

Patient-Specific, CAD/CAM-Designed and 3D-Printed Fixation Plates in the Management of Acute Traumatic Mandibular Fractures: A Scoping Review and Evidence-Gap Analysis

A protocol-informed scoping synthesis prepared in accordance with PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews)

DR SUBHA SANDHYA SARANGI, DR SANTOSH KUMAR SUBUDHI, DR ANWESHA GARNAIK,

DR MARKANDAIYA ACHARYA

Abstract—

Background: Additive manufacturing (3D printing) and computer-aided design/computer-aided manufacturing (CAD/CAM) have enabled individually customized, patient-specific fixation plates for craniomaxillofacial surgery. Their role in oncologic mandibular reconstruction is well described, but their use in acute traumatic mandibular fractures — a distinct clinical population with different biomechanics, healing environment, and urgency of care — has not been mapped as a dedicated body of evidence.

Objectives: To map the current landscape of clinical evidence on patient-specific, CAD/CAM-designed and/or 3D-printed fixation plates for acute traumatic mandibular fractures; to determine whether this question has already been adequately answered by existing systematic reviews; and to identify a defensible, literature-supported research gap to guide a future systematic review and meta-analysis.

Methods: A structured search of PubMed-indexed literature and the ClinicalTrials.gov registry was conducted, using a Boolean strategy combining concepts of mandibular fracture, patient-specific/customized terminology, 3D-printing/CAD-CAM terminology, and plate/fixation terminology. Studies involving oncologic reconstruction, free-flap reconstruction, orthognathic surgery, animal models, and pure finite-element or cadaveric work were excluded from the primary trauma synthesis and, where relevant, described separately. Existing systematic reviews addressing overlapping questions were identified and compared against the proposed review question to establish novelty. This is a scoping-level landscape assessment; it does not report pooled statistical estimates and is not a substitute for a full multi-database systematic search.

Results: One recent systematic review with meta-analysis (Nguyen et al., 2025) was identified that reports quantitative outcomes for patient-specific implants versus stock plates in mandibular fractures, but as one of four pooled surgical indications (mandibular reconstruction, non-cleft orthognathic surgery, cleft orthognathic surgery, and mandibular fractures) rather than as a dedicated trauma-focused synthesis. A small but growing primary-study base specific to trauma was identified, comprising at least one comparative study with randomized allocation, one randomized controlled trial, one retrospective case series, and several randomized controlled trials registered on ClinicalTrials.gov that are completed or nearing completion but not yet indexed as full-text publications. A separate systematic review addressing generic, non-customized "3D-shaped" (anatomically pre-formed) miniplates for condylar fractures was also identified and is distinguished from the patient-specific plate literature, since pre-formed geometric plates and truly individualized, patient-specific plates are frequently conflated in the literature despite representing different technologies.

Conclusions: The specific question of patient-specific/3D-printed plates in acute traumatic mandibular fractures is partially, but not fully, answered by existing literature. A dedicated, trauma-focused systematic review is justified, but is not yet well positioned for meta-analysis given the small number of published comparative studies; feasibility will improve materially once the identified 2025–2026 cohort of randomized controlled trials is published in full. A revised, trauma-restricted PICO question, PROSPERO registration, and a delayed or staged definitive search are recommended.

Registration: Not registered. This scoping synthesis is presented as a pre-registration feasibility and evidence-mapping exercise; a full systematic review is planned for PROSPERO registration once the eligibility criteria below are finalized and a formal multi-database search is executed.

Index Terms—mandibular fracture; patient-specific implant; three-dimensional printing; additive manufacturing; computer-aided design; fracture fixation, internal; scoping review

I. INTRODUCTION

Mandibular fractures are among the most common injuries encountered in oral and maxillofacial and craniomaxillofacial trauma practice, and open reduction and internal fixation (ORIF) with titanium miniplates remains the standard of care for displaced or unstable fractures. Conventional fixation requires intraoperative contouring of stock plates to the patient's bony anatomy — a process that is time-consuming, introduces residual mechanical stress into the plate at the bend, and depends heavily on surgeon experience for an accurate fit.

The introduction of computer-aided design and computer-aided manufacturing (CAD/CAM), together with additive manufacturing (three-dimensional, or 3D, printing), has made it possible to design and fabricate fixation plates that are individually matched to a patient's own anatomy before surgery, using virtual surgical planning on preoperative computed tomography data. These patient-specific plates may be produced either by true additive manufacturing (selective laser melting or similar 3D-printing processes, typically in titanium or polyetheretherketone [PEEK]) or by CAD/CAM milling of a pre-designed geometry; the two manufacturing routes are not interchangeable, since additive manufacturing avoids the intraoperative bending altogether, while milled or pre-bent plates may still be adapted to a 3D-printed anatomical model without being manufactured additively.

The clinical rationale for patient-specific plates in craniomaxillofacial surgery is best established in oncologic mandibular reconstruction and free-flap fixation, where individualized reconstruction plates and miniplates have been associated with improved surgical precision and, in some series, reduced complication rates. Whether these advantages translate to the acute trauma setting — where fracture geometry is simpler, healing is generally unimpaired by prior irradiation or tumor resection, and urgency of care limits the time available for planning and fabrication — is a distinct clinical question that has received comparatively less dedicated synthesis.

A recently published systematic review and meta-analysis (Nguyen et al., 2025) compared patient-specific implants against stock plates across four craniomaxillofacial surgical indications, including mandibular fractures, and reported that patient-specific implants improved occlusal function at three months but did not significantly improve fracture healing or reduce complications in the trauma subgroup. Because this finding sits within a broader, four-indication review rather than a dedicated trauma-focused synthesis, and because a discrete cohort of trauma-specific randomized controlled trials has emerged in the literature and trial registries since that review's search was conducted, the present work was undertaken to (a) map the currently available trauma-specific evidence, (b) formally assess whether the research question is already adequately answered, and (c) define a literature-supported gap and a revised PICO question to guide a future, dedicated systematic review and meta-analysis.

II. METHODS

2.1 Design

This work is reported as a scoping review, using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) framework, rather than as a completed systematic review with meta-analysis. This design was chosen deliberately: the primary trauma-specific comparative literature is still small and includes several randomized controlled trials that are registered as completed but not yet available as indexed full-text publications, making a defensible quantitative pooled synthesis premature. Reporting pooled effect estimates at this stage would misrepresent the maturity of the evidence base.

2.2 Eligibility criteria

Population: adult patients with acute traumatic mandibular fractures requiring surgical fixation.

Intervention: patient-specific fixation plates individually designed via virtual surgical planning, manufactured either by additive manufacturing (3D printing, titanium or PEEK) or by CAD/CAM milling.

Comparator: conventional fixation using hand-contoured titanium miniplates or generic, non-customized pre-shaped plates.

Outcomes: postoperative malocclusion, hardware/fixation failure, surgical-site infection, fracture healing/union (primary); operative time, pain, patient satisfaction, mouth opening, neurosensory disturbance, plate-removal rate, accuracy of reduction, hospital stay, and cost (secondary).

Exclusions: oncologic mandibular reconstruction, free-flap reconstruction (unless fracture-specific data were separately extractable), orthognathic surgery, prophylactic or pathologic-fracture-prevention plating without a traumatic fracture, animal studies, and pure finite-element or cadaveric studies (the latter two are described narratively as a distinct evidence stratum rather than integrated into the clinical synthesis).

2.3 Information sources and search strategy

PubMed-indexed literature was searched, with cross-referencing against ScienceDirect, SpringerLink, PubMed Central, and the ClinicalTrials.gov trial registry. The search combined four concept blocks — mandibular fracture terminology; patient-specific/customized terminology; 3D-printing/CAD-CAM/additive-manufacturing terminology; and plate/fixation terminology — joined with the Boolean AND operator, with synonym expansion within each block joined by OR:

("Mandibular Fractures"[Mesh] OR mandibular fracture[tiab] OR jaw fracture*[tiab]) AND (patient-specific[tiab] OR custom-made[tiab] OR customized[tiab] OR individualized[tiab] OR bespoke[tiab]) AND ("3D printed"[tiab] OR "three-dimensional printing"[tiab] OR "additive manufacturing"[tiab] OR "computer-aided design"[tiab] OR "CAD/CAM"[tiab])*

OR "Printing, Three-Dimensional"[Mesh]) AND (plate*[tiab] OR miniplate*[tiab] OR osteosynthesis[tiab] OR "internal fixation"[tiab] OR "Fracture Fixation, Internal"[Mesh])

This scoping synthesis was informed by that strategy but was not executed as a full, exportable, de-duplicated multi-database search; accordingly, no formal PRISMA flow diagram with total-records-identified, duplicates-removed, and full-text-screened counts is reported. A definitive systematic review should re-run this string (and the Embase/Scopus/Cochrane equivalents) in full before PROSPERO registration and before undertaking meta-analysis.

2.4 Existing-review search

A parallel search for existing systematic reviews, meta-analyses, and scoping reviews addressing overlapping questions was conducted, to determine whether the proposed review question had already been adequately answered (novelty assessment).

III. RESULTS

3.1 Existing systematic reviews addressing overlapping questions

Table 1 summarizes the systematic reviews identified that overlap, to varying degrees, with the proposed question.

TABLE 1: EXISTING SYSTEMATIC REVIEWS ADDRESSING OVERLAPPING QUESTIONS

Review	Year	Population / question	Relevant finding	Overlap
Nguyen AT, Li RA, Gosain AK, Galiano RD. Skeletal Fixation in Craniomaxillofacial Surgery: A Systematic Review and Meta-Analysis of Patient-Specific Implants Versus Stock Plates. J Craniofac Surg. 2025;36(8):2722-2727.	2025	20 studies / 1,066 patients across mandibular reconstruction, non-cleft orthognathic surgery, cleft orthognathic surgery, and mandibular fractures	In the mandibular-fracture subgroup: patient-specific implants improved occlusal function at 3 months (SMD 1.88, 95% CI 1.11–2.65, $P<0.0001$) but did not significantly improve fracture healing (RR 1.11, $P=0.30$) or reduce complications (RR 0.67, $P=0.64$).	High — directly on-topic but trauma is one of four pooled indications, not the primary focus
The Use of Titanium 3D Mini-Plates in the Surgical Treatment of Fractures of the Mandibular Condyle: A Systematic Review and Meta-Analysis of Clinical Trials. 2021.	2021	13 trials of anatomically pre-formed ("3D-shaped") condylar miniplates	Reoperation and screw-loosening correlate with plate/screw-hole design features.	Low — pre-formed geometric plates, not individually patient-specific plates; frequently conflated in the literature with the present topic
Complications after different methods for fixation of mandibular angle fractures: network meta-analysis of randomized controlled trials. PROSPERO CRD42020160829.	2021	Six angle-fracture fixation methods, one arm labeled "3D" plate, 3,584 records screened	Network comparison of complication rates across fixation configurations.	Low — "3D" again denotes pre-shaped plate geometry, not patient-specific manufacturing
Effective strategies in the management of anterior mandibular fractures: a comprehensive systematic review. PROSPERO CRD42024413746.	2024	Anterior mandibular fracture fixation modalities broadly (lag screws, miniplates, 3D-printed plates, resorbable plates, endoscopic fixation)	3D-printed plates discussed as one modality among several; not a dedicated comparative synthesis.	Moderate — anatomically restricted to the anterior mandible and not primarily focused on patient-specific plates
The Effectiveness of Three-Dimensional Osteosynthesis Plates versus Conventional Plates for the Treatment of Skeletal Fractures.	2023	Preformed/patient-specific vs. conventional plates across all skeletal fracture sites	Broad, multi-anatomic-site synthesis; not mandible-specific.	Moderate — same general question, different anatomic scope

3.2 Trauma-specific primary evidence identified

Table 2 summarizes the trauma-specific (non-oncologic, non-reconstructive) primary studies and registered trials identified. This is a landscape map of the studies located through this scoping search, not an exhaustive, de-duplicated systematic count; a formal multi-database search is required before PRISMA-level totals can be reported.

TABLE 2: TRAUMA-SPECIFIC PRIMARY EVIDENCE IDENTIFIED

Source	Year	Design / status	Fracture site	Intervention vs. comparator
Precision of patient-specific screw-hole-locating surgical guide and pre-bent plate osteosynthesis versus classical workflow in management of Brown Class III mandibular fracture. Maxillofac Plast Reconstr Surg.	2025	Randomized controlled trial, n=26, published	Brown Class III (angle/body)	Patient-specific surgical guide + pre-bent plate vs. classical (freehand) workflow
Digital technology revolutionizing mandibular fracture treatment: a comparative analysis of patient-specific plates and conventional titanium plates. Clin Oral Investig.	2024	Comparative study with randomized allocation, n=20, published	Mixed sites	Patient-specific plates (virtual surgical planning) vs. conventional titanium plates

Cho RY, Byun SH, Park SY, On SW, Kim JC, Yang BE. Patient-specific plates for facial fracture surgery: a retrospective case series. J Dent. 2023;137:104650.	2023	Retrospective case series, published	Facial fractures including mandible	Patient-specific plates (single-arm)
Custom-Made 3D PEEK Plates Versus 3D Titanium Plates in Mandibular Angle Fracture Fixation. ClinicalTrials.gov NCT07156812.	2025–2026	RCT, Phase 4, status: completed; full-text results not yet indexed	Angle	Custom-made 3D PEEK plate vs. pre-bent 3D titanium plate (n=18, 9 per arm)
Evaluation of Accuracy of Patient-Specific Plate for Reduction and Fixation of Mandibular Angle Fracture. ClinicalTrials.gov NCT07231042.	2024–2025	Interventional study, status: completed October 2025; full-text results not yet indexed	Angle	Patient-specific plate (accuracy outcome)
Patient-Specific 3D Titanium Plate Versus Standard Two Mini-Plates in the Fixation of Mandibular Angle Fractures. ClinicalTrials.gov NCT07390734.	2025–2026	RCT, status: active, not recruiting	Angle	Patient-specific 3D titanium plate vs. two conventional miniplates
Comparative Evaluation of 3D-Printed (PEEK) Plates Versus Titanium 3D Plate for Fracture Fixation at the Mandibular Angle. ClinicalTrials.gov NCT07520227.	2026	RCT, n=22, status: registered/recruiting	Angle	Patient-specific CAD/CAM PEEK plate vs. conventional 3D titanium plate
Precision of Patient-Specific 3D-Printed Occlusal Stent, Surgical Guide, and Titanium Plates in Management of Mandibular Fracture. ClinicalTrials.gov NCT07499726.	2025–2026	Prospective case series, n=6, status: registered	Isolated mandibular fractures	Patient-specific occlusal stent, guide, and titanium plate (single-arm)

A distinct, adjacent stratum of finite-element and biomechanical studies of patient-specific implants for mandibular condyle fracture fixation was also identified (e.g., Aquilina et al., Craniomaxillofac Trauma Reconstr, 2014), but is more than a decade old and condyle-specific; it is not integrated into the clinical-outcomes synthesis above but is noted as background evidence for the biomechanical rationale of patient-specific plate design.

3.3 Manufacturing-route distinction

Across the identified literature, three related but distinct device categories are frequently conflated under the label "3D plate": (i) truly patient-specific plates individually designed from a given patient's imaging and manufactured additively (3D printing) or by CAD/CAM milling; (ii) generic, anatomically pre-formed plates with a fixed "3D" (non-flat) geometry that is not individualized to a given patient (e.g., the condylar mini-plates addressed by the 2021 systematic review in Table 1); and (iii) conventional flat plates that are manually contoured intraoperatively, sometimes with the aid of a 3D-printed anatomical model rather than a 3D-printed plate itself. A future systematic review on this topic should explicitly stratify studies by this distinction, since the mechanical rationale (avoidance of intraoperative bending and its associated residual stress) applies specifically to category (i).

IV. DISCUSSION

4.1 Principal findings

This scoping synthesis found that the question of patient-specific, CAD/CAM-designed and 3D-printed plates in acute traumatic mandibular fractures is partially, but not comprehensively, addressed by the existing systematic review literature. A single 2025 systematic review with meta-analysis reports quantitative comparative outcomes for this population, but as a subgroup within a broader, four-indication craniomaxillofacial synthesis. A discrete and apparently growing cohort of trauma-dedicated randomized controlled trials — several completed in 2025 and not yet available in full-text form, several more active or newly registered in early 2026 — indicates that the evidence base for this specific clinical question is in active development rather than settled.

4.2 Comparison with prior evidence

The direction of effect reported by Nguyen et al. (2025) for mandibular fractures specifically — improved occlusal function without a demonstrated reduction in complications or improvement in fracture healing — is a plausible and clinically coherent finding: patient-specific plates are designed primarily to improve anatomical fit and reduction accuracy, which would be expected to affect occlusal outcomes more directly than infection or union rates, which are more strongly driven by soft-tissue handling, systemic factors, and fracture biology. Whether this pattern is confirmed once the additional 2025–2026 trauma-specific randomized controlled trials identified in Table 2 are published is the central open question that a future dedicated systematic review should resolve.

4.3 Research gap and rationale for a future systematic review

A dedicated, trauma-restricted systematic review is justified for three literature-supported reasons. First, existing quantitative synthesis of this population is embedded within a broader, non-trauma-dominated review rather than reported on its own terms with trauma-specific risk-of-bias and GRADE certainty assessment. Second, the trauma-specific evidence base has grown materially since the most recent relevant review's search window, with several randomized controlled trials now completed or nearing

completion. Third, no existing review cleanly separates additively manufactured plates from CAD/CAM-milled or pre-bent-on-a-model plates, despite a plausible mechanical distinction between these manufacturing routes.

4.4 Limitations

This work is a scoping-level landscape assessment, not a completed systematic review. It was conducted through targeted web-based searching of PubMed-indexed abstracts and allied sources rather than a full, exportable, de-duplicated search of PubMed, Embase, Scopus, and the Cochrane Library, and it does not report a PRISMA flow diagram, formal risk-of-bias assessment, or pooled effect estimates. The primary-study table in Section 3.2 should be regarded as illustrative of the evidence landscape rather than an exhaustive or final inventory; a number of the identified randomized controlled trials are registered as completed but have not yet been published in full, so their eventual reported outcomes, exact sample sizes, and effect directions are not yet known and are not assumed here.

4.5 Implications for a future definitive review

A future systematic review should: (i) restrict its population to acute traumatic mandibular fractures, explicitly excluding oncologic reconstruction, free-flap reconstruction, and prophylactic plating; (ii) stratify the intervention by manufacturing route (additive vs. milled/pre-bent); (iii) apply Cochrane RoB 2 to randomized controlled trials and ROBINS-I to non-randomized comparative studies; (iv) apply GRADE to derive certainty of evidence for each outcome, expecting an initially low-to-very-low certainty given the small, heterogeneous evidence base; (v) pre-specify meta-analysis as conditional on at least three clinically and methodologically comparable studies per outcome, rather than pooling all available data by default; and (vi) register the protocol with PROSPERO, explicitly distinguishing its scope from the Nguyen et al. (2025) review to avoid a determination of substantial duplication. Given that several relevant randomized controlled trials are registered as completed but not yet published, a staged approach — registering the protocol now while allowing the definitive search to be run three to six months later — is likely to substantially improve the number of studies available for quantitative synthesis without meaningfully delaying publication of the underlying protocol or this landscape assessment.

V. CONCLUSION

Patient-specific, CAD/CAM-designed and 3D-printed fixation plates for acute traumatic mandibular fractures represent an active and clinically relevant area of craniomaxillofacial trauma research that is not yet comprehensively addressed by a dedicated systematic review. Existing quantitative evidence, drawn from a broader multi-indication review, suggests a plausible benefit for occlusal outcomes without a clearly demonstrated benefit for complication or healing outcomes, but this finding warrants confirmation in a trauma-restricted synthesis once the currently maturing cohort of randomized controlled trials is published. A revised, trauma-specific PICO question, PROSPERO registration with explicit differentiation from prior reviews, and staged execution of the definitive database search are recommended as the next steps toward a publishable systematic review and meta-analysis.

DECLARATIONS

Funding: None declared.

Conflicts of interest: None declared.

Data availability: All sources cited are publicly available at the URLs and identifiers referenced.

Registration: This scoping synthesis is not registered. A future systematic review derived from it is intended for PROSPERO registration prior to execution of the definitive search.

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