In Vivo Accuracy of Autonomous Dental Implant Robotic Surgery: Systematic Review and Meta-analysis

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Purpose: To systematically analyze the accuracy of autonomous dental implant robotic (ADIR) surgery for dental implant placement. ***Materials and Methods:*** PubMed, Embase, and Cochrane CENTRAL were searched on February 21, 2024. Any clinical studies, with the exception of case reports, assessing ADIR accuracy by superimposing preoperative digital planning with postoperative CBCT images were included. The risk of bias was assessed, and a meta-analysis was performed using a random-effects model to evaluate linear and angular deviations between planned and placed implants. ***Results:*** Data from six clinical studies reporting ADIR accuracy in 96 patients with 299 dental implants were included (102 implants in 69 partially edentulous patients, 197 implants in 27 complete-arch scenarios). The meta-analysis at the implant level reported a mean overall accuracy of ADIR of 0.60 mm (95% CI [0.5133; 0.6965]) at the platform and 0.63 mm (95% CI [0.5663; 0.6909]) at the apex and 1.242 degrees (95% CI [1.2182; 1.6320]) of angular deviation. ADIR accuracy resulted in significantly higher values than static and dynamic computer-assisted implant surgery. ***Conclusions:*** Within the limitations of this review, ADIR surgery has shown to be feasible for placing implants in both partially and completely edentulous patients, achieving consistent mean linear and angular deviations of approximately 0.6 mm and 1.40 degrees, respectively. However, clinical practicality of ADIR surgery remains cumbersome, with well-trained operators needed to plan and assist ADIR procedures as well as a technical expert providing backup control. *Int J Oral Maxillofac Implants 2025;40:683–690. doi: 10.11607/jomi.11238.*

Keywords: accuracy, autonomous dental implant robotic surgery, dental implant, digital dentistry, implant guides, meta-analysis, robotic surgery

Continuous technologic development of computer-assisted implant surgery (CAIS) over the last two decades has enabled clinicians to achieve more predictable and accurate implant placements.[1] Low deviations in respect of implant planned coordinates are considered essential for delivering a successful prosthetic design, closely related to peri-implant health maintenance.[2–4] CAIS can be categorized into three different technologies: *(1)* static (s-CAIS), *(2)* dynamic (d-CAIS), and *(3)* robotic (r-CAIS).[5]

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The s-CAIS approach uses removable 3D printed surgical templates with solid sleeves that guide the sites' preparation and implant placement.[6] Conversely, d-CAIS dynamically tracks the motion of two dynamic reference frames, one that firmly secures to the patient's anatomy (teeth or bone) and one that's rigidly attached to the surgical handpiece. The tracked data are computed and displayed in real time to assist surgical drilling accordingly to planned implant coordinates without the need of a physical template that might obstruct the surgical field.[7]

While both s-CAIS and d-CAIS achieve significantly lower deviations compared to the freehand technique, certain limitations in their clinical application can compromise the overall accuracy.[8,9] Robotics in implant surgery was gradually introduced to address these limitations and enhance clinical procedures.[10] The r-CAIS integrates various advanced technologies such as artificial intelligence (AI), machine vision, multi-sensor information dataset fusion, and 3D graphics visualization.[11]

Yang et al[12] classified six levels of autonomy for medical robotics. The r-CAIS involves the use of an operator-controlled (level 1 or semi-active) or an autonomous robotic arm (level 2 or autonomous dental implant robotic [ADIR]) for both osteotomy preparation and implant placement.[13] In level 1, the robot offers semi-active control, providing mechanical support or guidance while the surgeon maintains control over the robot's actions. The robotic arm, controlled by the operator, is maneuvered in and out the patient's mouth to the implant recipient site. This setup allows the robot to manage angular adjustments while the surgeon oversees the speed and force applied during drilling and implant placement. In level 2, the robot has autonomy in drilling and implant placement, it can execute specific pre-defined subtasks while the surgeon is assisting, and it can provide a backup control through a dedicated computer screen.[14] The robotic arm can autonomously enter the patient's mouth, reach the target coordinates, and exit following the reversed trajectory in an autonomous manner.

The autonomous movement of the robot relies on multiple factors: *(1)* the surgeon establishing the initial and final points for the robot's motion based on information from the bone and mucosa within the software; *(2)* the robot and jaws are connected within the infrared visual space; and *(3)* the robot executes surgical procedures following a predetermined path under the guidance of infrared vision.[10]

ADIR surgery, which minimizes the operator influence, can accurately perform implant drilling and placement under visual-force feedback cooperative control, thereby standardizing the clinical performance regardless type of edentulism, the type of jaw, and other site characteristics. However, there has been no systematic assessment of ADIR accuracy published to date. Therefore, this systematic review and meta-analysis aimed to analyze a substantial body of evidence on ADIR surgery accuracy in vivo and provide a high-quality, valuable summary for clinicians.

MATERIALS AND METHODS

Protocol and Registration

This review was registered at the International Prospective Register of Systematic Review (PROPERO) of the National Institute of Health Research (registration no.: CRD42024511771). This review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines.[15] Ethical approval was not required for this systematic review.

Population, Intervention, Comparison, Outcomes, and Study Design

The question of the research was reported in the population, intervention, comparison, outcomes and study design (PICOS) format:

- **P** *(population)*: patient treated with dental implant
- **I** *(intervention)*: implant placement using r-CAIS ADIR
- **C** *(comparison)*: preoperative planned implant on software
- **O** *(outcomes)*: accuracy of implant placement
- **S** *(study design)*: clinical studies including randomized clinical trials (RCTs), prospective trials, retrospective trials, and case series' (case reports were excluded)

Inclusion Criteria

The inclusion and exclusion criteria were defined before the start of the study. The inclusion criteria were as follows: *(1)* studies published in the English language, *(2)* based on human subjects with at least 10 patients, *(3)* reported accuracy of implant placed by ADIR systems, *(4)* the main research subject had to evaluate the accuracy in terms of linear (mm) and angular (degrees) deviations between planned and placed implants by means of ADIR. All the analyzed studies were published until February 24, 2024. The exclusion criteria were as follows: *(1)* studies that reported the same data as later publications by the same authors; or *(2)* systematic reviews, commentaries and letters to the editor, case reports, in vitro studies, and studies in animal models. Relevant systematic reviews, as well as the reference lists of all included articles, were searched by hand to identify further publications.

Search Strategy

Electronic research was performed involving different databases (MEDLINE, PubMed, Embase, and Cochrane Library) without any limitation for publication year. The electronic search syntax in MEDLINE and PubMed, Embase, and Cochrane CENTRAL were: "(robotic surgery[Title/Abstract] AND (dental implant [MeSH Terms])", "robotic surgery*:ab,ti AND dental implant*:ab,ti", "robotic surgery* AND dental implant*" in title/abstract/keywords, respectively. Moreover, bibliographies of relevant systematic reviews were analyzed to cross-check the data. Additionally, a manual search of the reference lists of included studies and examinations of meeting abstracts related to the PICOS question was executed.

Selection Criteria

A full-text screening, study selection, and data extraction was performed in duplicate by two reviewers independently (P.C. and C.L.). The inter-reviewer reliability (kappa [κ] correlation coefficient) of the title/abstract screening and full-text screening was 0.84 and 0.86, respectively. Any disagreement was discussed until it was resolved by consensus.

Data Extraction

Following the PICOS question, data on accuracy evaluation (O)—in terms of differences at the implant

Fig 1 Accuracy evaluation superimposing preoperative CBCT digital planning with postoperative CBCT outcome.

platform, apex and main axis between the planned and the final implant coordinates (C)—were extracted from the included clinical trials (S) on human subjects (P) treated by means of ADIR (1) (Fig 1).

Risk of Bias

The quality of the included studies was assessed independently by the authors (C. L. and P. C.) using the Newcastle-Ottawa scale[16] for non-randomized clinical trials. The Newcastle-Ottawa Scale was an eight-item tool that provides a rating system ranging from 0 to 9 stars, on "selection", "comparability" and "outcome". Scores ≥ 7 can be considered high quality and scores < 7 were considered as low quality. Any disagreement was discussed until it was resolved by consensus.

Outcomes

- Global platform deviation (mm): overall 3D distance between the platform centroids of the planned and placed implants
- Global apical deviation (mm): overall 3D distance between the apex centroids of the planned and placed implants
- Angular deviation (degrees): angle formed by the vertical axes of the planned and placed implants

Statistical Analysis

Meta-analyses were performed using the random-effect model to evaluate the deviations between planned and placed implants at platform, apex, and angular deviation. Cochran's Q-statistic and the I^2 statistic were used to assess any publication bias and to calculate heterogeneity between the included studies. *P* values of < .05 were considered statistically significant.

Box 1 Excluded Studies and Reasons for Exclusion

Study and year of publication	Reason for exclusion
Shi 2023, Qiao SC 2023, Rawal S 2023	The technology used was not ADIR.
Jain 2023, Takasc 2023, Pimkhokham 2023, Zhao 2023, Sin M 2023, Yang S 2023, Bai SZ 2023, Yuan FS 2023	The nature of the study was in vitro, an animal study, a case report, or a review.
Klass 2023	There were fewer than 10 implants evaluated.
Oppermann 2023	The study was not related to implant dentistry.

I^2 values of 25%, 50%, and 75% corresponded to the cutoff points for low, moderate, and high degrees of heterogeneity, respectively. A minimum of three studies were needed to perform the meta-analysis.

Certainty Assessment

The grading of recommendations assessment, development, and evaluation (GRADE) guidelines (McMaster University and Evidence Prime) were used to conduct a GRADE assessment for evidence quality and was measured as very low, low, moderate, or high.

RESULTS

Identified Articles

The search resulted in 59 titles. After screening all titles and abstracts, 19 potentially relevant studies were identified. After the exclusion of 13 studies (Box 1), a total of 6 studies were included for the qualitative analysis (Fig 2).

Table 1 Main Characteristics of the Included Studies

Primary author and year	Study design	No. of implants evaluated	No. of treated patients	Type of rehabilitation	Type of robot	Global platform deviation ± SD (mm)	Global apex deviation ± SD (mm)	Angular deviation ± SD (degrees)
Yang 2023	Case series	10	10	Single tooth gap	Remebot	0.74 ± 0.29	0.73 ± 0.28	1.11 ± 0.46
Zhang 2023	Retrospective	62	39	Partially edentulous	Remebot	0.68 ± 0.36	0.69 ± 0.36	1.37 ± 0.92
Jia 2023	Retrospective	30	20	Partially edentulous	Yakebot	0.43 ± 0.18	0.52 ± 0.18	1.48 ± 0.59
Wang 2023	Prospective	36	5	Complete arch	Yakebot	0.65 ± 0.25	0.65 ± 0.22	1.43 ± 1.18
Xie 2024	Prospective	102	12	Complete arch	Yakebot	0.53 ± 0.19	0.58 ± 0.17	1.83 ± 0.82
Li 2023	Retrospective	59	10	Complete arch	Remebot	0.67 ± 0.37	0.69 ± 0.37	1.27 ± 0.59

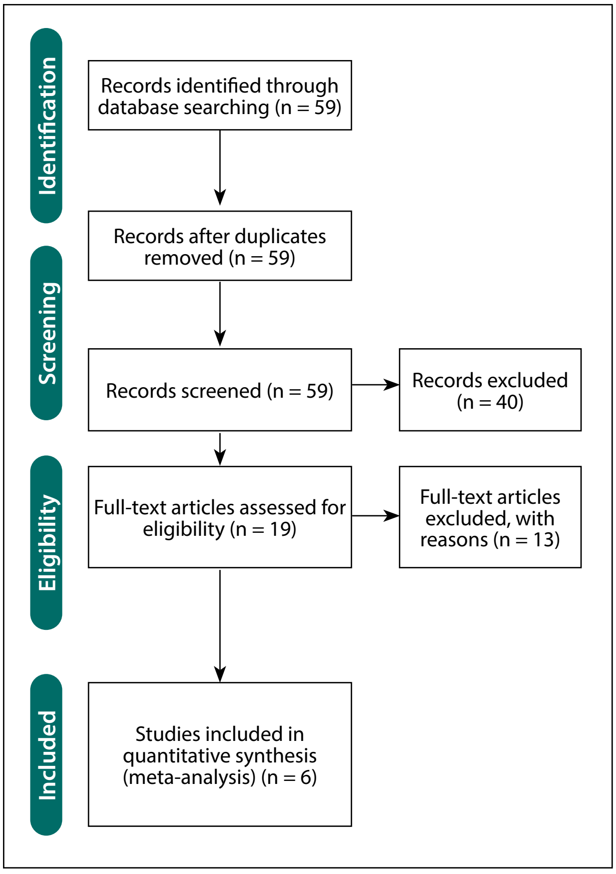

Fig 2 PRISMA flowchart.

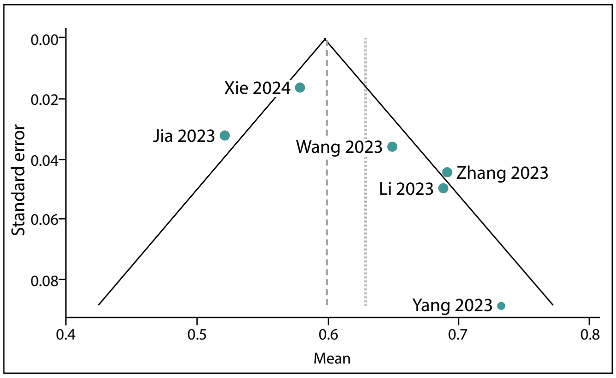

Fig 3 Funnel plot for global platform deviation.

Study Characteristics

The main characteristics of the included studies were described in Table 1. A total of 96 patients (mean age = 55.58 years; females = 42, males = 54) received 299 dental implants placed by means of ADIR surgery (121 in the maxilla and 178 in the mandible). Concerning the type of edentulism, 1 prospective case series investigated a single tooth gap, 2 retrospective studies investigated partially dentate patients with edentulous space characterized by ≥ 1 tooth missing, and 1 retrospective and 2 prospective studies investigated complete arch rehabilitations. Two ADIR systems were used: Remebot (Baihui Weikang Technology) and Yakebot (Yake Wisdom Technology).

Heterogeneity of Included Studies

The test for heterogeneity revealed a Cochran's Q-statistic index of 36.86 (platform), 18.71 (apex), and 33.32 degrees (angular deviation). It also showed a I^2 statistic index of 87.1% (platform), 73.3% (apex), and 85% (angular deviation) (Figs 3 to 5).

Risk of Bias

Risk of bias were assessed using the Newcastle-Ottawa Scale, investigating on the "selection", "comparability" and "outcome" criteria. All the included studies were rated as "high quality", scoring from 9 to 7. A detailed quality assessment of the included studies is displayed in Table 2.

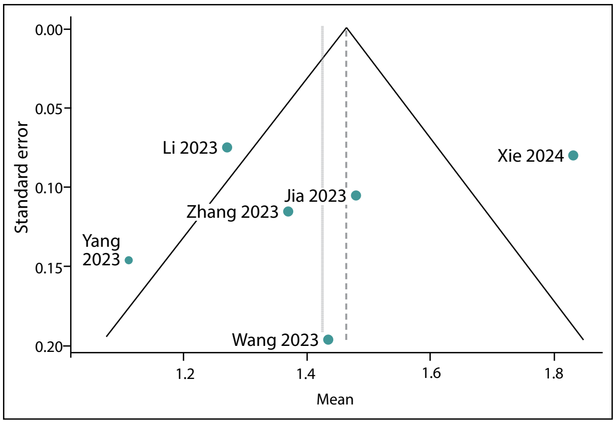

Fig 4 Funnel plot for global apex deviation.

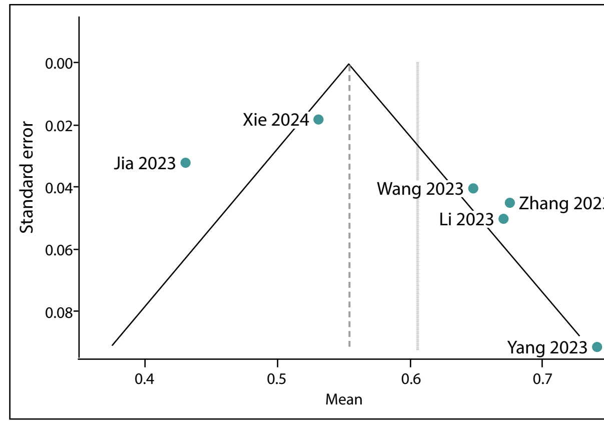

Fig 5 Funnel plot for angular deviation.

Table 2 Risk of Bias Assessment of Observational (Prospective and Retrospective) Studies Following the Newcastle-Ottawa Scale

	Selection				Comparability		Outcome			
Primary author and year	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration of outcome	Study controls for accuracy	Study controls for any additional factor	Assessment of outcome	Follow-up long enough	Adequacy of follow-up cohorts	Overall quality
Yang 2023	+		+	+	+		+	+	+	High
Zhang 2023	+	+	+	+	+	+	+	+	+	High
Jia 2023	+	+	+	+	+		+	+	+	High
Wang 2023	+	+	+	+	+		+	+	+	High
Xie 2024	+		+	+	+	+	+	+	+	High
Li 2023	+		+	+	+		+	+	+	High

Accuracy of r-CAIS

The meta-analysis reported a mean overall accuracy of r-CAIS of 0.60 mm (95% CI [0.5133; 0.6965]) at platform, 0.63 mm (95% CI [0.5663; 0.6909]) at apex, and 1.42 degrees (95% CI [1.2182; 1.6320]) of angular deviation (Figs 6 to 8).

Certainty of the Evidence

Quality of evidence for the studies of the present meta-analysis was graded as moderate using the GRADE approach and displayed in Appendix Table 1 located in the online version of this article. Reasoning behind this was the significant heterogeneity present in all the studies and the absence of RCTs.

DISCUSSION

Despite s-CAIS and d-CAIS demonstrating significantly lower deviations compared to the freehand technique, inherent technologic and clinical protocol limitations may constrain their clinical application and compromise overall accuracy. Robotics in implant surgery were developed to further enhance the accuracy and predictability of s-CAIS and d-CAIS, addressing key limitations and minimizing human operator bias.

This systematic review and meta-analysis aimed to assess accuracy of ADIR surgery for implant placement in-vivo. The meta-analysis reported a mean overall accuracy of ADIR implant surgery as follows: 0.60 mm (95% CI [0.5133; 0.6965]) at platform, 0.63 mm (95% CI [0.5663; 0.6909]) at apex, and 1.42 degrees (95% CI [1.2182; 1.6320]) of angular deviation. These findings

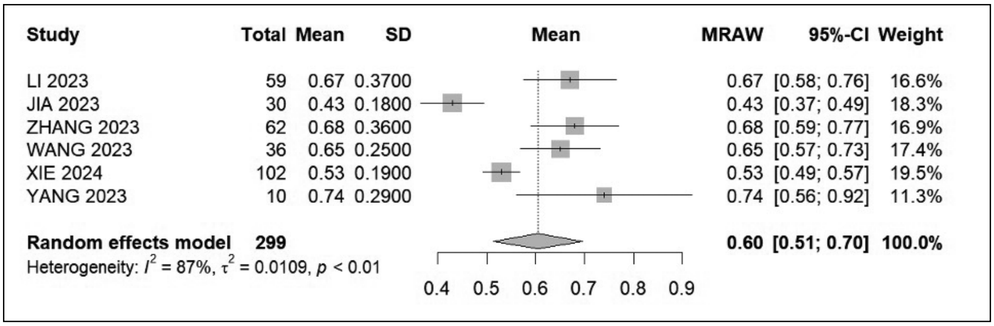

Fig 6 Meta-analysis for global platform deviation with related forest plot.

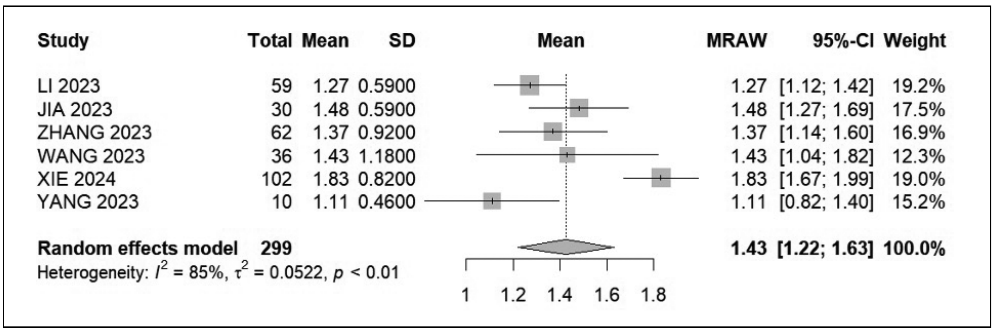

Fig 7 Meta-analysis for global apex deviation with related forest plot.

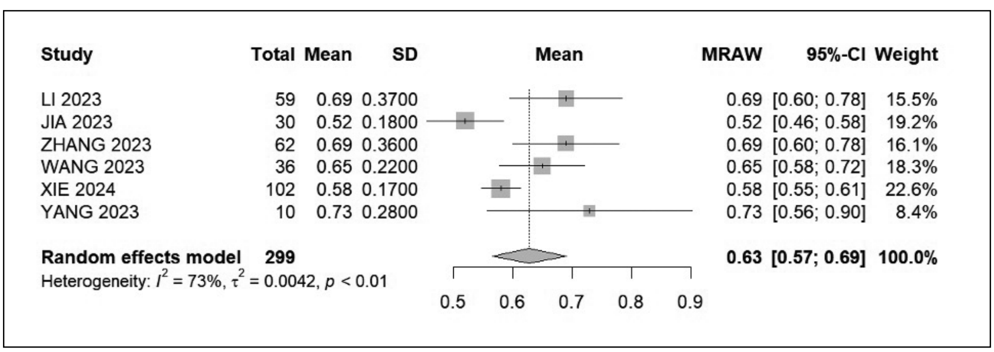

Fig 8 Meta-analysis for angular deviation with related forest plot.

align with a recent systematic review on r-CAIS (Shi et al 2024)[14], which reported deviations at the platform, apex, and angular deviations as 0.68 mm (0.57 mm, 0.79 mm), 0.67 mm (0.58 mm, 0.75 mm), and 1.69 degrees (1.25 degrees, 2.12 degrees), respectively. However, please note that these summary results came from a meta-analysis that included different robotic technologies—including r-CAIS level 1—where the robot provided semi-active control, offering mechanical support or guidance while the surgeon retained control over the robot's actions. The level 1 r-CAIS setup entailed the robot managing angular adjustments, while the surgeon controlled the drilling speed and applied force during implant placement. In contrast, the present meta-analysis focused explicitly on in-vivo ADIR systems with level 2 autonomy. At level 2, an autonomous robotic arm precisely navigates within the patient's mouth to reach the target coordinates and retraces its path autonomously. ADIR surgery excludes operator influence on the accuracy outcomes, maintaining full autonomy in trajectory control, drilling speed, and implant placement, while the surgeon assists and provides a backup control through a dedicated computer interface.

In recent years, there has been a growing trend in medical robot technology towards performing increasingly complex tasks with greater levels of autonomy. The r-CAIS technology is somewhat similar to d-CAIS in the way that neither uses a physical template to guide the clinician or the robot during the surgical procedures. A recent systematic review on d-CAIS by Yu et al[17] reported encouraging data of mean global platform deviation (1.07 mm; 95% [CI: 0.96 to 1.17]), global apex deviation (1.27 mm; 95% [CI: 1.06 to 1.47]), and angular deviation (3.43 degrees; 95% [CI: 2.94 to 3.93]). Moreover, a recently published prospective clinical trial[18] evaluating the accuracy of d-CAIS for complete-arch restorations reported overall platform, apex, and angular deviations of 1.17 mm (SD = 0.57 mm), 1.30 mm (SD = 0.62 mm), and 2.19 degrees (SD = 1.26 degrees), respectively. The findings of the present meta-analysis showed that ADIR performed better in terms of accuracy, dramatically reducing 3D linear and angular deviations. This improvement may be attributed ADIR's ability to automatically adjust for slight movements of the patient's head by continuously capturing real-time positional data through optical tracking of the patient. Any deviations occurring during the implant site preparation were immediately corrected through an autonomous adjustment in the drilling process, including (when necessary) a reset and re-calculation of the drilling trajectory.

A recent RCT by Yotpibulwong et al[19] examined the accuracy of dynamic and static guided implant placement in a single tooth gap. They reported deviations at platform (mm) of 1.06 ± 0.67 for dynamic guided implant placement and 1.02 ± 0.45 for static guided implant placement. At the apex, the deviations for dynamic and static guided implant placements were 1.40 ± 0.71 mm and 1.28 ± 0.50 mm, respectively, and the angular deviations were 3.18 ± 2.04 degrees and 3.28 ± 1.57 degrees, respectively. Additionally, a RCT by Yimarj et al[20] evaluated the accuracy of s-CAIS and d-CAIS in partially edentulous patients, with deviations of 1.04 ± 0.67 mm and 1.24 ± 0.39 mm at the implant platform, 1.54 ± 0.79 mm and 1.58 ± 0.56 mm at the apex, and 4.08 ± 1.69 degrees and 3.78 ± 1.84 degrees of angular deviation, respectively. These two RCTs indicated that both s-CAIS and d-CAIS can optimize implant placement by reducing linear and angular deviations without significant differences between the two technologies. However, data from the present systematic review revealed a consistently higher accuracy for ADIR implant placement across various clinical scenarios. From a single tooth-gap to complete arch restorations, implants placed using ADIR surgery reported lower mean global and angular deviations from the pre-planned 3D coordinates to the actual implant positioning compared to s-CAIS and d-CAIS. Furthermore, all included studies reported low SDs, demonstrating that ADIR is feasible for implant placement with accuracy that is not influenced by the type of edentulism or arch. These positive outcomes stem from ADIR surgery addressing the intrinsic limitations of the different CAIS techniques. s-CAIS required a wide mouth opening due to the need of for a dedicated drill kit with "sleeve extension" length, and the production and seating of 3D printed templates in the patient mouth may contribute to an increase in overall surgical deviations. Additionally, the inability of s-CAIS to detect and correct the drilling path in the event of deviation may account for its comparatively minor accuracy relative to r-CAIS.

Regarding the accuracy of complete arch s-CAIS accuracy, a recent systematic review reported average global platform deviations, global apex deviations, and angular deviations of 1.23 mm (95% CI 0.97–1.49), 1.46 mm (95% CI 1.17–1.74), and 3.42 degrees (95% CI 2.82–4.03), respectivly.[1] This clinical performance was not further improved by a recent proof-of-concept prospective study,[21] which attempted to merge the positive characteristics of both s-CAIS and d-CAIS systems.

In contrast, r-CAIS has further improved the clinical performance of d-CAIS. This improvement was achieved through tracking the motion of the dynamic reference frame, which is securely on the patient's anatomy. The tracked data is computed in real time, allowing for simultaneous and autonomous adjustments to the drilling trajectory. Unlike d-CAIS, ADIR eliminates the need for the operator to handle the surgical handpiece as the robotic arm precisely completes the drilling path. Moreover, ADIR surgery does not require real-time information to be displayed on a screen as is necessary with the navigation systems. In d-CAIS, the necessity for real time alignment between visual and tactile feedback—along with the related brain response—can potentially lead to deviations from the planned coordinates. This setup also requires the operator to focus on the screen instead of the surgical field. Moreover, navigation-assisted surgical drilling involves a learning curve, and its accuracy can be influenced by a surgeon's training and expertise.[22]

The included manuscripts reported on 69 partial edentate ADIR surgical procedures (102 implants) and 27 complete-arch ADIR surgical procedures (197 implants). Therefore, the number of partial edentate ADIR surgical procedures was more than double that of complete-arch procedures. These results may support the authors' assumption that ADIR positioning errors were not related to the type of clinical scenario (single, partial, or complete-arch), because ADIR surgery eliminated human-related surgical deviations that are significantly influenced by the site characteristics. Indeed, ADIR procedures in partially edentulous patients may be as accurate as those in complete-arch treatments, as evidenced by the similar deviations reported in the included articles of the present study.

The main limitation of the present review was related to the high heterogeneity among the included studies, with three out of six studies being retrospective. Moreover, the absence of RCTs precluded any subgroup analysis comparing the performance of investigated robotic systems and in the different clinical scenarios. Finally, all the included studies were conducted in China, where the ADIR systems were developed and are currently approved for clinical use. This relative limitation may hinder the generalization of the outcomes. However, all the studies were published in peer-reviewed scientific journals qualified in the Q1 rank in dentistry. It is important to note that both robotic systems featured in the included manuscripts used autonomous level 2 robotic surgical technology. Therefore, a direct comparison of these two robotic systems at this early stage of ADIR clinical validation would not contribute significant scientific value but rather potentially convey a commercial message. Additionally, given the current scarcity of robust evidence on this topic—with few well-conducted RCTs and prospective clinical trials—such a comparison would be more speculative than conclusive. Nevertheless, six "high quality" studies—as assessed by the Newcastle-Ottawa scale—were included, providing accuracy data of 299 dental implants placed by ADIR surgery in 96 patients. Although, a direct comparison of the three different CAIS technologies could not be performed in meta-analysis, the accuracy of ADIR surgery was found significantly higher than that of s-CAIS and d-CAIS.

CONCLUSIONS

Within the limitations of this review, ADIR surgery demonstrated feasibility in placing implants in both partial and complete edentulous patients, achieving consistent mean linear and angular deviations of approximately 0.6 mm and 1.40 degrees, respectively. The accuracy of ADIR was significantly higher than that of s-CAIS and d-CAIS. However, the clinical practicality of ADIR surgery remained cumbersome. Well-trained operators are needed to plan and assist ADIR procedures and a technical expert is required to provide backup control. Moreover, due to the paucity of comparative studies, the findings of this review should be interpreted with caution. Further research is necessary to confirm the positive clinical performance of ADIR surgery.

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Author contributions: A.P., P.C, and C.L.: conceived study aims and design; P.C., C.L., and A.P.: collected the data; A.P., P.C., and C.L.: analyzed the data; A.P., P.C., C.L., HL.W, J.C., and G.G. led the writing. Both Alessandro Pozzi and Paolo Carosi are the primary authors as they have contributed equally.

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APPENDIX

Appendix Table 1 GRADE Assessment Results.

Summary of findings:

Accuracy of autonomous dental implant robotic surgery (ADIR) for partially or complete edentulous patients

Patient or population: partially or complete edentulous patients

Setting: university or private practice

Intervention: Implants placed by ADIR

Comparison: Pre-operative planned coordinates

Outcomes	Anticipated absolute effects (95% CI)		Relative effect (95% CI)	No of participants (studies)	Certainty of evidence (GRADE)	Comments
	Risk	Risk with ADIR				
Comparison of planned and placed implants by means of ADIR for Global platform deviation	The mean comparison between planned and actual positioned implants for global platform was 0	MD 0.60 higher (0.5133 to 0.6965 higher)		299 (6 studies)	⊕⊕⊕◯ Moderate[a]	MD 0.60 (0.5133 to 0.6965)
Comparison of planned and placed implants by means of ADIR for Global apex deviation	The mean comparison between planned and actual positioned implants for global apex was 0	MD 0.63 higher (0.5663 to 0.6909 higher)		299 (6 studies)	⊕⊕⊕◯ Moderate[a]	MD 0.63 (0.5663 to 0.6909)
Comparison of planned and placed implants by means of ADIR for Angular deviation	The mean comparison between planned and actual positioned implants for angular deviation was 0	MD 1.42 higher (1.2182 to 1.6320 higher)		299 (6 studies)	⊕⊕⊕◯ Moderate[a]	MD 1.42 (1.2182 to 1.6320)

CI: Confidence interval; **MD:** mean difference

GRADE Working Group grades of evidence

High quality: Further research is very unlikely to change our confidence in the estimate of effect.

Moderate quality: Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.

Low quality: Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.

Very low quality: We are very uncertain about the estimate.

Explanation:

a. High heterogeneity