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Augmented Reality Assisted Intraoral Scanning in Dentistry: A Systematic Review and Exploratory Meta-Analysis

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ADMINISTRATIVE INFORMATION

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 6 June 2026 and was last updated on 6 June 2026.

INTRODUCTION

Review question / Objective To methodically assess the efficacy of traditional intraoral scanning (IOS) with augmented reality-assisted intraoral scanning (ARIOS) in dentistry. The review specifically seeks to determine whether ARIOS enhances operator workload, ergonomics, usability, training outcomes, scan acquisition efficiency, scan image/photo count, scan accuracy (trueness and precision), and clinical applicability. Additionally, the review aims to investigate the available data on the possible advantages and drawbacks of ARIOS in workflows related to restorative, prosthodontic, orthodontic, implant, educational, and digital dentistry.

Rationale Intraoral scanning (IOS) is becoming a crucial part of modern digital dentistry. Conventional IOS processes, on the other hand, necessitate operators to constantly switch their visual focus between the patient, the scanner tip, and the external monitor. This can lead to scanning errors or rescanning, increase cognitive effort, and decrease ergonomic efficiency. By superimposing scan data directly within the operator's field of vision, augmented reality-assisted intraoral scanning (ARIOS) has become a cutting-edge technology that may enhance visualization, scanner orientation, workflow efficiency, and user experience.

While there have been extensive reviews of augmented reality applications in dentistry, including implant navigation, oral and maxillofacial surgery, education, and prosthodontics, no targeted systematic review has examined the use of augmented reality during intraoral scan acquisition. The number of ARIOS investigations that have already been conducted is few, their designs are diverse, and their results on scan accuracy, efficiency, ergonomics, and clinical application have been inconsistent. In order to evaluate the potential relevance of ARIOS in digital

dentistry workflows, identify existing knowledge gaps, and critically synthesize the available information, a dedicated systematic review and exploratory meta-analysis are required.

Condition being studied In dentistry, augmented reality-assisted intraoral scanning (ARIOS). During intraoral scan acquisition, ARIOS uses augmented reality or mixed-reality technology, such as head-mounted displays, smart glasses, or augmented-reality head-up displays (AR-HUDs). While taking digital impressions, these devices allow real-time display of scanned data within the operator's range of vision. In comparison to traditional intraoral scanning workflows, the evaluation examines the effects of ARIOS on scan acquisition time, scan image/photo count, scan accuracy (trueness and precision), ergonomics, workload, usability, training outcomes, technical feasibility, and clinical relevance.

METHODS

Search strategy From database creation until May 2026, a thorough electronic search will be carried out in PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and the Cochrane Library. Google Scholar, ResearchGate records, manufacturer or institutional websites, and manual screening of pertinent article and review reference lists are additional sources.
The search strategy will be modified for each database as needed. Only English-language publications that describe the direct application of augmented reality during intraoral scan acquisition will be taken into consideration. To find more relevant studies, the reference lists of the included papers and pertinent reviews will be manually searched.

The following terms will be combined in the search strategy: ("augmented reality" OR "mixed reality" OR "smart glasses" OR "head mounted display" OR "optical see-through" OR "AR-HUD" OR "heads-up display") AND ("intraoral scanning" OR "intraoral scanner" OR "digital impression" OR "optical impression" OR "IOS") AND (dentistry OR dental OR prosthodontics OR implant*).

Participant or population Patients, dental students, clinicians, typodonts, dental casts, and simulation models undergoing or used for intraoral scanning with augmented reality-assisted intraoral scanning (ARIOS) systems.

Intervention The use of augmented reality (AR) or mixed reality technologies directly during intraoral scan acquisition is known as augmented reality-assisted intraoral scanning (ARIOS). AR head-up displays (AR-HUDs), optical see-through head-mounted displays (OST-HMDs), smart glasses, mixed-reality visualization systems, and AR overlays that offer scanner guidance, real-time visualization, or scan-progress feedback during digital impression procedures are examples of eligible interventions.

Comparator Standard non-augmented reality workflows are used for conventional intraoral scanning (IOS). Regular screen-based intraoral scanning, in which operators observed scan progress on an external monitor without utilizing augmented reality, mixed reality visualization, head-mounted displays, smart glasses, or AR-guided scan overlays during scan acquisition, was one of the comparators.

Study designs to be included First research assessing the capture of intraoral scans using augmented reality-assisted intraoral scanning (ARIOS). Clinical studies, pilot clinical studies, in vitro studies, typodont-based studies, proof-of-concept investigations, within-subject studies, crossover studies, educational/operator-training studies, quasi-experimental studies, and technical feasibility or prototype studies are all acceptable study designs as long as augmented reality was used directly during the intraoral scanning procedure and at least one pertinent outcome was reported.

Eligibility criteria Original research assessing augmented reality (AR) or mixed reality technologies applied directly during intraoral scan acquisition was included. Clinical, pilot, in vitro/typodont, proof-of-concept, within-subject or crossover, educational/operator, and technological feasibility studies were among the designs that qualified. At least one pertinent outcome, such as scan acquisition time, scan image/photo count, scan accuracy (RMSE, RMS, trueness, or precision), scan completeness, ergonomics, workload, usability, user preference, training effect, technical feasibility, or clinical applicability, had to be reported by the studies. Posters with adequate methodological description, conference proceedings, accepted manuscripts, and full-text English-language articles were taken into consideration.
Implant navigation, surgical guidance, tooth preparation, endodontic access, virtual articulation, calibration, and other dental procedures that did not need direct intraoral scan acquisition were all omitted from the study. Reviews, editorials, letters, procedures, narrative comments, photogrammetry studies without ARIOS, conventional intraoral

scanner comparative studies without an AR intervention, and research without extractable ARIOS-related outcomes were also omitted.

Information sources From the database's creation until May 2026, electronic searches were carried out in PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and the Cochrane Library. Google Scholar, ResearchGate records, manufacturer and institutional websites, and manual checking of reference lists from included papers and pertinent reviews were additional sources. Early prototype studies, conference proceedings, posters, and challenging-to-index papers pertaining to augmented reality-assisted intraoral scanning (ARIOS) were found by searching these additional sources.

Main outcome(s) Scan acquisition time and scan image/photo count during intraoral scanning techniques were the main results. When comparing augmented reality-assisted intraoral scanning (ARIOS) to traditional intraoral scanning (IOS), secondary outcomes included scan accuracy metrics like trueness (RMSE) and precision (RMS), scan completeness, ergonomics, operator workload (e.g., NASA-TLX), usability, user preference, training effect, technical feasibility, and clinical applicability.

Additional outcome(s) These are outcomes that provide supplementary information related to the intervention effects, such as:
Quality of life measures
Patient satisfaction
Adverse events / complications
Longevity or survival of treatment/intervention
Functional outcomes (e.g., chewing efficiency, speech improvement in dental studies)
Biological or clinical parameters not defined as primary outcomes
Cost-effectiveness or economic impact
Secondary outcomes include peri-implant health parameters, marginal bone loss, prosthesis survival rate, complication rate, and patient-reported outcomes.

Data management A standardized and pilot-tested data extraction form created especially for prosthodontic, implant, and intraoral scanner (IOS)-based investigations will be used to capture all pertinent data from eligible studies. Study design, year of publication, sample size, patient demographics, kind of prosthodontic or implant intervention, implant system or IOS system utilized, scanning protocols, prosthesis type, length of follow-up, and reported clinical and digital outcomes are among the data that will be collected.

Important results will be documented, including implant survival rate, marginal bone loss, peri-implant health indicators, prosthesis problems, scanning accuracy (trueness and precision), and digital workflow efficiency. When available, patient-reported outcomes such as comfort, contentment, and quality of life will also be included.
To ensure dependability and minimize bias, data extraction will be carried out by two independent reviewers. A third reviewer will be consulted or consulted in order to address any differences. Before analysis, the extracted data will be arranged in Microsoft Excel or a comparable database, verified for accuracy, and cleaned. To ensure confidentiality and data integrity during the review process, duplicate records will be eliminated and all information will be safely stored with limited access.

Quality assessment / Risk of bias analysis Two reviewers will independently evaluate the included studies' methodological quality and bias risk using suitable, validated instruments based on the study design. A third reviewer will be consulted or consulted in order to settle any disputes.

The Cochrane Risk of Bias tool (RoB 2) will be used for randomized controlled trials (RCTs), assessing areas such the randomization procedure, deviations from intended interventions, missing outcome data, outcome assessment, and selective reporting. The Newcastle–Ottawa Scale (NOS), which evaluates study group selection, comparability, and outcome/exposure assessment, will be used for non-randomized investigations (cohort and case-control studies).
An appropriate customized quality evaluation checklist will be utilized to assess methodological rigor, sample standardization, measurement reliability, and reporting quality for in vitro investigations pertaining to intraoral scanner accuracy, prosthesis fit, or material attributes.

The risk of bias evaluation will be carried out by two independent reviewers, and any disagreements will be settled by consensus or by consulting a third reviewer. The interpretation and synthesis of findings will take into account the quality assessment results, which will be displayed in tabular and/or graphical form.

Strategy of data synthesis Depending on the type and consistency of the included research, a narrative and quantitative synthesis will be carried out. To summarize research features, interventions,

outcomes, and methodological quality, all retrieved data will first be methodically tabulated.
A meta-analysis will be carried out using the proper statistical tools if the included studies are sufficiently similar in terms of research design, participants, interventions (such as implant systems, prosthodontic regimens, or IOS devices), and outcome measures. Effect sizes will be presented as mean differences (MD) or standardized mean differences (SMD) for continuous outcomes (e.g., marginal bone loss, scanning accuracy, prosthetic fit) and risk ratios (RR) or odds ratios (OR) for dichotomous outcomes (e.g., implant survival, complication rates). If there is anticipated clinical or methodological variability, a random-effects model will be applied.
The Chi-square test will be used to evaluate statistical heterogeneity, and the I2 statistic will be used to quantify it. When appropriate, subgroup analysis can be carried out based on factors such the kind of implant system, IOS device, prosthetic material, or study design. Sensitivity analysis will be used to eliminate studies with a high risk of bias in order to evaluate the robustness of the results.
A structured narrative synthesis that highlights trends, patterns, and important findings across studies will be offered if meta-analysis is not practical because of excessive heterogeneity or a lack of data. When interpreting the results, the certainty of the evidence will be taken into account.

Subgroup analysis When there is enough information to investigate possible sources of heterogeneity and compare results across clinically relevant categories, subgroup analyses will be carried out. Subgroups can be identified in prosthodontic, implant, and intraoral scanner (IOS)-based research according to:
1.Implant system type (e.g., tissue-level versus bone-level implants)
2.Protocol for implant loading (immediate, early, or conventional loading)
3.Type of prosthesis (single crown versus full-arch restorations; fixed versus detachable prostheses)
4.Prosthesis material (zirconia, metal-ceramic, resin-based materials)
5.Intraoral scanner type (several iOS brands/ models)
6.Conventional workflow versus digital workflow
7.Patient-related variables (maxilla vs. mandible, edentulous vs. partially edentulous patients)
8.Duration of follow-up (short-term versus long-term results)
Differences in primary and secondary outcomes, including implant survival rate, marginal bone loss, prosthetic problems, scanning accuracy (trueness and precision), and patient-reported outcomes, will be evaluated using subgroup comparisons when appropriate. Results will be presented narratively if there is not enough data for a formal subgroup analysis.

Sensitivity analysis Sensitivity analysis will be carried out to evaluate the overall findings' robustness and reproducibility and to ascertain whether particular studies or methodological choices have an impact on the outcomes.
Sensitivity analysis in prosthodontic, implant, and intraoral scanner (IOS)-based research may entail excluding studies with small sample numbers, non-randomized designs, or high risk of bias in order to assess their influence on pooled findings. To investigate consistency of results, additional analyses can be carried out using other statistical models (fixed-effect vs. random-effects models).
In order to evaluate their impact on the overall effect size, studies with extreme outliers in outcomes like marginal bone loss, implant survival rates, prosthetic complications, or IOS accuracy (trueness and precision) will be eliminated one after the other.

If the effect's direction and size don't change following these modifications, the results' stability will be verified. After certain studies are excluded, any notable changes in the results will be presented and interpreted in light of their clinical significance.

Language restriction No language restrictions will be imposed during the literature search. Studies will be considered eligible irrespective of the language of publication.

Country(ies) involved This systematic review will include studies conducted globally with no country restriction. The authors are indian nationals and affliated to Institution of Saudi Arabia.

Other relevant information This systematic review will be conducted in accordance with established guidelines such as PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). The review protocol will be registered in INPLASY prior to commencement to ensure transparency and reduce risk of duplication. Any deviations from the protocol during the review process will be clearly documented and justified in the final report.

Keywords augmented reality, intraoral scanning ,digital impression, digital dentistry, ergonomics, scan accuracy, scan time, scan image count, systematic review.

Dissemination plans The findings of this systematic review will be disseminated through publication in peer-reviewed dental and prosthodontic journals and presentation at national and international conferences. Results will also be shared with academic institutions, dental professionals, and researchers involved in implantology, prosthodontics, and digital dentistry. In addition, summaries may be used for teaching purposes in undergraduate and postgraduate dental programs to support evidence-based clinical practice.

Contributions of each author

Author 1 - MOHAMED SAHEER KURUNIYAN - Conceptualization of the study, development of the research question, design of the systematic review protocol, formulation of search strategy, screening of studies, data extraction, risk of bias assessment, data synthesis, and drafting of the manuscript.
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Author 2 - RAVINDER SING SAINI - Assistance in refining the study design, validation of search strategy, independent screening of studies, verification of extracted data, risk of bias assessment, contribution to data interpretation, critical revision of the manuscript, and final approval of the submitted protocol.
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