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Accuracy of dynamic navigation-assisted implant surgery compared with freehand and static guide techniques: a systematic review and meta-analysis

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ADMINISTRATIVE INFORMATION

Support - Completed but not published.

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Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 3 November 2026 and was last updated on 3 November 2026.

INTRODUCTION

Review question / Objective To update and refine the evidence on the three-dimensional accuracy of dynamic computer-assisted implant surgery (dCAIS) compared with freehand (FH) placement and static computer-assisted implant surgery (sCAIS), with explicit attention to the overlap with previously published systematic reviews and meta-analyses.

Condition being studied Dental implant placement is a surgical procedure used to rehabilitate partially or completely edentulous patients. Accurate three-dimensional positioning of dental implants is essential for prosthetically driven rehabilitation and may influence the emergence profile, screw-access location, occlusal load distribution, proximity to anatomical structures, and the risk of biological or technical complications. Conventional freehand implant placement depends heavily on operator experience and may be less predictable in anatomically demanding situations. Computer-assisted implant surgery, including dynamic computer-assisted implant surgery (dCAIS) and static computer-assisted implant surgery (sCAIS), has been developed to improve the accuracy of implant placement. This systematic review and meta-analysis evaluates the comparative three-dimensional accuracy of dCAIS, freehand placement, and sCAIS in clinical dental implant surgery.

METHODS

Participant or population Adult patients aged 18 years or older with partial or complete edentulism requiring single or multiple dental implants, irrespective of jaw, implant site, or timing of implant placement. The population includes patients undergoing conventional dental implant placement, immediate implant placement, and zygomatic implant placement in clinical settings.

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Intervention Dynamic computer-assisted implant surgery (dCAIS) using optical tracking, machine-vision tracking, or another real-time navigation system for dental implant placement. The intervention involves real-time visual feedback to guide implant positioning according to the preoperative virtual plan.

Comparator The comparators are conventional freehand (FH) dental implant placement without computer-assisted guidance and static computer-assisted implant surgery (sCAIS) using premanufactured surgical templates. Static guidance includes fully guided, partially guided, and pilot-drill static templates.

Study designs to be included Randomised controlled trials (RCTs) and prospective clinical comparative studies evaluating dynamic computer-assisted implant surgery against freehand placement or static computer-assisted implant surgery. Only clinical studies providing extractable three-dimensional implant-placement accuracy outcomes will be included.

Eligibility criteria Studies will be eligible if they meet the predefined PICOS criteria: (1) adult patients aged 18 years or older with partial or complete edentulism requiring single or multiple dental implants; (2) dynamic computer-assisted implant surgery using a real-time navigation system; (3) comparison with freehand implant placement or static computer-assisted implant surgery; (4) reporting of at least one extractable three-dimensional accuracy outcome, including global apical deviation (GAD), global coronal deviation (GCD), or angular deviation (AD); and (5) randomised controlled trials or prospective clinical comparative studies.
Studies will be excluded if they are duplicate publications or involve overlapping cohorts; in vitro, ex vivo, animal, or cadaver studies; case reports; non-comparative case series; reviews; editorials; letters; conference abstracts without extractable data; studies with incorrect interventions or comparators; studies without extractable GAD, GCD, or AD outcomes; studies with insufficient data after contacting the authors; or studies for which the full text is unavailable.

Information sources The following electronic databases will be searched from inception to April 1, 2026: PubMed, Web of Science, Cochrane Library, Embase, Scopus, China National Knowledge Infrastructure (CNKI), Wanfang Database, VIP Database, and SinoMed.
The search strategy will combine controlled vocabulary and free-text terms related to dental implants, dynamic navigation, computer-assisted surgery, freehand implant placement, static surgical guides, and clinical comparative study designs. No language restrictions will be applied during eligibility assessment.
Reference lists of eligible studies and recent systematic reviews on the same topic will also be screened to identify additional relevant studies. Corresponding authors of potentially eligible studies will be contacted when required data are missing or unclear.
Chinese-language records will be screened using the predefined PICOS criteria. The complete search strategies for all databases will be provided in the supplementary materials.

Main outcome(s) The primary outcomes are the three-dimensional accuracy of dental implant placement, assessed using the following measures:
1. Global apical deviation (GAD): the three-dimensional Euclidean distance between the planned and actual positions of the implant apex centre, measured in millimetres.
2. Global coronal deviation (GCD): the three-dimensional Euclidean distance between the planned and actual positions of the implant platform centre, measured in millimetres.
3. Angular deviation (AD): the three-dimensional angle between the long axes of the planned and actual implants, measured in degrees.
These outcomes will be extracted from the clinical studies at the reported postoperative accuracy assessment timepoints. The effect measure will be the standardised mean difference (SMD) with its 95% confidence interval (CI), comparing dCAIS with FH placement and sCAIS separately.

Quality assessment / Risk of bias analysis The risk of bias of included randomised controlled trials will be assessed independently by two reviewers using the Cochrane Risk of Bias 2 (RoB 2) tool. The five domains will be evaluated: (1) bias arising from the randomisation process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome; and (5) bias in selection of the reported result. Overall risk-of-bias judgements will be made according to RoB 2 guidance.
Potential concerns, including incomplete reporting of allocation concealment, lack of blinded operators, unclear assessor blinding, and selective reporting of accuracy outcomes, will be considered. Disagreements between reviewers will be resolved through discussion.
The certainty of evidence for each outcome and comparison will additionally be evaluated using the Grading of Recommendations Assessment,

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Development and Evaluation (GRADE) framework, considering risk of bias, inconsistency, indirectness, imprecision, and publication bias.

Strategy of data synthesis Data will be extracted independently by two reviewers using a standardised data extraction form. Extracted information will include study characteristics, country, study design, sample size, patient and implant numbers, demographic characteristics, implant site, jaw, timing of placement, dynamic-navigation system, comparator type, guide support, guide protocol, measurement method, follow-up timing, mean deviations, standard deviations, and relevant analytical details. Disagreements will be resolved through discussion or consultation with a third reviewer. Corresponding authors will be contacted when data are missing or unclear.
Meta-analyses will be performed using Stata 17.0. The standardised mean difference (SMD) with a 95% confidence interval (CI) will be used as the effect measure. Random-effects models will be applied to account for anticipated clinical and methodological heterogeneity.
Separate meta-analyses will be conducted for dCAIS versus FH placement and dCAIS versus sCAIS for each of the three outcomes: GAD, GCD, and AD. Heterogeneity will be assessed using Cochran's Q test and the I^2 statistic.
Exploratory funnel plots will be used to evaluate potential publication bias when fewer than 10 studies are available. Egger's test will not be performed because of insufficient statistical power. Sensitivity analyses will be conducted using the leave-one-out approach.
The findings will be interpreted considering the magnitude of pooled effects, confidence intervals, heterogeneity, sensitivity-analysis results, and the certainty of evidence assessed using GRADE. Statistical significance will be considered at $P < 0.05$.

Subgroup analysis Formal subgroup analyses or meta-regression are not planned because the number of included studies contributing to each comparison is limited, which may prevent robust subgroup analysis. Potential sources of clinical and methodological heterogeneity will be explored descriptively, including implant site, jaw, timing of implant placement, flap or flapless protocol, conventional versus zygomatic implant placement, navigation system, operator experience, measurement method, guide support, and static-guide protocol (fully guided, partially guided, or pilot-drill-only). These characteristics will be considered when interpreting the pooled results and the observed heterogeneity.

Sensitivity analysis Sensitivity analyses will be performed using the leave-one-out approach. Each included study will be sequentially excluded from the meta-analysis to assess the influence of individual studies on the pooled standardised mean difference (SMD), 95% confidence interval (CI), statistical significance, and heterogeneity.
The stability of the pooled estimates will be evaluated by examining changes in the direction and magnitude of the effect, confidence intervals, and I^2 statistics following the exclusion of individual studies. Particular attention will be given to analyses showing substantial heterogeneity or potential influence from individual studies. The sensitivity-analysis findings will be considered when interpreting the robustness of the evidence and the certainty of the pooled estimates.
Results will be interpreted cautiously if the pooled effects are sensitive to the exclusion of individual studies.

Country(ies) involved China.

Keywords Dental Implantation, Endosseous; Dental Implants; Surgery, Computer-Assisted; Dynamic Navigation; Static Guide; Dimensional Measurement Accuracy.

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