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Accuracy Of Surgical Guides For Dental Implants In Half Guided Surgery- A Metaanalysis

Dr. Ila Sharma[1*], Dr. Swapnil Parlani[2], Dr. Vijayta Sharva[3], Dr. Akanksha Mourya[4], Dr. Gaurav Majumdar[5], Dr. Garima Bhambhani [6]

[*1]Postgraduate Student, Department of Prosthodontics Crown and Bridges, People's College of Dental Sciences & Research Centre, Bhanpur, Bhopal, Madhya Pradesh, India

[2]Vice Dean, Professor & HOD, Department of Prosthodontics Crown and Bridges, People's College of Dental Sciences & Research Centre, Bhanpur, Bhopal, Madhya Pradesh, India

[3]Professor, Department of Public Health Dentistry, People's Dental Academy, Bhanpur, Bhopal, Madhya Pradesh, India

[4]Sr. lecturer, Department of Prosthodontics Crown and Bridges, People's College of Dental Sciences & Research Centre, Bhanpur, Bhopal, Madhya Pradesh, India

[5]Sr. Lecturer, Department of Prosthodontics Crown and bridges, People's College of Dental Sciences & Research Centre, Bhanpur, Bhopal, Madhya Pradesh, India

[6]Professor, Department of Public Health Dentistry, People's College of Dental Sciences & Research Centre, Bhanpur, Bhopal, Madhya Pradesh, India

***Corresponding Author:**

Dr. Ila Sharma

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ABSTRACT

Purpose-The aim of this meta-analysis was to compare the accuracy of surgical templates in half guided approach in terms of trueness and evaluate their impact on clinical procedures, providing valuable insights for clinicians.

Materials and Methods: A systematic review was conducted following PRISMA and Cochrane Collaboration guidelines to assess the accuracy of surgical guides in half-guided dental implant procedures. A comprehensive literature search was performed using databases like PubMed, CENTRAL, and Embase, applying the PICO approach. Inclusion criteria focused on peer-reviewed studies reporting coronal and apical deviation data. Risk of bias was evaluated using the Newcastle–Ottawa Scale to ensure study reliability.

Results: The review included 11 studies assessing the accuracy of surgical guides in half-guided implant surgery. Coronal deviation ranged from 0.22 to 1.987 mm, while apical deviation varied from 0.19 to 2.24 mm. Meta-analysis showed no significant difference between anterior and posterior sites, with overall deviation being low. Statistical analysis confirmed high accuracy ($p<0.00001$) despite study heterogeneity.

Conclusion: This meta-analysis confirms that half-guided implant surgery using digital surgical guides yields high accuracy in both anterior and posterior sites, with no significant site-specific differences in coronal or apical deviation. These findings support the clinical versatility of half-guided protocols in implant dentistry.

Keywords: *surgical templates, Computer-aided implantology, half guided surgery, dental implants.*

1. INTRODUCTION

Over the last decades, computer-aided implantology has drawn more and more attention due to its potential for more accurate, predictable, and minimally invasive surgeries. Unlike traditional freehand surgeries that rely heavily on the operator's experience, computer-aided implantology adheres to a "prosthesis-driven" principle, ensuring optimal conditions for implant placement. Commercial planning software combined with three-dimensional (3D) tissue information from cone beam computed tomography (CBCT) and optical scans, facilitates precise preoperative designs. However, the challenge lies in transferring these designs into reliable surgical procedures. Recent advances in computer-aided design/manufacturing (CAD/CAM) and 3D printing have enabled the creation of static surgical templates, allowing clinicians to reproduce virtual treatments intraoperatively. 1

Despite improvements since the early 1990s, the accuracy of guided surgery remains debatable, with potential deviations at each stage of the computer-aided implantology workflow. Surgical templates are classified into half-guided and full-guided systems based on the requirement for guided cylinders during implant installation. In a full-guided procedure, implant bed preparation and placement are both guided by the template, whereas in a half-guided approach, only the initial steps of the implant bed preparation are guided by the template; finalization of the implant beds and implant placement is carried out in a free-handed fashion. Both approaches reduce surgical time and, therefore, postoperative discomfort. The full-guided approach enables flapless surgery, which further reduces postoperative morbidity. However, flap elevation and a half-guided approach enhance cooling of the drills used, promote the preservation of keratinized mucosa and allow slight correction of implant positions if deemed necessary.1

Accuracy of implanting guide comprises trueness and precision (iso 5725–1:1994). Trueness refers to the deviation between postoperative placement and preoperative plan of the implant; precision refers to the deviation of repetitive test results. Generally, accuracy discussed in clinical studies refers to trueness, while in vitro studies (e.g., implant on plaster models) may involve both trueness and precision. Despite the lack of a universal evaluation standard for implantation surgical accuracy, common indicators including coronal deviation (mm), apical deviation (mm), depth deviation/vertical deviation (mm), angular deviation (°) are applied in existing literatures and discussed in this meta-analysis.2

This study aims to compare the accuracy of these templates in half guided approach in terms of trueness and evaluate their impact on clinical procedures, providing valuable insights for clinicians.

METHODOLOGY

REVIEW QUESTION:- ACCURACY OF SURGICAL GUIDES FOR DENTAL IMPLANTS IN HALF GUIDED SURGERY

2. MATERIALS & METHODS

In this review, preferred reporting items for systematic reviews and meta-analyses and Cochrane Collaboration criteria are used as guideline to formulate review question, identify studies and assess their quality of selected studies, data extraction, and reporting. A protocol was developed before starting the search process for this review.

Identification and selection of relevant studies

Literature search was carried out in electronic databases in February 2025. Cochrane Central Register of Controlled Trials (CENTRAL), PubMed, and Embase were the electronic databases to retrieve the primary studies. In PubMed, filters were used to limit the search to clinical trials conducted on human, published during the past 10 years (from 2015 to 2024).

To obtain additional data, a manual search was performed using the reference lists of included articles. Inclusion and exclusion criteria were also considered in hand-searched articles.

Search Strategy:

The search was performed using keywords based on the PICO approach. The PICO was formulated as follows: Participants (P) = patients of dental implantation; Intervention (I) = implants placed using digital surgical guides; Comparison or control (C) =IMPLANT SITE, ARCH OF IMPLANT; Outcome measures (O) = coronal deviation (mm), apical deviation (mm),

1. The search strategy was based on controlled vocabulary [Mesh Terms] of the Pubmed database, pubmed central, Google Scholar along with free keywords that was combined with the Boolean operators.
2. The “participant” and intervention concepts from the PICO question was combined with Boolean Operator [AND] and [OR].
3. This review applied the keywords: computer-aided implant surgery (CAIS); static surgical guide; accuracy; deviation; dental implants) and MeSH terms (Surgery, Computer-Assisted) AND (Dental Implants). “Half-guided surgery,"
4. Literatures were screened using predetermined inclusion and exclusion criteria as follows

Selection criteria were as follows:

Inclusion criteria

The following criteria were included in the study:

1. Types of literature were limited to Randomized controlled trials (RCTs),retrospective study, or observational studies on accuracy of surgical template in half-guided surgery that were peer reviewed and published in WOS or PubMed cited scientific journals.

2. Titles and abstracts of the articles were related to the accuracy of digital surgical guides for dental implantation.

3. At least one of the following in vivo or in vitro deviation data must be involved: coronal deviation (mm), apical deviation (mm),

4. Written in English.

5. The year of publication was restricted in recent 10 years (2015–2024).

Exclusion criteria were

1. Studies with insufficient data on the accuracy outcomes.

2. Case reports, reviews, and non-peer-reviewed articles.

3. Written in languages other than English.

4. Published before 2015.

5. Reviews, meeting abstracts, grey literature or nonpeer- reviewed literature were excluded.

To minimize the potential for reviewer bias, two reviewers (CM and JS) independently conducted literature searches and performed the study selection. Both reviewers strictly followed the inclusion and exclusion criteria, and any disagreement was resolved by discussion.

Data were extracted by one reviewer (JS) and examined by another reviewer (CM). The following data were directly collected from the included articles: literature information (authors, year, and title), research type (clinical/cadaver/in vitro), number of patients/cadavers/ models, number of implants, surgical information (full-/ half-guided, planning software, implant site, jaw position, deviation data including global/horizontal coronal deviation (mm), global/horizontal apical deviation (mm), angular deviation (°) and vertical deviation (mm). The form of deviation data included mean ± SD and/or median (min, max)

To assess the risk of bias and degree of reliability, clinical studies were scored based on the Newcastle–Ottawa Scale (NOS) adapted by Chambrone et al. [18] including evaluation of four subcategories: sample selection of study groups, comparability, outcome and statistical analysis. 1: Methods. A maximum of 13 points could be obtained for each study, with a score of 10–13 indicating high study quality, a score of 7–9 indicating moderate study quality, and a score of less than 7 indicating low study quality.

Following the PRISMA guideline (Fig. 1), the search strategy reported 686 records, among which 148 duplicate records were firstly removed. After overviewing the titles, abstracts and keywords, the investigators excluded 34 reviews, 20 articles written in languages other than English, and 443 records with no considerable information about accuracy of surgical guides for dental implantation. The remaining 41 records were sought for full-text retrieval and assessment of data availability and out of these 41 full text articles only 11 articles considered half guided implant surgery for their research. These 11 articles were considered for final review.

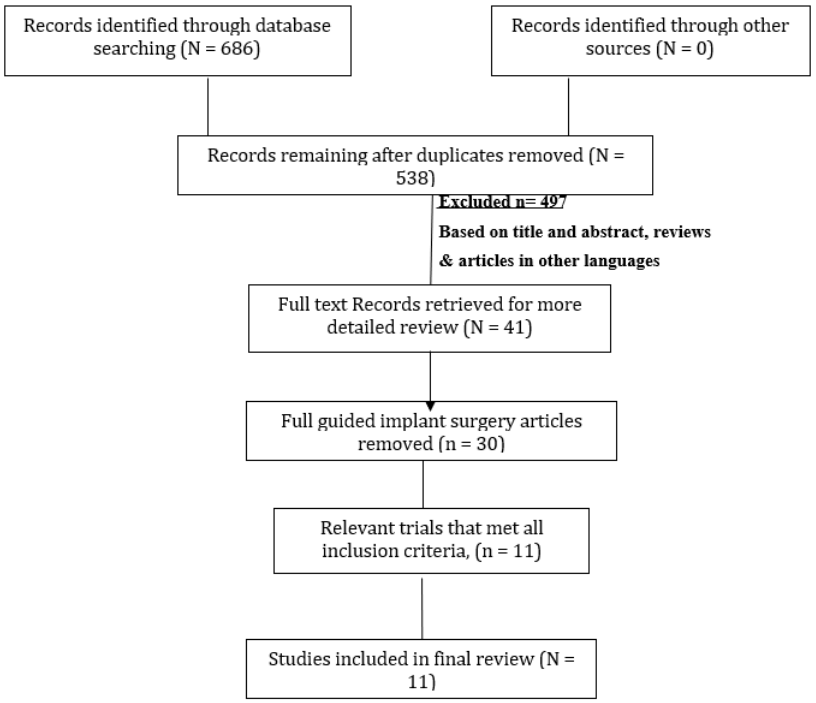


Figure 1: Retrieval and selection of eligible articles for review of accuracy of half guided implant surgery

3. RESULTS

TABLE 1: CHARACTERISTICS OF INCLUDED STUDIES

Reference	Year	Design	PATIENTS	IMPLANTS	IMPLANT SITE	SUPPORT TYPE	FABRICATION
Kristof Orban[3]	2022	IN VITRO COHORT	20	20	P	Unilateral tooth-supported	3D printer
Fangzhi Lou[4]	2021	IN VITRO CLINICAL TRIAL	20	36	A/P	Bilateral tooth-supported	3D printer
David Schneider[5]	2021	INVITRO	24	72	A/P	Bilateral tooth-supported	3D printer
Jaafar Abduo[6]	2021	RCT	14	14	A/P	Bilateral tooth-supported	3D printer
Chalermchai Ngamprasertkit[7]	2021	INVITRO RCT	15	15	A/P	Bilateral tooth-supported	3D printer
Johannes Spille[8]	2021	INVITRO	6	24	A/P	MucoSA supported	NR
Arndt Guentsch[9]	2021	INVITRO	20	20	A/P	Bilateral tooth-supported	3D printer
Yen-Ting Han[10]	2021	RCT	30	18	A/P	Bilateral tooth-supported	3D printer
Yuan Chen[11]	2020	RCT	30	37	A/P	Bilateral tooth-supported	3D printer
Márton Kivovics[12]	2020	CLINICALTrial	6	18	A/P	Mucosa supported	3D printer

Rai-Jei Chang[13]	2018	INVITRO	17	20	P	Unilateral tooth-supported	NR

Table 1 describes characteristics of included studies in terms of author name year of publication, design, no. Of patients, total no. Of implants, implant site , support type and type of fabrication. Most of the studies having half guided criteria were done in 2021. 6 out of 11 were clinical trials, 1 was cohort and remaining 4 were invitro studies. Support type for these studies were also described in the table and it can be seen that only 2 studies were mucosa supported and others were tooth supported. 9 out of 11 were having 3d printing method of fabrication and 2 studies did not define about their fabrication type.

TABLE 2: MEAN +/- SD OF OUTCOME (IMPLANT DEVIATION)

S. NO.	AUTHOR YEAR	CORONAL DEVIATION(MM)	HORIZONTAL DEVIATION (MM)	APICAL DEVIATION (MM)	Horizontal Apical deviation (MM)
1	Kristof Orban 2022	1.20 ± 0.46	1.06 ± 0.52,	1.45 ± 0.79	1.28 ± 0.83
2	Fangzhi Lou 2021	0.69 ± 0.10 0.39 ± 0.12	NR	0.80 ± 0.08 0.28 ± 0.09	NR
3	David Schneider 2021	NR	0.70 ± 0.48 0.49 ± 0.33	NR	0.77 ± 0.53 0.51 ± 0.33,
4	Jaafar Abduo 2021	NR	0.53 ± 0.26 0.34 ± 0.24	NR	1.49 ± 0.54 0.76 ± 0.52
5	Chalermchai Ngamprasertkit 2021	0.74 ± 0.36 0.48 ± 0.22	0.57 ± 0.39 0.39 ± 0.26	1.29 ± 0.61 0.71 ± 0.31	1.17 ± 0.68 0.64 ± 0.37
6	Johannes Spille 2021	NR	1.009 ± 0.415	NR	1.068 ± 0.384
7	Arndt Guentsch 2021	0.20 ± 0.14	NR	0.19 ± 0.13,	NR
8	Yen-Ting Han 2021	1.84 ± 0.64	1.12 ± 0.40	2.24 ± 0.97	1.57 ± 0.96
9	Yuan Chen 2020	0.59 ± 0.28 1.04 ± 0.64	NR	0.99 ± 0.41 1.46 ± 0.64	NR
10	Márton Kivovics 2020	1.987 ± 0.7049 1.879 ± 0.7893	NR	1.954 ± 0.685 2.124 ± 0.837	NR
11	Rai-Jei Chang 2018	0.40, (0.00, 1.00) 0.95, (0.30, 1.30)	NR	0.65(0.10, 1.90 1.35(0.10,3.60)	NR

Table 2 describes mean and standard deviations of implant deviation for coronal and apical regions for the included studies in mms. It can be seen that, range of coronal deviation was in the range of 0.22 to 1.987mm, coronal horizontal deviation in the range of 0.34 to 1.12 mm. Apical deviation was in the range of 0.19 to 2.24mm. Horizontal apical deviation was in the range of 0.51 to 1.57mm. Lowest coronal deviation was observed in the study of guentsch et al whereas highest deviation was seen in the study of kivovics et al. Similarly least apical deviation was seen in the study of guentsch et al while highest apical deviation was seen in the study of han et al.

FIGURE 1: FOREST PLOT 1

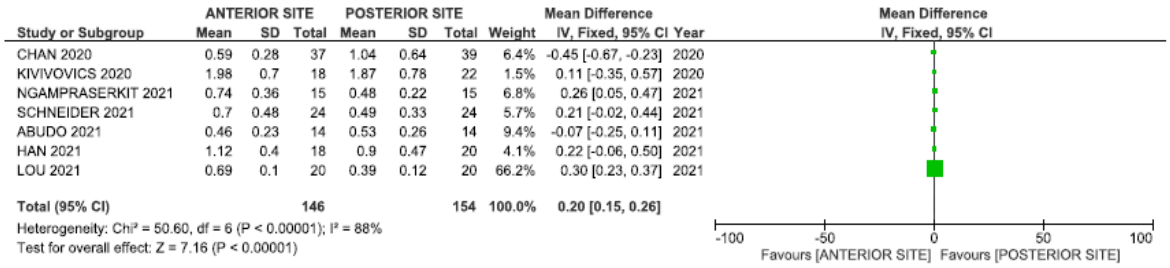
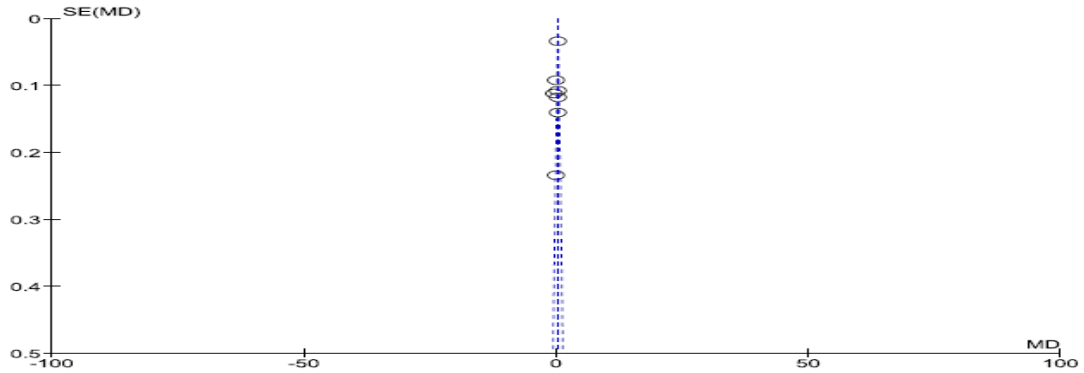


Figure 1 describes the forest plot of the 7 included studies for the average coronal deviations at two implant sites ie. Anterior and posterior ones. 4 studies which were the part of our original table for included studies did not provide complete information for their respective deviations at desired site or direction ie. Horizontal or apical or coronal, so they were not included in final meta-analysis. The forest plot of included 7 studies revealed that no site either anterior or posterior for implantation was favourable. In other words, half guided surgery accuracy was same at both the sites. Although the included studies did had significant accuracy in term of deviation. ($p<0.00001$) the heterogenity level between the included studies in the meta-analysis was around 50% means 50 % studies differed from each other in terms of different criterias like, design, no. Of patients, randomization etc. Overall deviation for the included studies in the analysis was o.20 which was significantly low.

FUNNEL PLOT 1;



FOREST PLOT 2

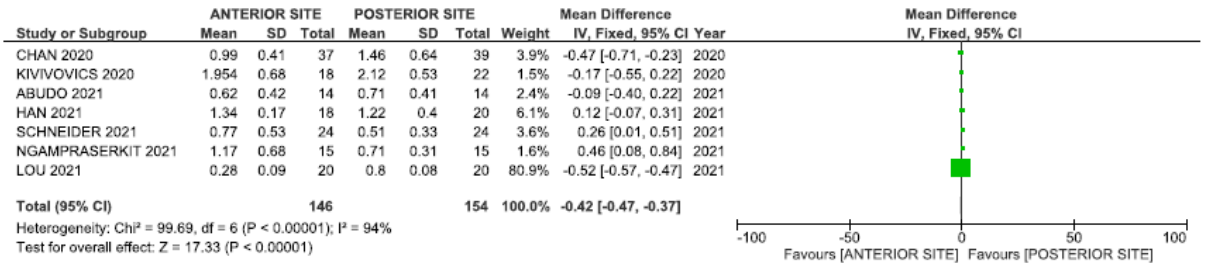
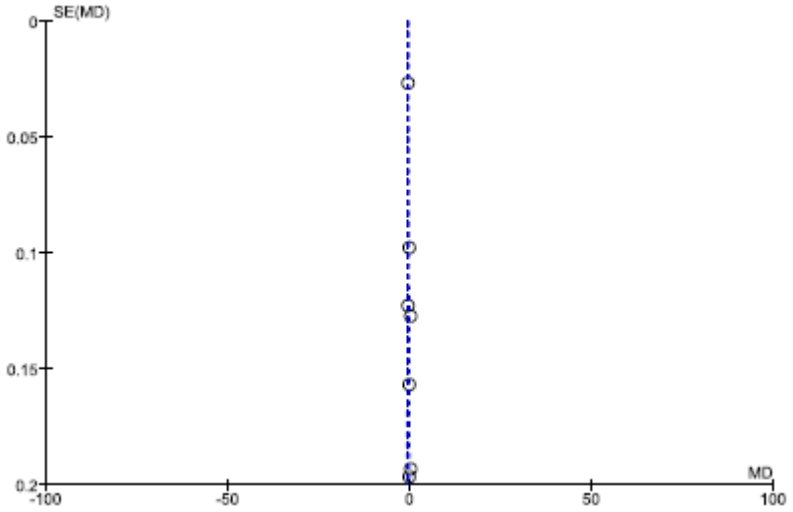


Figure 2 describe the forest plot for the average apical deviation for the included studies in the meta analysis. The overall average apical deviation was -0.42mm(range -0.47, -0.37). This means that overall apical deviation at both the site was in the range of 0.37 to 0.47mm which was significantly low. ($p<0.00001$), but since all the 7 included studies are plotted on the null line so, no site was favorable for half guided implant surgery.

FUNNEL PLOT 2.



4. DISCUSSION

This meta-analysis evaluated the accuracy of dental implant placement using digital surgical guides in half-guided surgery protocols, specifically comparing deviations at anterior versus posterior implant sites. The findings demonstrate that the accuracy of half-guided implant placement is comparable between these anatomical regions, with no statistically or clinically significant preference for either site.

The current review considered two outcome variables in terms of implant accuracy ie. Average coronal deviation and average apical deviation in anterior and posterior location. Our null hypothesis was that their was difference in the accuracy of half guided implant surgery in anterior and posterior locations. Since our main objective was to analyze the deviation of coronal and apical direction in half guided implant surgery, we considered studies pertaining to this criterion in our review.

The coronal deviation (CD) is the linear distance of coronal centers between the two implants. The apical deviation (AD) is the linear distance of apical centers between the two implants. According to the literature. To achieve a clinically acceptable results despite an unavoidable deviation of the implant position from the planned position, a safety distance of at least 2 mm from the sensitive anatomical structures should be included.14 This meta-analysis revealed the coronal and apical deviations were within the normal ranges irrespective of location of implant site.

The forest plot of included 7 studies revealed that no site either anterior or posterior for implantation was favorable. In other words, half guided surgery accuracy was same at both the sites.

The included studies did have significant accuracy in term of coronal deviation. The average coronal deviation across all included studies was 0.20 mm, indicating high precision at both anterior and posterior locations. While this value reached statistical significance, the magnitude of deviation is minimal and unlikely to translate into clinical relevance.

Similarly, the overall average apical deviation was -0.42 mm (Range -0.47, -0.37). This means that overall apical deviation at both the site was in the range of 0.37 to 0.47mm which was significantly low, suggesting a consistent, small apical offset in guided placement; however, this was not significantly associated with implant site. The distribution of studies along the null line in the forest plot further reinforces the lack of a directional effect favoring either site. These findings collectively indicate that half-guided protocols offer equivalent accuracy for implant positioning in both the anterior and posterior regions of the jaw.

The comparable performance across implant sites may be attributed to the nature of half-guided techniques, which provide controlled osteotomy while still relying on manual implant insertion. It is possible that this surgical flexibility mitigates site-specific anatomical challenges, such as limited inter arch space in posterior regions or esthetic sensitivity in anterior areas. Our results align with most of the previous individual studies that reported minimal deviation differences between implant sites when using digital surgical guides. studies have consistently shown that digital planning improves overall accuracy, particularly when surgical guides are stabilized and supported appropriately, regardless of implant location. This supports the broader application of half-guided techniques in diverse clinical scenarios. Cho et al. (2021) similarly reported mean coronal and apical deviations of 1.28 mm and 1.80 mm, respectively, in a partially guided system. However, they noted a significant correlation between implant site (anterior vs posterior) and deviation, but again, the differences were not clinically meaningful. 15

Park et al. (2017) found that implant location did not significantly influence deviation when CAD/CAM surgical guides were used, supporting our conclusion of consistent accuracy across implant site.16

In contrast, El Kholy et al. (2019) emphasized that posterior guide support provided higher accuracy than anterior-only support in partially edentulous models. This discrepancy may stem from the influence of guide design rather than implant site alone.17

This meta-analysis revealed the coronal and apical deviations were within the normal ranges irrespective of location of implant site. Previous study done by Abduo and Lau et al had compared fully guided, pilot-guided, and freehand methods for the accuracy of implant placement in anterior and posterior sites and found that anterior and posterior implants of the Fully Guided protocol had similar accuracy, the hypothesis that there is no influence of the location of the implant on the accuracy of implant placement was accepted. However, this hypothesis cannot be accepted for the Partially or half Guided and Free Hand protocols as the anterior implants were generally more accurate than the posterior implants. This was different finding from our results as there was no difference in the accuracy of half guided implant surgery in anterior and posterior locations.6

The superior accuracy and the less variation of the FG protocol is most likely related to the control of all the drilling steps and the implant placement via sequential use of precision sleeves. This eliminated the manual orientation and handling of the drills at any stage of drilling or implant placement. In accordance with these observations, Noharet et al. reported a better accuracy of the FG protocol compared with the conventional surgical guide.18 However, the actual difference between the FG and PG protocols in all the variables is minimal, and still within the recommended safety zone of 2 mm, it can still be of clinical significance in cases where the available bone is limited, surgical site is compromised, and the implant is in close proximity to natural teeth and vital anatomical structures.19

The comparable performance between anterior and posterior sites enhances the versatility of half-guided techniques. Clinicians can confidently apply these guides across the full dental arch, optimizing workflow efficiency and patient outcomes, particularly in cases where full guidance may not be feasible.

However, several limitations must be acknowledged. First, heterogeneity in guide design, support type (tooth-supported, mucosa-supported, bone-supported), and operator experience across the included studies may influence accuracy outcomes. Second, variation in imaging protocols and software for digital planning could contribute to methodological bias. Lastly, the analysis did not differentiate between maxillary and mandibular arches, which could reveal subtle arch-related differences in accuracy.

Future research should focus on stratifying results by arch type and examining the influence of guide support design on accuracy outcomes. Additionally, randomized controlled trials with standardized protocols would strengthen the evidence base for recommending half-guided surgery across implant sites.

5. CONCLUSION

This meta-analysis confirms that half-guided implant surgery using digital surgical guides yields high accuracy in both anterior and posterior sites, with no significant site-specific differences in coronal or apical deviation. These findings support the clinical versatility of half-guided protocols in implant dentistry.

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