to its the main limitation of OTA-OFC is that it is not widely used in daily practice because it is complex. Although it provides more details than Gustilo-Awhile, retaining it it can be hard to use routinely. The proposed GG-OFCSS uses the multidomain approach but keeps the familiar Gustilo grade and the proven Ganga tissue-score framework, core injury to the cores, skeletal structures, and functional tissues, and adds comorbid factors that influence treatment and outcome [11,12]. It was designed primarily for decision-making on limb salvage versus amputation and for reconstructive planning, not as a universal anatomical classification. Reported thresholds generally identify injuries with a score of 14 or below as salvage-favourable, 17 or above as amputation-consideration injuries, and 15-16 as a grey zone requiring individualised judgement [12,13].

A 2023 systematic review and meta-analysis found high diagnostic accuracy for GHOISS at a threshold of 14 for predicting primary or secondary amputation in complex lower-limb injuries [13]. This provides strong justification for retaining GHOISS as the prognostic component of a combined system. However, GHOISS alone does not provide the common Gustilo label and does not explicitly encode anatomical site, contamination subtype, vascular category, nerve status, and treatment timing in a compact classification code.

Mangled extremity scores

Scores such as MESS, LSI, PSI, NISSSA, and others were developed to help determine what to do with severely injured limbs. However, large studies such as the Lower Extremity Assessment Project (LEAP) and subsequent research show that these scores do not predict long-term functional outcomes well after limb reconstruction [28,29]. They should not be the sole factor in deciding between amputation and salvage. The proposed GG-OFCSS is mainly a descriptive and prognostic documentation tool, not a simple rule for amputation.

Proposed Classification: Gustilo-Ganga Open Fracture Classification and Severity Score

Purpose

The GG-OFCSS is designed to answer three linked questions:

1) What is the open fracture category in familiar clinical language? This is recorded by the Gustilo-Anderson grade.
2) How severe is the injury biologically and reconstructively? This is recorded by GHOISS tissue-domain scoring.
3) Which modern treatment modifiers must be visible for decision-making, audit, and research? These are recorded as contamination, vascular, nerve, and timing modifiers.

The proposed system does not abolish the Gustilo-Anderson or GHOISS classifications. Instead, it explicitly combines them: Gustilo-Anderson provides the base classification, GHOISS provides the prognostic tissue score, and modifiers provide the missing treatment-critical descriptors.

Recommended format:

Anatomical site / GA grade / GHOISS total and tissue domains / K contamination / V vascular / N nerve / T timing-system modifier

Example: Tibia shaft / GA-IIIB / GHOISS 16: Cov4-Skel4-Fxn4-Com4 / K2 V0 N1 T2

This describes a severe open tibial shaft fracture that needs soft-tissue reconstruction, has high tissue severity, heavy contamination, no arterial repair, a nerve injury, and delayed or less-than-ideal timing or system factors.

Ganga tissue-score layer

The original GHOISS score should be recorded when the injury is a lower-limb open injury in which the score is applicable, especially severe tibial injuries. For non-tibial anatomical regions, the domains can still be recorded descriptively, but prospective validation is required before applying tibia-derived thresholds to all sites.

Recommended notation: GHOISS total: Cov-Skel-Fxn-Com.
Example: GHOISS 16: Cov4-Skel4-Fxn4-Com4.

For severe lower-limb injuries, a score of 14 or less usually supports limb salvage if resources and patient factors are suitable. A score of 17 or more means high risk, and primary amputation should be considered carefully. Scores of 15-16 are a grey area and need discussion with senior orthoplastic, vascular, and rehabilitation teams, as well as the patient and family. These cutoffs should not be used for upper limb, foot, hand, or children's injuries without further validation.

Mandatory modifiers

V: vascularity	V1	Abnormal pulse, abnormal ABI, vasospasm, intimal injury, or vascular concern not requiring repair.
V: vascularity	V2	Arterial injury requiring repair/shunt/bypass with viable limb.
V: vascularity	V3	Ischemic threatened limb, prolonged ischemia, failed revascularization, or combined vascular injury with questionable viability.
N: nerve	N0	No major named nerve deficit.
N: nerve	N1	Partial deficit, neuropraxia, or sensory/motor deficit without confirmed transection.
N: nerve	N2	Complete named nerve palsy, nerve discontinuity, or nonreconstructable nerve loss.
T: timing/system	T0	Antibiotics within 1 hour, appropriate transfer, early senior orthoplastic plan, definitive closure/coverage planned within accepted standards.
T: timing/system	T1	Minor delay in antibiotics, debridement, transfer, or coverage but no biological deterioration.
T: timing/system	T2	Delayed presentation/referral, repeated provisional debridement, delayed coverage, or system limitation increasing risk.
T: timing/system	T3	Missed injury, established infection, failed early coverage, or inadequate initial care requiring salvage revision.

Classification examples

Example 1: Forearm / GA-II / GHOISS not applicable / K0 V0 N0 T0. Interpretation: clean moderate open forearm fracture without neurovascular injury and timely treatment.

Example 2: Tibia shaft / GA-IIIB / GHOISS 13: Cov4-Skel3-Fxn3-Com3 / K1 V0 N0 T0. Interpretation: severe open tibial fracture requiring flap coverage, but salvage-favourable tissue score and optimal orthoplastic pathway.

Example 3: Tibia shaft / GA-IIIC / GHOISS 18: Cov5-Skel5-Fxn4-Com4 / K2 V3 N2 T2. Interpretation: limb-threatening ischemic open tibial injury with gross contamination, major tissue loss, nerve injury, and delayed/system-risk factors; amputation versus salvage requires multidisciplinary discussion.

2. Literature Support for Each Domain

Soft-tissue envelope and coverage

Soft-tissue injury is a key factor in infection, nonunion, the need for flaps, and the complexity of reconstruction. Gustilo IIIB is still important in practice because it indicates the need for soft-tissue reconstruction, which distinguishes it from IIIA. However, IIIB covers a wide range, from local flap coverage to free flaps, circumferential degloving, and bone loss. GHOISS gives more detail by scoring covering tissue separately. BOAST and orthoplastic literature stress the importance of early planned coverage and joint orthopaedic-plastic decision-making [11,12,15,20,21].

Muscle and functional tissue injury

Muscle health can change after injury and after debridement. Dead muscle increases infection risk and shows a high-energy injury. GHOISS specifically scores muscle and functional tissue injury, while OTA-OFC treats muscle injury as its own category [6,7,11]. Nerve injury affects final function and should not be hidden in an overall severity score. That is why GG-OFCSS records nerve injury separately, even though GHOISS also includes nerve, tendon, and muscle injury in its functional tissue score.

Contamination

Contamination is a key factor in infection risk, antibiotic selection, the need for rapid debridement, and whether repeat surgery is required. Wounds contaminated by farm, sewage, water, blasts, or delays are not the same as clean wounds of the same size. BOAST recommends immediate debridement for highly contaminated wounds from farms, water, or sewage [15]. Reviews show that contaminated wounds increase the risk of infection after open fractures [26,27]. So, a separate contamination modifier is necessary.

Vascular injury

Vascular injury is already included in Gustilo IIIC, but the simple label does not distinguish between abnormal blood flow without repair, repairable arterial injury, threatened or failed blood flow, or long-lasting ischemia. OTA-OFC found arterial injury to be one of the most reliable categories [7]. BOAST requires that the vascular status is documented and checked again after reduction or splinting [15]. So, the V modifier is justified both clinically and for reliability.

Bone loss and skeletal reconstruction

Comminution, segmental fractures, periosteal stripping, and major bone defects affect how the bone is fixed, whether an antibiotic spacer is used, the need for an induced membrane, bone transport, grafting, healing time, and the risk of additional surgery. Gustilo-Anderson only partly covers skeletal injury. Both the GHOISS skeletal score and the OTA bone loss category support separating the burden of skeletal reconstruction from wound size [6,8,12].

Timing and system readiness

Modern open fracture care depends not just on injury severity but also on the quality of the care process. Early antibiotics are always stressed; BOAST recommends giving intravenous antibiotics as soon as possible, ideally within 1 hour of injury [15]. Lack et al. found that delays in antibiotic and wound coverage both increase the risk of infection in Type III open tibia fractures [17]. Recent evidence suggests that the strict 6-hour rule for debridement is less important, but urgent debridement by the right team remains essential, especially for high-energy, contaminated, or vascularly compromised wounds [18,19]. Achieving final coverage within 72 hours remains a key goal in orthoplastic care [15,20,21]. The T modifier includes these changeable care pathway factors that affect outcomes but are not part of older classification systems.

Host factors

A patient's biology affects infection risk, bone healing, and the success of reconstruction. Conditions like diabetes, smoking, obesity, multiple injuries, vascular disease, kidney failure, and immunosuppression are often linked to problems after open fractures [26,27]. GHOISS already includes these comorbid factors, so GG-OFCSS suggests recording the GHOISS comorbid score rather than creating a separate host domain. If GHOISS does not apply, a host-risk modifier could be added in future studies.

Clinical Use and Treatment Implications

The proposed code is not meant to decide treatment automatically, but to help guide structured team decisions. For example, a GA-IIIB injury with GHOISS 12, K0, V0, N0, T0 is very different from a GA-IIIB injury with GHOISS 17, K2, V2, N2, T2. The first case may be suitable for early fixation and flap coverage, while the second may need staged debridement, input from several specialities, discussion about amputation risk, and early rehabilitation planning.

- Emergency department: provisional GA grade, K, V, N, and T0/T1 risk should be recorded after initial examination and wound photography.
- Operating theatre after debridement: final GA grade, GHOISS tissue score, contamination grade, vascular status, nerve status, and timing modifier should be confirmed.
- Postoperative plan: the code should trigger orthoplastic review, vascular plan, infection prophylaxis pathway, flap/bone reconstruction plan, and audit entry.
- Registry/research: each domain can be analysed independently against deep infection, nonunion, flap failure, amputation, unplanned reoperation, time to union, and patient-reported outcomes.

Validation Strategy

Since GG-OFCSS is a proposed classification, it needs to be validated before any claims of superiority can be made. A step-by-step validation program is recommended.

Phase 1: Expert consensus

A Delphi process should include orthopaedic trauma surgeons, plastic/reconstructive surgeons, vascular surgeons, rehabilitation specialists, infection specialists, and trauma registry representatives. The aim should be to refine definitions, remove redundant domains, confirm the coding syntax, and agree on the minimum photographic/operative information required for scoring.

Phase 2: Reliability testing

A video- and image-based interobserver study should compare Gustilo-Anderson alone, GHOISS alone where applicable, OTA-OFC, and GG-OFCSS. Raters should include consultants and trainees from orthopaedics and plastic surgery. Outcomes should include overall agreement, weighted kappa, intraclass correlation for GHOISS total, and domain-specific reliability. Reliability should be tested before and after a brief training module.

Phase 3: Prospective multicentre outcome validation

A prospective registry should enrol adult and paediatric open extremity fractures. Key outcomes should include deep infection/fracture-related infection, nonunion/delayed union, flap requirement, flap failure, bone reconstruction, amputation, unplanned reoperation, length of stay, time to union, return to work, and patient-reported outcome measures. Models should test whether GG-OFCSS improves prediction beyond Gustilo-Anderson alone and beyond GHOISS alone in tibial injuries. Appropriate methods include multivariable logistic regression, ordinal regression, survival analysis for union, calibration curves, decision-curve analysis, and internal/external validation.

Phase 4: Implementation and audit

Implementation should check if the classification improves documentation of nerves and blood vessels, timing of antibiotics, planning for debridement, orthoplastic involvement, flap timing, and the quality of registry data. A classification system is only useful if it helps communication and decision-making without making things more complicated than needed.

3. Discussion

The central problem with open fracture classification is that no single system meets all the needs for communication, consistency, prognosis, treatment planning, and audit. Gustilo-Anderson is simple and widely used, but it is not complete. GHOISS is very useful for severe open tibial injuries but is primarily a prognostic score rather than a general classification. OTA-OFC is detailed and reliable, but not as familiar in daily use. The proposed GG-OFCSS aims to bring together the strengths of these systems, not to replace them.f layers. The Gustilo grade remains the label; GHOISS becomes the reconstructive severity score; K, V, N, and T modifiers make explicit the variables most often under-described in routine notes. This structure allows a clinician to retain the phrase "Gustilo IIIB" without losing the details that determine infection risk, flap planning, vascular sequencing, functional prognosis, and treatment delay.

The system also addresses a common criticism of severity scores: the risk of relying on a single number to make a final decision about amputation. GG-OFCSS should not be used as the only rule for amputation. Even GHOISS cutoffs should be considered along with patient health, blood flow, surgical skill, rehab resources, patient preferences, and expected function. This view matches evidence that lower-limb injury scores alone do not predict recovery well after reconstruction [28,29].

Another benefit is that the system is ready for use in registries. Modern trauma systems need to track antibiotic timing, transfers, debridement, orthoplastic coverage, and outcomes. A code like Tibia shaft / GA-IIIB / GHOISS 16 / K2 V0 N1 T2 is much easier to analyse than just saying "bad open tibia fracture" or even "Gustilo IIIB." It allows for both detailed and overall severity analysis.

4. Limitations

This paper suggests a system based on the literature and does not include new patient data, reliability data, or outcome validation. The system might be too complex for settings with fewer resources unless simpler forms or mobile tools are made. GHOISS cutoffs work best for severe open tibial injuries and should not be used for other injuries without more validation. The T modifier combines biological and system factors for audit and should not be seen as solely indicating injury severity. Experts need to agree on modifier definitions before using them in practice.

5. Conclusion

The Gustilo-Ganga Open Fracture Classification and Severity Score is proposed as a combined descriptive and prognostic system for open extremity fractures. It keeps Gustilo-Anderson as the main language, adds Ganga Hospital tissue scoring for reconstructive severity and prognosis, and includes required modifiers for contamination, blood flow, nerve injury, and timing or system readiness. The system is supported by literature on Gustilo-Anderson's limits, GHOISS's predictive value, OTA-OFC's reliability, and modern orthoplastic standards. It needs to be validated in multicentre studies before it can be recommended as a standard classification.

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Table 1: Conceptual comparison of existing systems and proposed GG-OFCSS

System	Primary strength	Primary limitation	Role in proposed system
Gustilo-Anderson	Simple, widely recognized, linked to treatment pathways	Single grade; subjective; incomplete representation of contamination, muscle, bone loss, host and timing	Retained as the base grade
OTA-OFC	Multidomain pathoanatomic structure; improved reliability	More complex and less universally used in daily communication	Provides domain logic for modifiers
GHOISS	Tissue-specific prognosis; limb salvage and reconstruction planning, especially severe tibial injuries	Primarily a lower-limb/tibial prognostic score rather than universal classification	Integrated as severity score layer
MESS/other mangled limb scores	Quick trauma severity assessment	Limited prediction of functional outcome; risk of oversimplified amputation decisions	Not used as core system; may be recorded separately
GG-OFCSS	Combines familiar grade, tissue score, and modern modifiers	Conceptual until validated prospectively	Proposed unified documentation and research framework

Proposed Classification: Gustilo-Ganga Open Fracture Classification and Severity Score

Purpose

The GG-OFCSS is designed to answer three linked questions:
1) What is the open fracture category in familiar clinical language? This is recorded by the Gustilo-Anderson grade.
2) How severe is the injury biologically and reconstructively? This is recorded by GHOISS tissue-domain scoring.
3) Which modern treatment modifiers must be visible for decision-making, audit, and research? These are recorded as contamination, vascular, nerve, and timing modifiers.

The proposed system does not abolish Gustilo-Anderson or GHOISS. Instead, it explicitly combines them: Gustilo-Anderson supplies the base classification, GHOISS supplies the prognostic tissue score, and modifiers supply the missing treatment-critical descriptors.

Coding of the Fracture:

Recommended format:
Anatomical site / GA grade / GHOISS total and tissue domains / K contamination / V vascular / N nerve / T timing-system modifier

Example: Tibia shaft / GA-IIIB / GHOISS 16: Cov4-Skel4-Fxn4-Com4 / K2 V0 N1 T2

This communicates a severe open tibial shaft fracture requiring soft-tissue reconstruction, with high tissue severity, gross contamination, no arterial repair, a nerve deficit, and delayed or suboptimal timing/system factors.

Table 2: Proposed GG-OFCSS coding structure

Component	Code	Definition	Clinical purpose
Anatomical site	A	Bone and segment: tibia shaft, distal femur, forearm, foot, hand, etc.	Allows registry stratification and site-specific prognosis
Gustilo-Anderson	GA	I, II, IIIA, IIIB, IIIC	Preserves common international language
Ganga tissue score	GHOISS	Covering tissue, skeletal tissue, functional tissue, comorbid factors	Quantifies reconstructive severity and salvage burden
Contamination	K0-K3	Clean to established/high-risk contamination	Guides urgency, antibiotic strategy, serial debridement and infection risk

Vascularity	V0-V3	Normal perfusion to ischemic limb/revascularization	Identifies limb threat and vascular sequence
Nerve status	N0-N2	No major injury to complete named nerve injury	Captures functional prognosis
Timing/system readiness	T0-T3	Early integrated care to missed/infected/delayed referral	Captures modifiable treatment-system risk

Table 3: Gustilo-Anderson base grade retained in GG-OFCSS

Grade	Definition in combined system
GA-I	Low-energy open fracture; clean wound; minimal soft-tissue injury; simple fracture pattern.
GA-II	Open fracture with wound greater than Type I and moderate soft-tissue injury, without extensive flap, avulsion, periosteal stripping, or major contamination.
GA-IIIA	High-energy or severe open fracture with adequate viable soft-tissue coverage after debridement.
GA-IIIB	Open fracture with extensive soft-tissue loss, periosteal stripping, exposed bone/tendon/implant, or need for local/regional/free flap coverage.
GA-IIIC	Open fracture associated with major arterial injury requiring repair or revascularization, irrespective of soft-tissue grade.

Mandatory modifiers

Table 4: Proposed mandatory modifiers

Modifier	Grade	Definition
K: contamination	K0	Clean wound; minimal visible contamination after exposure.
K: contamination	K1	Roadside/soil contamination that is removable at first debridement.
K: contamination	K2	Gross contamination, farm injury, sewage, aquatic exposure, embedded organic material, blast or ballistic contamination.
K: contamination	K3	Delayed contaminated wound, devitalized contaminated tissue, or established infection at presentation/referral.
V: vascularity	V0	Normal perfusion and pulses or Doppler signals.
V: vascularity	V1	Abnormal pulse, abnormal ABI, vasospasm, intimal injury, or vascular concern not requiring repair.
V: vascularity	V2	Arterial injury requiring repair/shunt/bypass with viable limb.
V: vascularity	V3	Ischemic threatened limb, prolonged ischemia, failed revascularization, or combined vascular injury with questionable viability.
N: nerve	N0	No major named nerve deficit.
N: nerve	N1	Partial deficit, neuropraxia, or sensory/motor deficit without confirmed transection.
N: nerve	N2	Complete named nerve palsy, nerve discontinuity, or nonreconstructable nerve loss.
T: timing/system	T0	Antibiotics within 1 hour, appropriate transfer, early senior orthoplastic plan, definitive closure/coverage planned within accepted standards.
T: timing/system	T1	Minor delay in antibiotics, debridement, transfer, or coverage but no biological deterioration.
T: timing/system	T2	Delayed presentation/referral, repeated provisional debridement, delayed coverage, or system limitation increasing risk.
T: timing/system	T3	Missed injury, established infection, failed early coverage, or inadequate initial care requiring salvage revision.

Additional Tables and Figures for Submission

Table 5: Literature-to-domain evidence map for the proposed modifiers

Domain	Literature-based rationale	Implementation in GG-OFCSS	Key references
Soft-tissue envelope / coverage	Gustilo IIIB and orthoplastic literature show that exposed bone, periosteal stripping, and flap requirement define a distinct reconstructive problem.	Keep GA-IIIB but document coverage need and GHOISS covering-tissue score.	[2,11,20,21,24]
Muscle / functional tissue	Devitalized muscle and functional-tissue loss influence infection, debridement extent, flap selection, limb function, and salvage feasibility.	Use GHOISS functional score and N modifier.	[11-14,23,24]
Contamination	Degree and type of contamination influence antibiotic selection, repeat debridement, infection risk, and urgency.	Use K0-K3 as mandatory code.	[15-19,22-27]
Vascular injury	GA-IIIC recognizes arterial repair, but a graded vascular axis captures abnormal perfusion, repairable injury, and ischemic threatened limb.	Use V0-V3 and document ischemia time separately when available.	[2,15,16,29-31]
Bone loss / skeletal injury	Comminution, segmental defect, periosteal stripping, and critical bone loss determine fixation, transport, spacer, grafting, and nonunion risk.	Record GHOISS skeletal score; add site-specific bone defect details.	[6-8,11,24,28]
Timing / treatment pathway	Early antibiotics, timely debridement, specialist combined planning, and definitive coverage are repeatedly emphasized in modern open-fracture care.	Use T0-T3 as a modifiable care-process and referral-delay modifier.	[15-21,23-25]
Host biology	Smoking, diabetes, vascular disease, obesity, renal disease, immunosuppression, polytrauma, and shock affect infection, union, and reconstruction success.	Retain GHOISS comorbid domain and record explicit host risk in registry dataset.	[26-28]

Table 6: Prospective validation strategy for GG-OFCSS

Validation target	Suggested design	Primary test	Preferred statistics/endpoints
Face and content validity	Delphi panel of trauma, orthoplastic, vascular, hand, foot/ankle, and infection specialists	Agreement on domains, grades, wording, and examples	Content validity index; predefined consensus threshold >=80%
Interobserver reliability	Multicentre case-vignette and intraoperative-photo study	Independent coding by trainees and consultants	Weighted kappa / Gwet AC; compare GG-OFCSS domains with GA alone
Construct validity	Prospective cohort of open extremity fractures	Association of higher modifier burden and GHOISS with injury severity and treatment complexity	Trend tests; regression against flap requirement, debridement count, fixation complexity
Predictive validity - infection	Prospective registry	Deep infection / fracture-related infection at 90 days and 1 year	AUC, calibration, decision-curve analysis versus GA and GHOISS alone
Predictive validity - union	Prospective registry	Delayed union, nonunion, bone graft/transport/induced membrane requirement	Time-to-union analysis; Cox or competing-risk models
Predictive validity - salvage	Severe lower-limb subgroup	Primary/secondary amputation, limb salvage, unplanned reoperation	Compare GHOISS alone versus combined code and modifiers
Implementation study	Pilot registry and operative-note template	Completeness, coding time, missing domains, user acceptability	Feasibility endpoints and audit compliance

Table 7: Example case coding using GG-OFCSS

Case	Clinical scenario	GG-OFCSS code	Interpretation
1	Clean open forearm shaft fracture	Forearm / GA-II / GHOISS not applicable / K0 V0 N0 T0	Moderate open fracture; no high-risk modifier; standard debridement and stabilization pathway.
2	Open tibial shaft fracture with exposed bone needing flap	Tibia shaft / GA-IIIB / GHOISS 13: Cov4-Skel3-Fxn3-Com3 / K1 V0 N0 T0	Severe open tibial fracture with flap need but lower modifier burden; salvage likely if resources permit.
3	Farm-contaminated tibial fracture with segmental bone loss	Tibia shaft / GA-IIIB / GHOISS 16: Cov4-Skel5-Fxn3-Com4 / K2 V0 N0 T1	High skeletal and contamination burden; plan staged debridement, fixation, coverage, and bone reconstruction.
4	Ischemic open tibia with complete peroneal palsy	Tibia shaft / GA-IIIC / GHOISS 18: Cov5-Skel5-Fxn4-Com4 / K2 V3 N2 T2	Limb-threatening vascular injury; salvage versus amputation requires vascular, orthoplastic, and patient-centred discussion.

Table 8: Recommended registry variables for future validation

Category	Minimum variables	Reason for inclusion
Patient/host	Age, sex, diabetes, smoking, vascular disease, renal disease, immunosuppression, polytrauma, shock	Adjustment for infection, union, flap failure, and salvage outcomes
Injury	Mechanism, site, side, segment, GA grade, GHOISS domains, K/V/N/T modifiers	Primary classification and risk stratification
Timing	Time to antibiotics, time to debridement, time to revascularization, time to coverage, transfer delay	Care pathway audit and modifiable risk analysis
Treatment	Fixation method, vascular procedure, flap/coverage method, antibiotic strategy, repeat debridement, bone reconstruction	Defines treatment burden and reconstructive sequence
Outcomes	Deep infection/FRI, flap failure, nonunion, amputation, reoperation, union time, return to work/function, PROMS	Validation endpoints for the proposed system

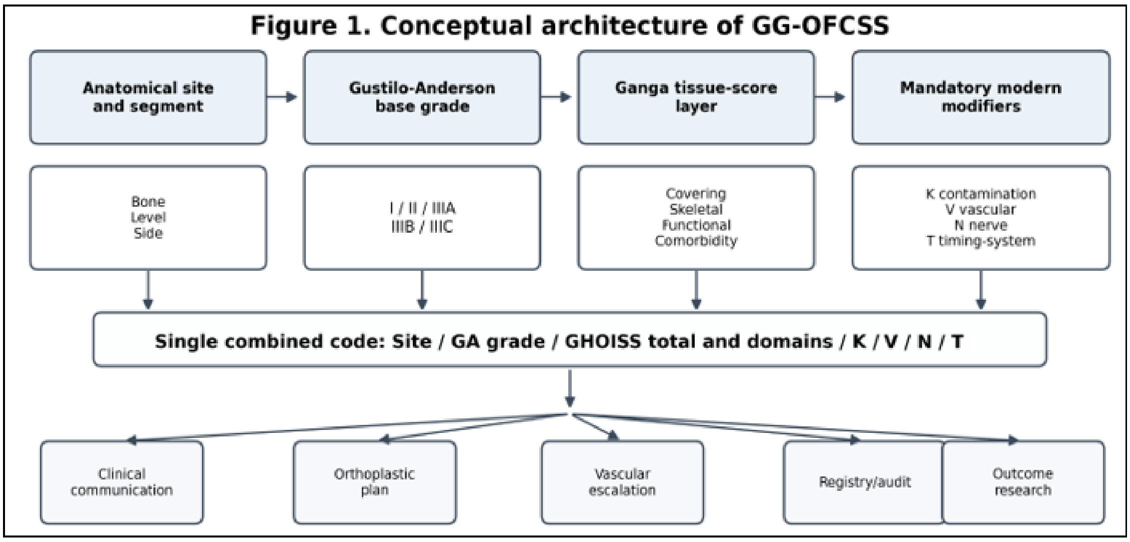

Figure 1: Conceptual architecture of the Gustilo-Ganga Open Fracture Classification and Severity Score

Legend: The base Gustilo-Anderson grade provides common language, the Ganga Hospital score provides tissue-domain prognostic severity, and K/V/N/T modifiers add contamination, vascular, neurological, and timing-system information.

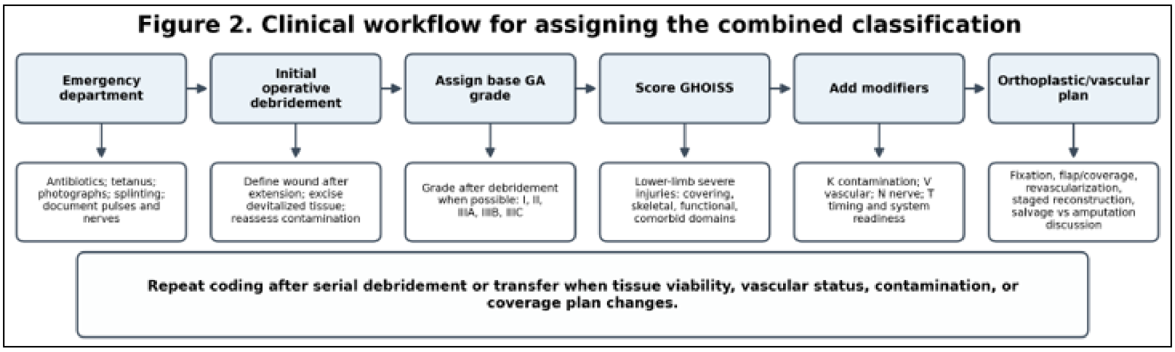

Figure 2: Clinical workflow for assigning GG-OFCSS

Legend: Coding should begin at presentation but should be finalized after debridement when the real soft-tissue envelope, contamination, vascular status, and reconstructive plan are evident. Re-coding after serial debridement or transfer is appropriate.

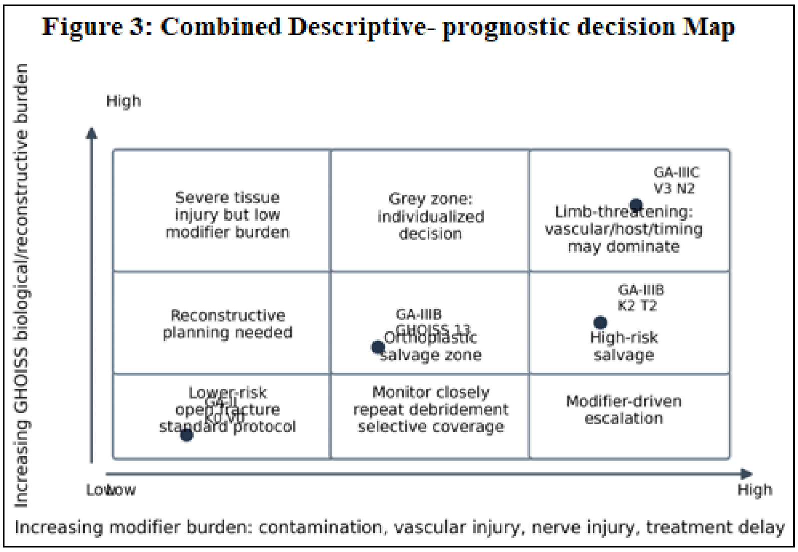

Figure 3. Decision map illustrating the descriptive-prognostic function of GG-OFCSS.

Legend: The system should not be used as an automatic amputation rule. It separates biological/reconstructive burden from modifier burden so that high-risk cases are explicitly identified for orthoplastic, vascular, and patient-centred decision-making.

Paper ID: SR26704092844 DOI: https://dx.doi.org/10.21275/SR26704092844