

INPLASY

Metal Alloys Processed by Additive Manufacturing for Dental Prostheses: A Scoping Review Protocol

INPLASY2026100015

doi: 10.37766/inplasy2026.10.0015

Received: 2 October 2026

Published: 2 October 2026

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ADMINISTRATIVE INFORMATION**Support** - No support.**Review Stage at time of this submission** - Formal screening of search results against eligibility criteria.**Conflicts of interest** - None declared.**INPLASY registration number:** INPLASY2026100015**Amendments** - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 2 October 2026 and was last updated on 2 October 2026.**INTRODUCTION**

Review question / Objective What is known about metal alloys produced by additive manufacturing for the fabrication of dental prostheses?

P (population): Studies involving any metallic alloy;

C (concept): Additive manufacturing processes for metals; and C (context): Clinical or laboratory procedure related to dental prostheses.

Objective: To identify and map the existing evidence on the types, processing parameters, microstructural characteristics, mechanical properties, and clinical or industrial applications of metal alloys produced by additive manufacturing for dental prostheses.

Background Additive manufacturing (AM), commonly referred to as 3D printing, encompasses a family of layer-by-layer fabrication processes that have fundamentally changed the landscape of materials science and manufacturing engineering. Unlike conventional subtractive or formative methods, AM enables the production of near-net-

shape components with complex internal architectures, functionally graded structures, and minimal material waste. Since the early 2010s, metal AM has grown from a prototyping tool into a mature manufacturing platform with applications spanning aerospace, biomedical, automotive, and dental industries.

Among metal additive manufacturing (AM) processes, powder bed fusion (PBF) techniques, such as selective laser melting (SLM) and, to a lesser extent, direct metal laser sintering (DMLS) and electron beam melting (EBM), are the most extensively investigated for dental prosthetic applications. In prosthodontics, these technologies enable the direct fabrication of metal frameworks from CAD-designed digital models, bypassing the multiple steps and material losses inherent to the conventional lost-wax casting technique. Reported clinical and laboratory applications include cobalt-chromium (Co-Cr) frameworks for removable partial dentures, copings and frameworks for fixed dental prostheses and metal-ceramic (porcelain-fused-to-metal) restorations, as well as titanium and Co-Cr superstructures and bars for implant-

supported prostheses. Compared with milling, PBF-based AM allows for greater design freedom and reduced material waste, while achieving marginal and internal fit values that are often comparable to or better than those obtained by casting. Each alloy–process combination, however, introduces distinct microstructural features, such as columnar grain growth, residual stresses, and metastable phases, that critically influence the mechanical and functional performance of the final prosthesis.

Co-Cr alloys processed by SLM have attracted particular interest in dentistry and orthopaedics due to their excellent corrosion resistance, biocompatibility, and high hardness. Titanium and titanium alloys, especially Ti-6Al-4V, dominate implantable device applications owing to their favourable strength-to-weight ratio and osseointegration capacity. Despite the exponential growth of publications in this area, the breadth of alloys, processes, post-processing treatments, and reported outcomes makes it difficult to synthesise the current state of the evidence. A scoping review is therefore warranted to systematically map the landscape, identify knowledge gaps, and guide future primary research and systematic reviews.

Rationale The volume of primary research on metal AM has grown exponentially over the past decade, covering a heterogeneous range of alloy systems, AM processes, processing parameters, post-processing strategies (e.g., heat treatment, hot isostatic pressing, surface finishing), and outcome measures (e.g., tensile strength, fatigue life, porosity, corrosion resistance, biocompatibility). This heterogeneity makes it challenging for researchers, clinicians, and engineers to obtain a clear picture of what is known, what remains uncertain, and where future investigation is most needed. Existing systematic reviews tend to focus on narrow questions (e.g., a single alloy or a single application), whereas a scoping review is the most appropriate methodology to chart the broad landscape of metal AM. To the authors' knowledge, no scoping review has comprehensively mapped the current state of the art across the major alloy classes and AM processes. A preliminary search of MEDLINE, the Cochrane Database, and JBI Evidence Synthesis confirmed the absence of such a review. A preliminary search of MEDLINE, the Cochrane Database, and JBI Evidence Synthesis confirmed the absence of such a review.

METHODS

Strategy of data synthesis A systematic search will be conducted in the following electronic

databases: MEDLINE (via PubMed), Embase (via Elsevier), Scopus, Web of Science (Core Collection) and Lilacs. Grey literature will be sought through ProQuest Dissertations and Theses Global, and Google Scholar (first 100 results). Expert consultations will be considered if the authors present 5 or more studies relevant to the research question of this scoping review. Reference lists of all included studies and relevant reviews will be hand-searched for additional sources. Parallel to the manual search, a snowballing technic (backward for studies cited by the included studies and forward for studies citing the included studies) will be assisted by CitationChaser online (version 0.0.3, available on <https://estech.shinyapps.io/citationchaser/>). No date or language restrictions will be applied.

Terms: ("Chromium Alloys"[mh] OR "Titanium"[mh] OR "metal alloy*" [tiab] OR "metallic alloy*" [tiab] OR "cobalt chromium [tiab] OR "Co-Cr"[tiab] OR "CoCr"[tiab] OR "titanium alloy*" [tiab] OR "Ti-6Al-4V" [tiab] OR "Ti6Al4V" [tiab] OR "commercially pure titanium" [tiab] OR "nickel-chromium" [tiab] OR "Ni-Cr" [tiab] OR "stainless steel" [tiab] OR "316L" [tiab] OR "17-4PH" [tiab]) AND ("Printing, Three-Dimensional" [mh] OR "additive manufacturing" [tiab] OR "3D printing" [tiab] OR "three-dimensional printing" [tiab] OR "selective laser melting" [tiab] OR "selective laser sintering" [tiab] OR "electron beam melting" [tiab] OR "directed energy deposition" [tiab] OR "laser powder bed fusion" [tiab] OR "powder bed fusion" [tiab] OR "binder jetting" [tiab] OR "direct metal laser sintering" [tiab] OR "SLM" [tiab] OR "SLS" [tiab] OR "EBM" [tiab] OR "DMLS" [tiab] OR "LPBF" [tiab]) AND ("Prosthodontics" [mh] OR "Dental Prosthesis" [mh] OR "Dental Prosthesis, Implant-Supported" [mh] OR "Dentures" [mh] OR "Crowns" [mh] OR "prosthodontics" [tiab] OR "prosthetic dentistry" [tiab] OR "dental prosthesis" [tiab] OR "dental prostheses" [tiab] OR "prosthetic restoration" [tiab] OR "fixed dental prosthesis" [tiab] OR "denture*" [tiab] OR "implant-supported prosthesis" [tiab] OR "implant-supported dental prosthesis" [tiab] OR "dental crown*" [tiab] OR "dental bridge*" [tiab] OR "metal-ceramic restoration" [tiab] OR "porcelain-fused-to-metal" [tiab] OR "PFM restoration" [tiab] OR "dental framework" [tiab]).

Eligibility criteria

POPULATION

Inclusion: Studies investigating metallic alloys, including but not limited to cobalt-chromium (Co-Cr) and cobalt-chromium-molybdenum (Co-Cr-Mo) alloys, commercially pure titanium and titanium alloys (e.g., Ti-6Al-4V), nickel-based superalloys, nickel-chromium (Ni-Cr) alloys, stainless steels

(e.g., 316L, 17-4PH), aluminium alloys (e.g., AlSi10Mg), and copper alloys. Studies reporting primary data on specimens, prototypes, or components fabricated from metallic alloys.

Exclusion: Studies involving exclusively non-metallic materials (polymers, ceramics, composites) with no metallic alloy component.

CONCEPT

Inclusion: Studies addressing metal additive manufacturing processes, including but not limited to selective laser melting (SLM), selective laser sintering (SLS), electron beam melting (EBM), directed energy deposition (DED), laser powder bed fusion (LPBF), binder jetting, and direct metal laser sintering (DMLS). Studies reporting at least one of the following outcomes: processing parameters (e.g., laser power, scanning speed, layer thickness), microstructural characteristics, mechanical properties (e.g., hardness, tensile strength, elastic modulus), corrosion resistance, or functional properties relevant to prosthetic dental applications.

Exclusion: Studies using exclusively subtractive fabrication methods (milling/CAD-CAM machining) or conventional casting (lost-wax technique) with no additive manufacturing step. Studies on additive manufacturing of non-metallic materials (e.g., 3D-printed resins, ceramics, or biological materials), unless directly compared to 3D-printed metallic alloys.

CONTEXT

Inclusion: Studies set within the context of prosthetic dentistry (prosthodontics), including fixed dental prostheses, removable partial and complete dentures, implant-supported prostheses, metal-ceramic (porcelain-fused-to-metal) restorations, prosthetic frameworks/substructures, crowns and pontics. Preclinical settings, including laboratory investigations and animal models, and clinical settings involving patients. Both involve an explicit or simulated prosthetic application (e.g., specimens designed to represent prosthetic components).

Exclusion: Studies in which the 3D-printed metallic alloy is applied to other medical or dental specialties unrelated to prosthodontics (e.g., orthopaedic implants, surgical instruments, orthodontic brackets, endodontic instruments), unless the study also addresses a prosthodontic application. Studies focused purely on materials science/metallurgy with no reference or intent toward dental prosthetic application.

Source of evidence screening and selection

The management of references identified during the literature search and screening process will be

conducted using EndNote Online (Clarivate, Philadelphia, PA, USA) and Rayyan (Rayyan Systems Inc., Cambridge, MA, USA). EndNote will be used as the primary reference management software to organize retrieved records, store bibliographic information, and identify and remove duplicate citations prior to the screening phase. The software will facilitate the systematic organization of studies obtained from the selected electronic databases and ensure accurate citation management throughout the review process. Following the removal of duplicates, the references will be exported to Rayyan, a web-based platform specifically designed to support systematic reviews. Rayyan will be used to conduct the title and abstract screening process independently by the reviewers. The platform allows efficient management of inclusion and exclusion decisions, facilitates blinded screening when required, and provides tools for resolving disagreements between reviewers. Additionally, Rayyan enables transparent documentation of screening decisions and enhances the reproducibility of the study selection process. The combined use of EndNote and Rayyan will contribute to a rigorous, organized, and transparent workflow for study identification, screening, and selection, in accordance with current methodological recommendations for systematic reviews.

Before formal screening, the two reviewers will pilot the eligibility criteria on a sample of title/abstract records and full-text articles to ensure consistent interpretation of the inclusion and exclusion criteria. Any disagreements will be discussed and used to refine the eligibility decision guide before formal screening begins.

Two independent reviewers (ATF and MCSD) will screen all titles and abstracts, followed by full-text assessment of potentially eligible records. Disagreements will be resolved by consensus; if unresolved, a third reviewer (RAM) will adjudicate. Records for which the full text cannot be obtained after contacting the corresponding author and using inter-library loan services will be listed as "full text not retrieved". Reasons for exclusion at the full-text stage will be documented for all excluded records. The study selection process will be reported in a PRISMA-ScR flow diagram.

Data management Data will be extracted independently by two reviewers (ATF and MCSD) using a standardised data extraction form developed a priori and piloted on a sample of ten included studies. One reviewer will extract data manually (ATF), while the other reviewer (MCSD) will extract data with the assistance of Gemini Notebook online (Google, Mountain View, CA, USA). Any disagreements will be resolved by

consensus or arbitration by a third reviewer (RAM). The following data will be extracted from each included source: author(s) and year of publication; country; study design; alloy type and composition; AM process; equipment manufacturer and model; processing parameters (laser/beam power, scan speed, layer thickness, hatch spacing, build orientation, atmosphere); feedstock characteristics (powder/wire size, morphology, purity); post-processing treatments (heat treatment, HIP, surface finishing, sterilisation); specimen geometry and dimensions; characterisation methods; microstructural outcomes (grain size, grain morphology, phase composition, texture, defects/porosity); mechanical properties (yield strength, ultimate tensile strength, elongation, hardness, fatigue limit, fracture toughness); functional properties (corrosion rate, wear rate, biocompatibility, cytotoxicity); and reported applications.

Reporting results / Analysis of the evidence

Extracted data will be analysed using a descriptive and narrative approach consistent with JBI scoping review methodology. Quantitative data (e.g., mechanical property values) will be presented in summary tables organised by alloy class and AM process type. Categorical data (e.g., type of AM process, type of post-processing) will be presented as frequency counts and percentages where appropriate. A narrative synthesis will describe and map the evidence across the following dimensions: 1 - alloy categories investigated; 2 - AM process types used; 3 - key processing parameters reported; 4 - microstructural features characterised; 5 - mechanical and functional properties reported; 6 - post-processing strategies applied; and 7 - reported applications for dental prostheses. Knowledge gaps and areas for future primary research will be identified and discussed.

Presentation of the results Results will be presented in accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR).

Language restriction There will be no language restriction imposed on the search.

Country(ies) involved The scoping review is being carried out in Brazil.

Other relevant information ABSTRACT

Introduction: Additive manufacturing (AM) has emerged as a disruptive technology for fabricating complex metallic components with unprecedented geometric freedom and material efficiency. A wide range of metal alloys, including cobalt-chromium

(Co-Cr) alloys, titanium and its alloys, stainless steels, nickel superalloys, and aluminium alloys, are currently processed by AM techniques such as selective laser melting (SLM), electron beam melting (EBM), direct energy deposition (DED), and binder jetting. Despite the rapid growth of the field, a comprehensive mapping of the current evidence on the types, processing parameters, and mechanical, microstructural, and functional properties of AM metal alloys applied to dental prostheses remains lacking. Objective: To identify and map the existing evidence on the types, processing parameters, microstructural characteristics, mechanical properties or clinical applications of metal alloys produced by additive manufacturing for dental prostheses. Methods: This scoping review will follow the JBI methodology for scoping reviews and will be reported according to the PRISMA-ScR guidelines. A systematic search will be conducted in PubMed, Embase, Scopus, Web of Science, Lilacs and grey literature sources. Two independent reviewers will screen titles, abstracts, and full texts, and data will be extracted and presented in tabular and narrative form. Expected results: This review is expected to provide a structured overview of the current state of metal alloys produced via additive manufacturing, identifying methodological and clinical trends and recurring limitations that will guide future research and support the clinical integration of these materials in the field of dental prostheses.

Keywords Additive manufacturing; Metal alloys; Selective laser melting; Cobalt-chromium alloy; 3D printing; Scoping review.

Dissemination plans The findings of this scoping review will be disseminated through publication in a peer-reviewed scientific journal in the field of dentistry and presentation at national scientific conferences. The results will also be incorporated into a thesis within the Department of Dentistry, School of Health Sciences, University of Brasília (UnB), Brasília.

Contributions of each author

Author 1 - Rodrigo Medeiros - Third Reviewer (Data analysis). C=Coordinator (Study conceptualization and design/ Data analysis). CA=Corresponding author. Review of the manuscript.

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