Accuracy And Effectiveness Of Robotic Implant Placement Compared To Static And Dynamic Navigation Systems: An Umbrella Review

Dr. Gaurang S. Mistry[1] , Dr. Mayuri Bacchav[2] , Dr. Sheetal Parab[3] , Dr. Amit Pokharkar[4] , Dr. Vibha Kailaje[5] , Dr. Shantanu Ladhe[6]

[1]M.D.S Affiliation: Department of Prosthodontics DY Patil University School of Dentistry, Nerul, Navi Mumbai, Maharashtra, India. Email: gaurang.mistry@dypatil.edu
[2]M.D.S Department of Prosthodontics DY Patil University School of Dentistry, Nerul, Navi Mumbai, Maharashtra, India. Email: mayuri.bachhav@dypatil.edu
[3]M.D.S Department of Prosthodontics DY Patil University School of Dentistry, Nerul, Navi Mumbai, Maharashtra, India. Email: sheetal.parab@dypatil.edu
[4]M.D.S Department of Prosthodontics DY Patil University School of Dentistry, Nerul, Navi Mumbai, Maharashtra, India. Email: amit.pokharkar@dypatil.edu
[5]Academic Qualification: M.D.S Department of Prosthodontics DY Patil University School of Dentistry, Nerul, Navi Mumbai, Maharashtra, India. Email: vibha.kailaje@dypatil.edu
[6]Academic Qualification: PG 2nd Year (MDS Prosthodontics) Department of Prosthodontics DY Patil University School of Dentistry, Nerul, Navi Mumbai, Maharashtra, India. Email: shantanuladhe21@gmail.com
Corresponding Authors' Details:
Dr. Shantanu Ladhe
Mailing address: Room No.01, Malvika Society, RM-03, Ganpati Visarjan Talao Road, Milapnagar, MIDC Phase 2, Dombivali East- 421203 Email: shantanuladhe21@gmail.com

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Abstract

Background: Robot-assisted computer-aided implant surgery (R-CAIS) is an emerging advancement in digital implantology, proposed to enhance placement precision beyond established computer-assisted modalities such as static guides (s-CAIS) and dynamic navigation (d-CAIS). However, the rapid expansion of systematic evidence necessitates higher-order synthesis to clarify comparative accuracy and clinical implications.

Objective: To evaluate the accuracy and effectiveness of robotic implant placement compared with static guidance, dynamic navigation, and freehand techniques using an umbrella review of systematic evidence.

Methods: An umbrella review was conducted following PRIOR guidelines, with protocol registration in PROSPERO (CRD420251066754). PubMed, Embase, Scopus, Web of Science, Cochrane Database of Systematic Reviews, and Google Scholar were searched through June 2025. Eligible studies were systematic reviews with meta-analysis that evaluated R-CAIS (semi-active or autonomous systems) versus s-CAIS, d-CAIS, or freehand placement and reported quantitative accuracy outcomes (coronal, apical, and/or angular deviations). Overlap was quantified using Corrected Covered Area (CCA). Methodological quality was appraised using AMSTAR-2, and certainty of evidence was assessed using GRADE where feasible.

Results: From 1,226 records, eight systematic reviews with meta-analysis (2023-2025) were included [19-26]. Collectively, they synthesized 195 unique primary studies and approximately 18,100 implant placements (9,066 in vitro; 9,044 clinical). Across reviews, R-CAIS showed consistently lower coronal and apical deviations and reduced angular deviation (≈1.5-1.8°), with pooled angular mean differences favoring robotics ranging from −1.22° to −1.58° versus navigated comparators.

Overlap was moderate (CCA 6.8%). Five reviews were high quality by AMSTAR-2, and GRADE certainty (available for two reviews) ranged from low to moderate.

Conclusions: Current synthesized evidence indicates that R-CAIS provides superior implant placement accuracy compared with s-CAIS, d-CAIS, and freehand techniques, although higher-certainty clinical trials with standardized outcomes and broader effectiveness endpoints are needed to guide implementation.

Introduction

The field of dental implantology experienced a transformation during the last thirty years because of digital diagnostic tools and computer-assisted planning systems and modern surgical techniques which work together to create implant placement methods that focus on precise prosthetic outcomes [1]. The main progress of computer-assisted implant surgery (CAIS) solves freehand placement problems through its ability to minimize human mistakes and enhance surgeons' ability to see during posterior surgeries and safeguard essential body structures [2]. The CAIS system uses R-CAIS as its main innovation because it performs robot-assisted implant placement which goes past navigation system guidance to execute preoperative plans through mechanical automation during real-time procedures [3,4].

The three fundamental elements which ensure freehand implant placement success include tactile feedback and spatial judgment and intraoperative visibility. The planned trajectory shows major angular and linear deviations when experienced clinicians perform implant placement according to [5,6]. The deviations between planned and actual bone positions create negative effects on primary stability and prosthetic fit and esthetic results and increase the risk for complications in the areas surrounding the maxillary sinus and inferior alveolar canal and adjacent teeth [6]. The stereolithographic drill guides which doctors used for CBCT-based planning enabled them to achieve higher precision when identifying both the entry point and osteotomy path [7]. The operation of static systems becomes restricted because they maintain fixed positions which can lead to error transmission when guide placement or stability or anatomical support becomes unstable.

The Dynamic navigation system provided surgeons with real-time instrument position feedback through tracking which expanded their surgical abilities and allowed them to adjust their technique based on anatomical or restorative needs during procedures [8]. The operation of dynamic systems continues to face challenges because operators must deal with three main factors which affect their performance: the need to coordinate their hands with their eyes and the process of learning new systems and the physical effects of operator fatigue [9]. Digital implant surgery has robotic systems as its future development through two main categories which include semi-active haptic platforms and fully autonomous robotic arms [10,11].

Semi-active systems (e.g., Yomi®) enable drilling operations to remain within a specific virtual space which maintains both precise spatial positioning and doctor-controlled force and depth control [12]. The Remebot® YakeBot® DentRobot® operate as fully autonomous systems which perform drilling operations through automated processes after users complete the registration process to minimize human interference during operations. The systems have the potential to decrease human errors which cause deviations while they help establish standardized workflows and improve workplace comfort [13,14]. The primary assessment method for adoption effectiveness requires researchers to use CBCT-based superimposition and STL overlays and proprietary registration software which enables them to measure implant positioning accuracy through coronal (entry) and apical and angular deviations [11-14].

The interpretation of evidence faces difficulties because previous systematic reviews have analyze different robotic systems and autonomous operation levels and different study designs which combine clinical and in vitro model research [10]. The evaluation of surgical performance depends on multiple outcome measures which include accuracy but also operative time and complications and learning curve and patient-centered results and cost-effectiveness data [15]. There is a need for advanced synthesis methods to merge systematic evidence that shows how different systems compare to each other. The present umbrella review presents the first comprehensive analysis of the published systematic reviews which have examined R-CAIS and its performance relative to other CAIS systems to help healthcare professionals choose cases and determine training needs and develop new technology.

Protocol and Reporting Standards

This umbrella review was planned and conducted in accordance with the Preferred Reporting Items for Overviews of Reviews (PRIOR) guidance to ensure transparency, reproducibility, and methodological rigor in the synthesis of systematic evidence. The protocol was developed before conducting the review and prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD420251066754.

Review Design and Objectives

An umbrella review design was adopted to consolidate and critically appraise findings from existing systematic reviews, with or without meta-analysis, that evaluated robotic implant placement in comparison with established computer-assisted implant surgery modalities. The primary objective was to synthesize the highest level of available evidence regarding the placement accuracy of robot-assisted computer-aided implant surgery (R-CAIS) relative to static CAIS (s-CAIS), dynamic CAIS (d-CAIS), and freehand implant placement. Accuracy outcomes were operationalized as quantitative deviations between planned and achieved implant positions, focusing on coronal (entry-point) deviation, apical deviation, and angular deviation as reported by the included reviews. Secondary objectives were to capture additional procedural outcomes, including operative time, intra-operative complications, and other clinically relevant performance indicators when such data were available and explicitly reported.

Eligibility Criteria

Eligible publications were peer-reviewed systematic reviews, with or without meta-analytic pooling, that applied explicit systematic methods to identify, appraise, and synthesize primary studies evaluating robotic implant placement. Reviews were required to include robot-assisted systems using either semi-active haptic guidance (for example, systems that constrain drill motion within a virtual envelope while retaining clinician control) or fully autonomous robotic platforms that execute drilling steps following registration and plan transfer. To ensure interpretability of comparative performance, included reviews needed to evaluate R-CAIS against at least one relevant comparator, namely static guidance using CAD/CAM-derived surgical guides, dynamic navigation using tracked instrumentation with real-time visualization, and/or conventional freehand placement. Reviews were eligible if they synthesized human clinical evidence and/or in vitro model studies simulating implant placement, provided that accuracy outcomes were quantified in millimetres and/or degrees. Only English-language articles published up to June 2025 were considered. Reviews were excluded when they were narrative, scoping, or integrative in nature; when robotic systems were not isolated or distinguishable from broader CAIS categories in the analysis; when publications were limited to abstracts, editorials, letters, or protocols without results; or when quantitative accuracy outcomes were not reported in a form suitable for extraction.

Information Sources and Search Strategy

A comprehensive literature search was conducted across PubMed, Embase, Scopus, Web of Science, the Cochrane Database of Systematic Reviews, and Google Scholar, with the final search update completed in June 2025. The strategy combined controlled vocabulary terms (where applicable) and free-text keywords related to robotic implant placement and navigation technologies, alongside filters to retrieve systematic reviews and meta-analyses. Core concepts included robotic assistance (including platform-specific terms such as Yomi and Remebot), implant placement, static and dynamic navigation, and accuracy outcomes (including angular and linear deviation). To maximize sensitivity, synonym variations and truncation were applied, and Boolean logic was used to link robotic and navigation concepts with evidence-synthesis terms. In addition to database searching, the reference lists of all included reviews were screened to identify potentially eligible reviews not captured through electronic searches. PROSPERO records were also examined to identify completed reviews that may not yet have been indexed comprehensively in bibliographic databases.

Study Selection and Inter-reviewer Agreement

Study selection was performed in a staged process designed to ensure consistency and minimize selection bias. All retrieved records were imported into reference management software and duplicates were removed before screening commenced. Two reviewers independently screened titles and abstracts against the predefined eligibility criteria, excluding records that were clearly irrelevant to robotic implant placement or did not represent systematic evidence. Full texts were obtained for all records considered potentially eligible and were assessed independently by the same reviewers to confirm inclusion. During full-text assessment, particular attention was given to whether the review employed systematic methods, explicitly included robotic systems, clearly identified comparator modalities, and reported extractable quantitative accuracy outcomes. Disagreements were resolved through discussion to reach consensus, and a third senior reviewer adjudicated when consensus could not be achieved.

Assessment of Overlap of Primary Studies

Because umbrella reviews are susceptible to redundancy arising from the same primary studies being included in multiple systematic reviews, overlap was explicitly assessed to reduce the risk of double-counting and over-weighting replicated evidence. A citation matrix was constructed to map the presence of each primary study across the included reviews using the Elicit systematic review ttool. The degree of overlap was quantified using the Corrected Covered Area (CCA), calculated as: $CCA = [(Nc \times Ns) - Ns] / [Nr - Ns]$, where Nc represents the number of included reviews, Ns represents the number of unique primary studies, and Nr represents the total number of primary-study occurrences across all reviews (including repeated occurrences). The magnitude of overlap was interpreted using conventional thresholds, with values below 5% indicating slight overlap, 5% to 10% indicating moderate overlap, and values above 10% indicating high overlap. When substantial overlap was identified, interpretive emphasis was placed on the most comprehensive and/or most recent synthesis to reduce redundancy, and conclusions were framed with explicit caution to avoid inadvertently inflating confidence due to repeated inclusion of the same primary evidence.

Data Extraction and Data Management

Data extraction was conducted using a structured, piloted Excel-based form developed specifically for this umbrella review. Two reviewers independently extracted and cross-checked data to ensure accuracy and completeness. Extracted information included bibliographic details, review characteristics (including whether meta-analysis was performed and whether PROSPERO registration was reported), search coverage and database sources, and the scope of included primary studies (including the number of studies and implants and whether evidence derived from clinical settings, in vitro simulations, or both). Intervention-specific details were captured to facilitate meaningful interpretation across heterogeneous robotic platforms, including whether the robotic system was semi-active or autonomous and, where reported, the tracking/registration approach. Comparator modalities were recorded as static, dynamic, and/or freehand placement. Outcome extraction focused on coronal deviation, apical deviation, and angular deviation, along with the measurement modality used (such as CBCT-based superimposition, STL overlay, or proprietary matching software). When available, secondary outcomes such as operative time and complications were extracted, recognizing that definitions and reporting thresholds may vary across reviews. Meta-analytic characteristics were also extracted where applicable, including model choice (fixed or random effects), heterogeneity metrics such as I^2, pooled effect estimates with confidence intervals, and the risk-of-bias tools applied by review authors to primary studies. Any discrepancies in extracted information were resolved through consensus discussion, with reference to the source text for verification.

Data Synthesis and Presentation of Results

Given the umbrella review objective of synthesizing existing systematic evidence while minimizing bias from overlapping primary data, no de novo meta-analysis was performed. Instead, findings were synthesized narratively and presented through structured cross-review comparisons, allowing interpretation of consistency, direction of effects, and context-specific performance without introducing statistical dependence from duplicated primary studies. The synthesis was organized to reflect clinically meaningful contrasts by first structuring evidence according to comparator type, enabling separate consideration of robotic performance relative to freehand placement, static guidance, and dynamic navigation. Because accuracy estimates from model-based studies often occur under controlled conditions that differ materially from clinical surgery, outcomes were presented separately for clinical and in vitro contexts whenever the included reviews allowed segregation; when reviews pooled these contexts, results were interpreted with explicit attention to indirectness and differences in external validity. Accuracy outcomes were interpreted within their reported metric frameworks, with coronal and apical deviations considered as linear measures of positional discrepancy and angular deviation considered as a measure of trajectory misalignment. Secondary outcomes, when reported, were synthesized qualitatively with attention to definitional heterogeneity, such as variations in how operative time was measured or how complications were ascertained and reported.

Methodological Quality Appraisal of Included Reviews

The methodological quality of each included systematic review was independently assessed using AMSTAR-2 (A MeaSurement Tool to Assess Systematic Reviews). Critical and non-critical aspects of review conduct, including protocol registration, adequacy and reproducibility of the search strategy, duplicate screening and extraction, transparency of exclusions, appropriateness of risk-of-bias assessment in primary studies, and whether risk of bias and heterogeneity were appropriately considered when interpreting the quality of each included systematic review. Each AMSTAR-2 item was rated according to the tool's guidance and synthesized into an overall confidence rating of high, moderate, low, or critically low. Two reviewers completed AMSTAR-2 assessments independently, and discrepancies were resolved through discussion to achieve consensus. The quality ratings were used to contextualize strength of inferences across reviews, with particular caution applied when conclusions relied heavily on reviews with critical methodological limitations.

Certainty of Evidence Assessment and Summary of Findings

The certainty of evidence for key accuracy outcomes was evaluated using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach. Certainty judgments considered risk of bias (based on the quality of the primary studies as assessed within the included reviews), inconsistency (including unexplained heterogeneity across studies), indirectness (including differences between clinical and model contexts and variability in robotic platforms and workflows), imprecision (including wide confidence intervals and limited effective sample sizes), and publication bias (when suggested by asymmetry, small-study effects, or selective reporting concerns as described by review authors). When GRADE ratings were already provided within an included review, these ratings were extracted and reported alongside their stated rationale. Otherwise, GRADE judgments were applied at the outcome level using the extracted information available from each review. Certainty was categorized as high, moderate, low, or very low, and these ratings were used to frame conclusions regarding whether observed differences in robotic accuracy were likely to be clinically meaningful and reliable.

Results

A total of 1 226 records were retrieved from the electronic and hand searches. After removal of duplicates and title/abstract screening, 31 full texts were examined in detail; 23 were excluded because they were narrative overviews, conference papers or lacked a robotic arm comparator. Eight systematic reviews with meta-analysis met all eligibility criteria and were synthesised in this umbrella review (Figure 1) [19-26]. The data extracted from these systematic reviews is collectively summarized in the Master Chart (Annexure 1).

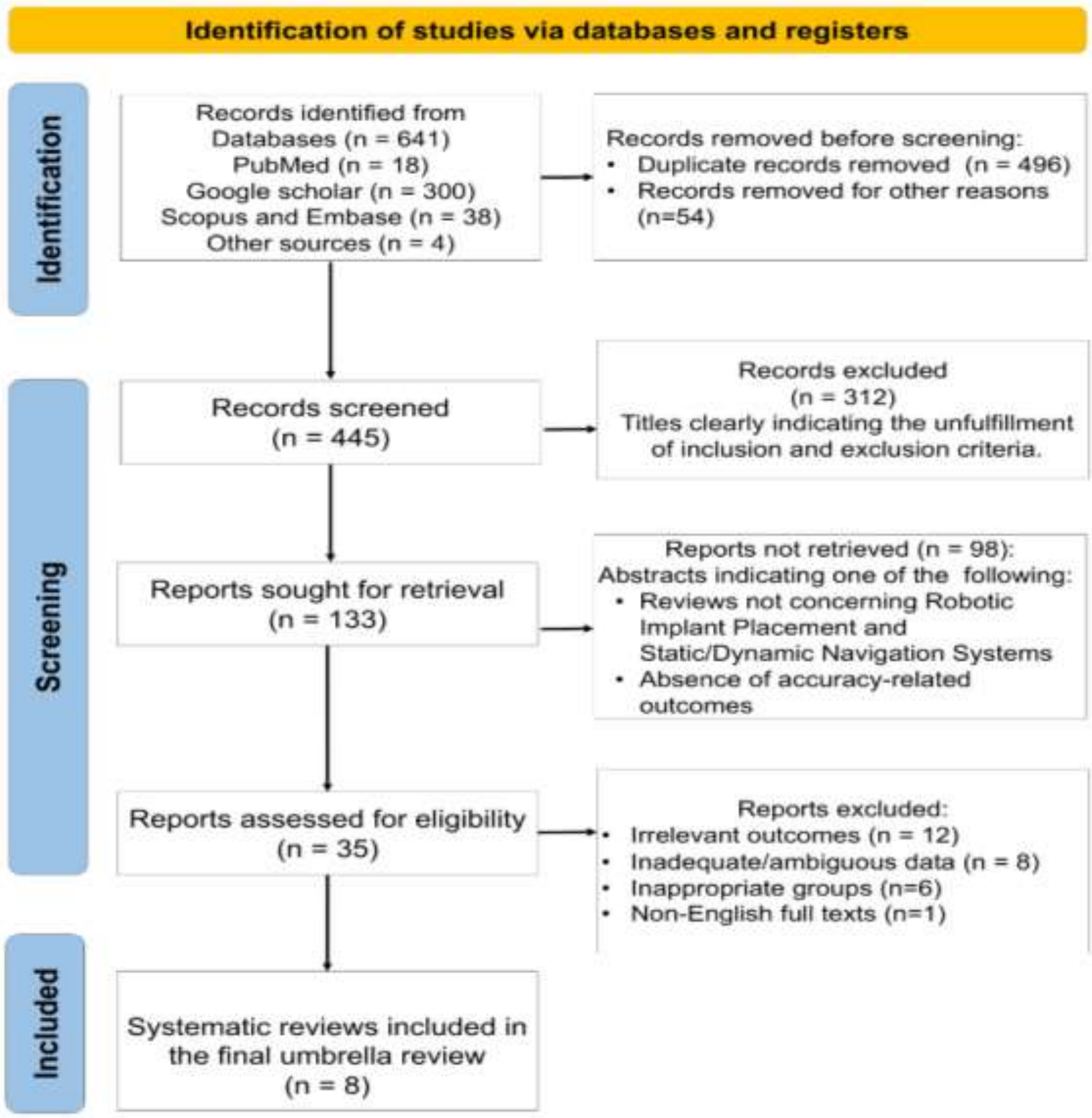


Figure 1: PRISMA Flow diagram

Characteristics of the included reviews

The eight reviews were published between 2023 and 2025 and were produced by teams based in China (n = 3), Thailand (n = 2), Saudi Arabia (n = 1), Pakistan (n = 1) and India (n = 1) [19-26]. All were full systematic reviews that incorporated quantitative pooling; seven had a prospectively registered protocol in PROSPERO. Search windows extended from January 2000 to October 2024, and all reviews drew on at least three major databases (median = 4; range = 3-6) plus hand-searching.

Collectively the reviews included 195 unique primary studies (range per review 5-67), analysing approximately 18,100 implant placements. Of these placements 9 066 were in vitro (phantom or resin models) and 9,044 were clinical in vivo insertions. The clinical data covered single-tooth sites, partially edentulous spans, and full-arch reconstructions; most in-vitro models simulated full arches.

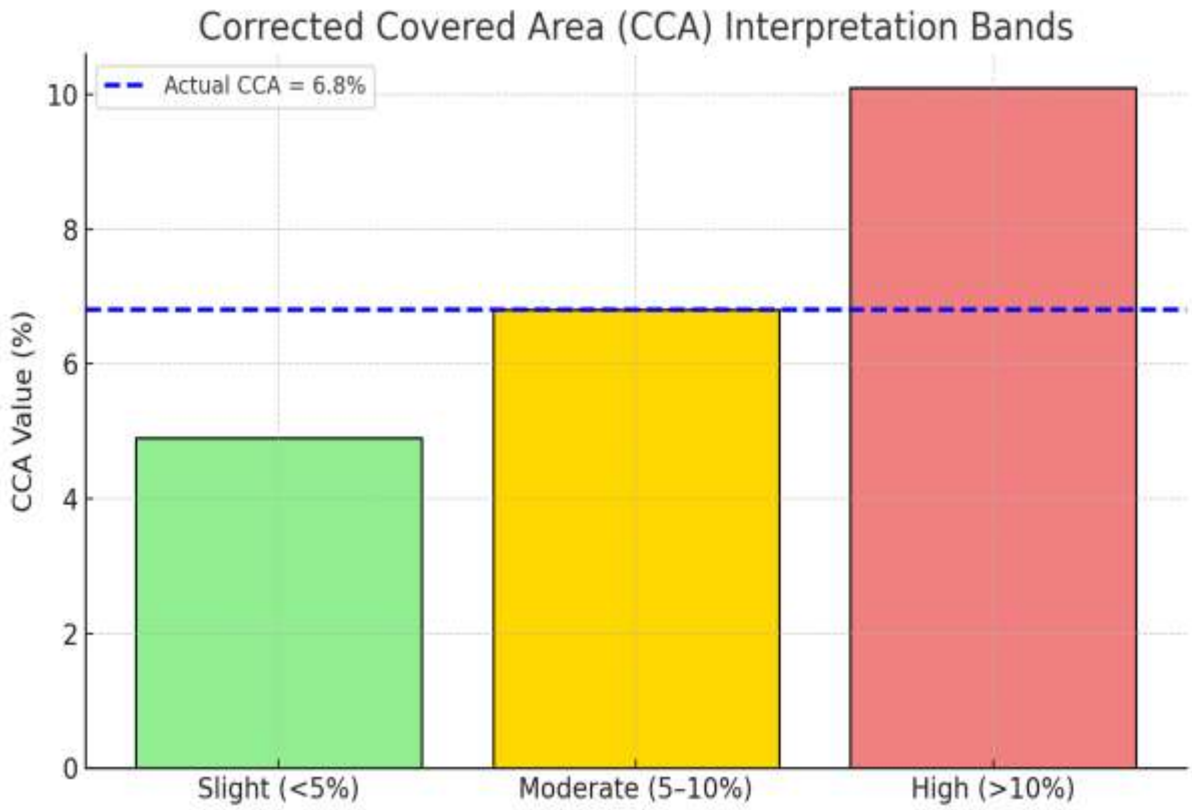
All reviews evaluated robot-assisted computer-assisted implant surgery (R-CAIS) [19-26]. The systems most frequently reported were Yomi® (semi-active haptic guidance) and Remebot® (task-autonomous arm), followed by YakeBot, THETA, Langyue, DentRobot and several research prototypes. Static CAIS (template-guided drilling) and dynamic CAIS (optical or electromagnetic real-time navigation) were the common comparators, and five reviews also incorporated conventional freehand placement. Robotic platforms used either mechanical encoders or optical/infrared cameras for tracking; static guides were almost invariably SLA-printed resin sleeves; dynamic navigation relied on LED or reflective marker arrays.

Accuracy outcomes

Despite methodological heterogeneity, findings were highly consistent. Robotic linear errors averaged 0.60-0.81 mm coronally and 0.67-0.80 mm apically in clinical series, versus 1.0-1.4 mm for static or dynamic navigation and ≥2 mm for freehand placement. Robotic angular deviation clustered around 1.5-1.8°, roughly half that reported for dynamic navigation (3°) and a quarter of that seen with static guides or freehand (4-6°). Every meta-analysis that directly compared R-CAIS with dynamic or static CAIS showed a statistically significant reduction in at least one deviation metric favouring robotic assistance; the pooled mean difference for angular error ranged from -1.22° to -1.58°. No review reported serious intra-operative complications attributable to the robot; two reviews noted slightly longer set-up times but similar drilling times once calibration was complete.

Corrected Covered Area Analysis

To evaluate the degree of redundancy among the included systematic reviews, a citation matrix was constructed to assess the overlap of primary studies. Across the eight included reviews, a total of 195 unique primary studies were identified. Among these, 49 studies were shared across two or more reviews. The CCA was 6.8%, which corresponds to a moderate level of overlap based on established interpretation thresholds. This indicates that while some duplication of primary evidence occurred, it was not excessive. The overlap was primarily seen in studies involving the Yomi® semi-active robotic system, particularly in in vitro accuracy evaluations, where a few high-impact trials were repeatedly included across reviews. The presence of moderate overlap justified careful management of evidence during synthesis. In instances where duplicate primary studies were identified, findings were extracted from the most comprehensive and highest-quality review to minimize undue weighting and ensure the reliability of conclusions.



Risk of bias assessment:

Citation	**1. Protocol Registered**	**2. Adequate Search Strategy**	**3. Justification for Exclusions**	**4. RoB Assessed**	**5. Duplicate Selection/Data Extraction**	**6. Study Characteristics Reported**	**7. Meta-Analysis Methods Appropriate**	**8. Publication Bias Assessed**	**9. Consideration of RoB in Interpretation**	**10. Conflict of Interest Disclosed**	**Overall AMSTAR-2 Rating**
Jain (2023)[19]	Yes	Yes	Partial Yes	Yes	Yes	Yes	Yes	No	Partial Yes	Yes	Moderate
Khan (2024) [20]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	High
Khahoehn (2024)[21]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Partial Yes	Yes	Yes	High
Wu (2024) [22]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Yang (2024) [23]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Moderate
Khahoehn (2025) [24]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Luo (2025) [25]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Sankar (202	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Moderate

5) [26]											

Out of the eight reviews, five were rated as high quality which consistently fulfilled all critical domains, including a priori protocol registration, application of rigorous selection and extraction procedures, comprehensive risk-of-bias evaluation, and appropriate meta-analytical techniques where applicable [20-22,24,25]. Furthermore, they addressed potential publication bias and disclosed conflicts of interest, reinforcing their methodological robustness.

The remaining three reviews were assigned a moderate AMSTAR-2 rating [19,23,26]. Their limitations included absence of protocol registration [23,26], Lack of publication bias assessment which undermines transparency and pre-defined methodological rigor [19,26], and Inapplicability of meta-analysis methods [26]. Notably, none of the included reviews were rated as critically low, and all fulfilled the essential standards for duplicate screening and data extraction, adequate search strategy, reporting of included study characteristics, and conflict of interest declaration. Risk-of-bias assessments in primary studies were uniformly present, and in most cases, their implications were reflected in the discussion and interpretation of review findings.

Certainty of evidence

Summary of Findings Table (GRADE)

Comparison	**Outcome**	**Effect Summary**	**Certainty of Evidence**	**Reasons for Downgrade**
Robot vs. Dynamic Navigation	Coronal deviation	Mean difference −0.42 mm in favor of robot	Moderate	Inconsistency ($I^2 > 60\%$)
	Apical deviation	Mean difference −0.39 mm in favor of robot	Moderate	Indirectness (many in vitro trials)
	Angular deviation	Mean difference −1.22° in favor of robot	Moderate	Imprecision (broad CIs in subgroup analyses)
Robot vs. Static Guide	Coronal deviation	Mean difference −0.78 mm in favor of robot	Low	Inconsistency, RoB in primary studies
	Apical deviation	Mean difference −0.75 mm in favor of robot	Low	Same as above
Robot vs. Freehand	Angular deviation	Mean difference −3.5° in favor of robot	Moderate	Imprecision
Robot vs. Static/Freehand	Operative time	Longer setup; drilling time similar across groups	Low	Heterogeneous measurement, lack of blinding

Of the eight systematic reviews included in this umbrella review, only two provided sufficient detail to enable GRADE-based certainty assessment [22,24]. The outcomes assessed included coronal deviation, apical deviation, and angular deviation. Overall, the GRADE-based evaluation indicated that robot-assisted implant systems provide superior accuracy compared to dynamic and conventional techniques, though the overall certainty of evidence ranged from low to moderate [18]. Variability in study design, outcome measurement, and patient populations contributed to downgrades. These findings support the growing confidence in robotic systems while highlighting the need for high-quality, adequately powered clinical trials with standardized outcome reporting to strengthen the evidence base.

Discussion

DISCUSSION

This umbrella review consolidates recent systematic evidence indicating that robot-assisted computer-aided implant surgery (R-CAIS) achieves consistently higher placement accuracy than static guidance, dynamic navigation, and freehand techniques. Across the eight included systematic reviews with meta-analysis, robotic systems demonstrated mean coronal deviations of approximately 0.60–0.81 mm and apical deviations of 0.67–0.80 mm in clinical settings, with angular deviations typically around 1.5–1.8° [19-26]. In comparison, dynamic navigation and static guides generally showed larger deviations, while freehand placement frequently exceeded 2 mm linearly and 4–6° angularly. Although in vitro studies tended to report smaller absolute deviations because they eliminate patient-related variables, the relative advantage of robotic systems remained consistent across both laboratory and clinical contexts [19-26]. This pattern is clinically relevant because small angular errors can translate into meaningful apical displacement and prosthetic emergence discrepancies, especially in prosthetically driven cases where precision directly influences esthetics, occlusion, and long-term biomechanical stability [27-28].

A key explanation for this accuracy advantage appears to be the way robotic systems reduce manual variability during osteotomy preparation. Semi-active haptic systems such as Yomi® physically constrain the drill path within a planned virtual envelope, thereby limiting off-axis movements while still allowing the clinician to control force and depth [29,30]. Fully autonomous platforms such as Remebot® reduce intraoperative hand-dependent variability further by executing drilling steps after registration, potentially minimizing tremor- and fatigue-related drift [31]. In contrast, static guides remain sensitive to cumulative errors originating from planning, manufacturing tolerances, and guide stability, and any minor seating discrepancy may propagate into clinically relevant positional error [32]. Dynamic navigation, while flexible, depends on continuous hand–eye coordination and real-time manual correction; therefore, micro-deviations can accumulate, particularly in restricted access areas or multi-implant procedures [33].

From a practical standpoint, improved accuracy with robotics may be most impactful near critical anatomy, where sub-millimetre control can reduce the margin of error around the inferior alveolar nerve, maxillary sinus, or incisive canal [34]. It also has implications in full-arch or tilted implant protocols, where maintaining planned angulation across multiple implants is essential for passive prosthetic fit and favorable load distribution [35,36]. The reviewed evidence also suggests that major robot-attributable intraoperative complications are uncommon, while setup time may be longer despite similar drilling time once calibration is completed [37-39]. This indicates that workflow costs may lie mainly in preoperative and registration steps rather than the surgical drilling phase.

Despite encouraging findings, the certainty of conclusions is influenced by the current evidence profile. A substantial proportion of pooled data remains in vitro, which introduces indirectness when extrapolating to real-world clinical performance [40]. In addition, cost and infrastructure requirements remain important constraints and likely justify adoption primarily in high-volume or complex-case settings where incremental accuracy gains carry greater clinical value [41,42]. Overall, the methodological quality of the included reviews was generally strong, but GRADE certainty ranged from low to moderate in key comparisons, reinforcing the need for well-designed multicenter clinical trials with standardized measurement protocols and broader outcomes beyond deviations, including complications, learning curves, and patient-reported endpoints.

Conclusion

This umbrella review indicates that robotic implant placement achieves consistently higher positional accuracy than static guides, dynamic navigation, and freehand techniques, with the clearest advantage in reducing angular deviation. While the overall evidence supports robotics as a precision-enhancing approach in digitally guided implantology, stronger multicenter clinical studies with standardized reporting and broader outcomes are still needed to guide routine adoption.

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