Fully Guided Versus Half-Guided and Freehand Implant Placement: Systematic Review and Meta-analysis

Jordi Gargallo-Albiol, DDS, MS, PhD[1]/Shayan Barootchi, DMD[2]/
Jordi Marqués-Guasch, DDS, MS[3]/Hom-Lay Wang, DDS, MS, PhD[2]

Purpose: To compare the accuracy of different modalities of implant placement—static fully guided, static half-guided, and freehand surgery—through meta-analysis. ***Materials and Methods:*** A thorough electronic and manual systematic search was conducted to identify applicable randomized clinical trials (RCTs) for evaluating the implant positioning accuracy between different static implant navigation surgeries. The coronal and apical horizontal deviation, vertical deviation, apical angle, and chair time were estimated as the weighted mean differences and standard deviation with confidence intervals. A *P* value of .05 was set for statistical significance. ***Results:*** Based on the 10 RCTs that met the inclusion criteria for the quantitative analyses, results from the meta-analyses demonstrated the following: *(1)* a coronal deviation significant difference favoring the fully guided approach compared with the half-guided (weighted mean difference of –0.51 mm) and freehand approaches (weighted mean difference of –1.18 mm); *(2)* a significant weighted mean difference between the fully guided and half-guided approaches in relation to the apical deviation (weighted mean difference of –0.75 mm); *(3)* the vertical comparison did not yield significant weighted mean differences between the fully guided and half-guided techniques (–0.23 mm) and lacked statistically significant difference between the fully guided and freehand techniques (weighted mean difference of –0.17 mm); *(4)* the apical angle deviation demonstrated a significant weighted mean difference in favor of the fully guided approach compared with the half-guided group (weighted mean difference of –3.63 degrees); and *(5)* the comparison of chair time between the investigated groups did not exhibit a significant difference in any of the techniques. ***Conclusion:*** Static fully guided implant navigation surgery has the highest accuracy for transmitting the presurgical positioning planning to the patient, followed by static half-guided surgery, while the freehand implant placement provides the least accuracy. *Int J Oral Maxillofac Implants 2020;35:1159–1169. doi: 10.11607/jomi.7942*

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Advancements in computer technology and navigation surgery have become an integral part of contemporary surgical procedures.[1] Implant navigation surgery provides safer, less-invasive surgical procedures and more accuracy in transmitting the presurgical planning of prosthetic design and implant locations to the patient.[2–5]

Two modalities of implant navigation surgery have been described: dynamic navigation and static navigation. Dynamic navigation involves the use of 3D exploration software simultaneously with bone drilling and implant placement,[6,7] while static navigation requires static surgical templates to transmit the information from the presurgical planning to the patient.[3,6,8] Today, static navigation presents the most common method used and includes fully guided and half-guided approaches.[8] According to the implant navigation surgery classification proposed in a previous article,[8] in the fully guided approach, with static computer-aided implant surgery (s-CAIS), the computer stent guides the entire surgical procedure from the bone drilling preparation to the implant placement.[9,10] In contrast, in the half-guided approach, the computer stent does not guide the entire surgical procedure. Only the pilot drill[10–12] or the full drilling sequence is guided[7] but not the implant placement. Additionally, non-computer guided approaches with laboratory-made stents have also been classified as the half-guided technique.[8] All the mentioned techniques differ from the freehand approach, which does not require templates during the

[1]Department of Oral and Maxillofacial Surgery, Universitat Internacional de Catalunya, Barcelona, Spain; Department of Periodontics & Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA.
[2]Department of Periodontics & Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, Michigan, USA.
[3]Department of Oral and Maxillofacial Surgery, Universitat Internacional de Catalunya, Barcelona, Spain.

Correspondence to: Dr Jordi Gargallo-Albiol, Department of Periodontics and Oral Medicine, University of Michigan, School of Dentistry, 1011 North University Ave, Ann Arbor, MI 48109-1078, USA. Fax: +1 (734) 936-0374. Email: jgargallo@uic.es

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entire surgical procedure or any planning software to simultaneously support the surgery.[9,12,13]

Many investigations have been focused on the accuracy of implant positioning since it has been linked with the following:

- Biologic consequences: Peri-implant soft tissue healing, marginal bone remodeling, and long-term soft and hard tissue stability
- Prosthetic considerations: Prosthesis contours, symmetry, allowing access for hygiene, determining the types of restoration (screw- vs cement-retained)
- Esthetics outcomes: The need for hard and soft tissue grafting, consideration of biologic bone remodeling for future implant long-term stability, and types of abutment and crown contours (concave or convex)[6,14]

Although prosthetically driven implant placement and its accuracy in relation to 3D implant planning has been extensively described,[15–21] studies with a comparative control group are rare. Hence, a study that assesses the accuracy of fully guided, half-guided, and freehand approaches during implant placement is needed. Furthermore, surgical procedures in terms of flap reflection (open flaps vs flapless), duration of the surgery, postoperative pain and swelling, and medication intake would also be interesting to compare regarding different surgical approaches. While several limitations still exist, there is no doubt that advancements in digital technology and its application in dentistry have increased greatly in the daily workflow.

Therefore, the main aim of the present systematic review was to use the data obtained from comparative randomized clinical trials to compare the accuracy of the following approaches of implant placement: static fully guided, static half-guided, and freehand surgery. As a secondary objective, the duration of the surgery was also analyzed.

MATERIALS AND METHODS

Study Registration

The review protocol was registered with an identification number (CRD42018092265) in the PROSPERO International Prospective Register of Systematic Reviews hosted by the National Institute for Health Research, University of York, Centre for Reviews and Dissemination.

Patient, Intervention, Comparison, Outcome (PICO) Question

This systematic review was performed using the Preferred Reporting Items Systematic review and Meta-Analyses (PRISMA) statement and checklist[22] and the Patient, Intervention, Comparison, Outcomes (PICO) method:

- (P) Patients receiving dental implant placement surgery
- (I) Static fully guided implant placement surgery
- (C) Static half-guided or freehand implant placement surgery
- (O) Primary outcomes: Comparison of accuracy among the static fully guided, static half-guided, and freehand navigation surgical approaches in terms of mean horizontal deviation, mean vertical deviation, and mean angle deviation. Secondary outcomes: Difference in the total surgical time (chair time)

Eligibility Criteria

Articles were included in this systematic review if they met the following criteria: *(1)* human randomized clinical trials (RCTs); *(2)* navigation implant surgery comparison between at least two approaches; *(3)* freehand or static half-guided implant placement as a comparative group to static fully guided; and *(4)* reported outcome measures following the surgical intervention on accuracy between the presurgical and postsurgical CBCT/3D image (millimeters of deviation or grades of angulation) and chair time (minutes). Consequently, the exclusion criteria consisted of the following: *(1)* studies without a comparison group; *(2)* non-RCTs, animal studies, ex vivo and in vitro studies, case series, and case reports; *(3)* studies focusing on technical descriptions or lacking measurable clinical outcomes; and *(4)* a lack of objective data for comparing the study group outcomes.

Information Sources and Search Strategy

Electronic and manual literature searches, conducted by two independent reviewers (J.G. and S.B.), covered studies until February 2020 across the National Library of Medicine (MEDLINE by PubMed), Embase, and the Cochrane Oral Health Group Trials Register, using different combinations (and Boolean operators: AND, OR, NOT) of the following search terms/MeSH/keywords: ((“image-guided surgery” (MeSH Term) AND “dental implants” (MeSH Term) AND “computer-assisted surgery” (MeSH Term) OR “freehand” OR “freehand” (All Fields) OR “half-guided” (All Fields)).

Additionally, a manual and complete search of related journals was conducted from 2008 until May 2019, including *Journal of Clinical Periodontology*, *Journal of Periodontology*, *Clinical Oral Implants Research*, *The International Journal of Oral & Maxillofacial Implants*, *Clinical Oral Investigations*, *The International Journal of Periodontics & Restorative Dentistry*, *Clinical Implant Dentistry and Related Research*, *European Journal of Oral Implantology*, *International Journal of Oral & Maxillofacial Surgery*, *Journal of Prosthetic Dentistry*, *The International Journal of Prosthodontics*, *Journal of Prosthodontics,* and *Journal of Prosthodontic Research*. Finally, previous systematic reviews investigating implant navigation surgery were also screened for possible article identification.

Studies were excluded independently by screening of the titles and abstracts by two investigators (J.G. and S.B.), and the final eligibility of an article was confirmed after discussion. In case of any disagreement, an additional investigator (H.L.W.) was consulted for reaching an agreement. The definitive stage of screening involved full-text reading using the predetermined data extraction form to confirm the eligibility of each study based on the previously mentioned inclusion and exclusion criteria.

Data Extraction

The information extracted from each article included the following: *(1)* author and year of publication; *(2)* patient and implant sample; *(3)* test and control group characteristics; *(4)* implant localization; *(5)* CBCT presurgery; *(6)* CBCT postsurgery; *(7)* surgical procedure in terms of flap reflection (reflecting flaps vs flapless); *(8)* horizontal coronal deviation; *(9)* horizontal apical deviation; *(10)* vertical deviation; *(11)* apical angulation deviation; *(12)* chair time; *(13)* surgical complications; *(14)* prosthetic complications; *(15)* postoperative medication; *(16)* painkiller intake; and *(17)* postoperative pain and swelling. Interexaminer agreement following full-text assessment was calculated via kappa statistics.

Quality Assessment

The risk of bias was evaluated independently by two authors (J.G. and S.B.) using the Cochrane Risk of Bias Tool for Randomized Controlled Trials.[23] The potential risk of bias was considered low only if a study provided detailed data on all the required parameters. A trial that had not provided data on only one of the parameters was deemed as having a moderate risk of bias, and lastly, if a study lacked information regarding two or more parameters, it was viewed as having a high risk of bias.

Data and Statistical Analysis

For evaluating the differences between the static fully guided vs the static half-guided approach, and the static fully guided vs the freehand technique, it was planned that according to data availability, and homogeneity among the selected trials, two sets of meta-analysis be performed. The differences in the horizontal coronal and apical deviation, vertical deviation, apical angle, and chair time were the focus of interest and outcomes to be estimated through weighted mean differences with standard deviations (SD) between both groups in each set of meta-analysis (fully guided vs half-guided and fully guided vs freehand). The metafor package[24] was planned for utilization during the analysis for estimating an effect size, as all arms in each of the groups are weighted according to the inverse variance of the mean (to account for the SD and the sample size) via the random effects model (the DerSimonian-Laird method) based on the presumed heterogeneity. Illustration through forest plots was planned for the weighted mean differences between the groups for each set of the assessed outcomes. After calculation of confidence intervals (CI), a *P* value of .05 was set for statistical significance. Heterogeneity assessment was done according to the chi-square (χ^2) test and the I^2 statistics, for interpretation according to the Cochrane Handbook for Systematic Reviews of Interventions,[23] and funnel plots for displaying the potential bias among the included RCTs. All analyses were done using statistical software for Macintosh (RStudio Version 1.1.383, RStudio).

RESULTS

Study Selection

The electronic systematic search yielded 1,237 articles, which were complemented by 16 additional references from the manual literature search, from which 1,010 remained subsequent to the duplicate removal. After elimination by screening all titles and abstracts, 42 studies were left for full-text assessment. Following thorough examination of the studies against the predetermined criteria, 10 RCTs[9,10,12,13,25–30] were selected for inclusion in the quantitative meta-analysis. The most common reasons for exclusion of the studies were lack of randomization, presence of an inappropriate comparative/control group, and study design not matching the review research protocol. Additionally, there was excellent interreviewer agreement throughout the selection process and data extraction (kappa scores of 0.923 and 0.987, respectively).[31] Details regarding the search, screening process, and the exclusion criteria are summarized in Fig 1. The bias risk assessment for the included RCTs is detailed in Appendix Table 1 (see Appendix in online version of this article at quintpub.com).

Characteristics of the Included Trials

All 10 studies selected for the meta-analysis were RCTs aimed at evaluating the accuracy of static fully guided implant placement, comparing presurgical and postsurgical CBCTs, via utilizing either the static half-guided or freehand implant placement protocols as the comparative groups. All studies were published in the English language. Seven studies consisted of only two treatment arms (half-guided vs freehand),[9,10,13,27–30] while the other three studies included three treatment

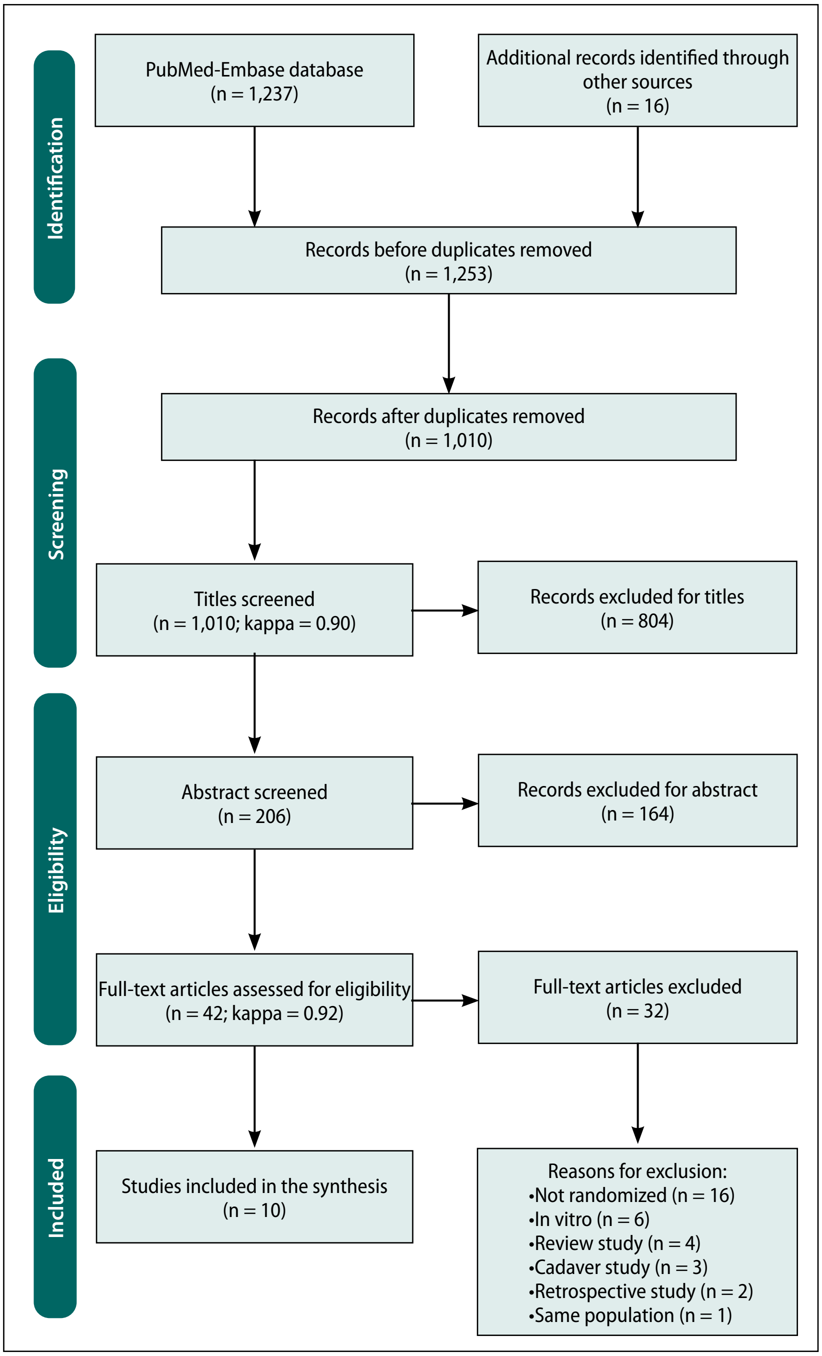

Fig 1 PRISMA flowchart of the screening process in the different databases.

groups (half-guided vs freehand vs fully guided).[12,25,26] Only one study employed a split-mouth design,[10] while the rest had parallel treatment groups. Except for the studies of Pozzi et al[9] and Tallarico et al,[29] which were conducted at different Italian private practices, and a study by Younes et al[12] that was conducted in two centers (Brussels University Dental Clinic and a private multidisciplinary practice), the rest of the trials were carried out at a single university center in the following countries: two in Belgium,[25,26] two in Switzerland,[27,28] one in Italy,[13] one in the United States,[10] and one in Thailand.[30] The year of publication of the included RCTs ranged from 2013 to 2019.

The selection of RCTs rendered the inclusion of 489 patients (284 fully guided, 135 half-guided, and 70 freehand), with a total of 1,256 implants (747 allocated to the fully guided group, 252 to the half-guided group, and 257 in the freehand group). Six studies included partially edentulous patients,[10,12,13,27,28,30] while two studies investigated completely edentulous patients,[25,26] and the studies of Pozzi et al[9] and Tallarico et al[29] included both types of edentulism: partially and completely edentulous patients. The fully guided protocol employed in 10 arms used computer-fabricated templates throughout the entire surgical procedure, and the half-guided group in 8 arms corresponded to a pilot-drill guided surgery or laboratory-made stent, while the freehand approach used in 5 arms referred to placement of implants without using any stents. Regarding flap reflection, two studies differentiated flapless surgery and flap surgery (corresponding to fully guided and half-guided or freehand groups, respectively),[10,12] although Amorfini et al[13] used minimally invasive flaps (without vertical releasing incisions) for fully guided and open flaps (vertical releasing incisions) for half-guided. However, other studies did not differentiate between the groups employing open flaps, minimally invasive flaps, or flapless approaches indistinctly.[9,25,26,29] Finally, three studies employed open-flap surgeries in all the groups.[27,28,30] A general overview of the study characteristics, guiding systems, and type of support can be found in Table 1.

Synthesis of Results from Meta-analysis

The clinical outcomes from the included RCTs were extracted and organized into tables to condense an overview for performing the meta-analysis. The comparison of static fully guided vs static half-guided was based on eight articles.[10,12,13,25–28,30] The outcome of coronal deviation

Table 1 General Overview of the Included Trials

Study (year)	Study design	Follow-up	Comparison protocols	Total number of patients/ implants	Edentulism (full/partial/ single implant)	Arch	Navigation system and software	Type of support	Implant characteristics	Site, setting, and funding
Farley et al[10] (2013)	RCT	CBCT post-surgery	Fully guided versus half-guided	20/20	Single implant	Maxilla, mandible	iDent	Tooth	Biomet 3i Certain	Ohio State University, partially supported by Biomet 3i
Pozzi et al[9] (2014)	RCT	CBCT post-surgery	Fully guided versus freehand	51/202	Full/Partial edentulous	Maxilla, mandible	Brånemark System Guided Surgery	Tooth, mucosa	NobelSpeedy Groovy (Nobel Biocare)	Italian private centers, no funding
Vercruyssen et al[25] (2014)	RCT	CBCT post-surgery	Fully guided versus half-guided and freehand	72/314	Full edentulous	Maxilla, mandible	Simplant (Materialise), Facilitate system	Mucosa, bone	OsseoSpeed Astra Tech (Dentsply)	Leuven University, partially supported by Dentsply and Materialise
Vercruyssen et al[26] (2015)	RCT	CBCT post-surgery	Fully guided versus half-guided and freehand	72/311	Full edentulous	Maxilla, mandible	Simplant (Materialise), Facilitate system	Mucosa, bone	OsseoSpeed Astra Tech (Dentsply)	Leuven University, partially supported by Dentsply and Materialise
Amorfini et al[13] (2017)	RCT	CBCT post-surgery	Fully guided versus half-guided	24/70	Partial edentulous	Maxilla	coDiagnostX (Straumann)	Tooth	Straumann Bone Level	University of Genova, no funding
Younes et al[12] (2018)	RCT	CBCT post-surgery	Fully guided versus half-guided and freehand	32/71	Partial edentulous	Maxilla	Max, Mand Simplant (Materialise) Facilitate system	Tooth	OsseoSpeed Astra Tech (Dentsply)	Brussels University, partially supported by Dentsply
Schneider et al[27] (2018)	RCT	STL post super-impost to 3D pre	Fully guided versus half-guided	73/73	Partial edentulous	Maxilla, mandible	Simplant (Dentsply Sirona)	Tooth	Astra Tech Implant System (Dentsply Sirona Implants) or Straumann	University of Zurich, partially supported by Dentsply Sirona and Swissmeda
Tallarico et al[29] (2018)	RCT	5 years	Fully guided versus free-hand	20/62	Partial edentulous	Maxilla, mandible	Nobel Biocare	Tooth	NobelSpeedy Groovy (Nobel Biocare)	Italian private centers, no funding
Smitkarn et al[30] (2019)	RCT	CBCT post-surgery	Fully guided versus half-guided	52/60	Single implant	Maxilla, mandible	coDiagnostiX (Straumann)	Tooth	Straumann Bone Level	Faculty of Dentistry, Chulalongkorn University, university funding
Schneider et al[28] (2019)	RCT	STL post super-impost to 3D pre	Fully guided versus half-guided	73/73	Partial edentulous	Maxilla, mandible	Simplant (Dentsply Sirona), SMOP (Swissmeda)	Tooth	Astra Tech Implant System (Dentsply Sirona Implants) or Straumann	University of Zurich, partially supported by Dentsply Sirona and Swissmeda

RCT = randomized clinical trial; STL = surface tesselation language.

was based on five trials,[10,12,26,28,30] apical deviation and apical angle deviation were based on four,[10,12,28,30] vertical deviation was based on five,[10,12,26,28,30] and lastly, chair time analysis was based on three trials that evaluated this outcome.[13,25,27]

For the comparison of static fully guided vs the freehand approach (five articles),[9,12,25,26,29] the assessment of coronal deviation was based on two trials,[12,26] vertical deviation was based on two trials,[12,26] and lastly, three articles had also evaluated the chair time differences.[9,25,29] General characteristics of the intervention and results are detailed in Table 2.

Coronal Deviation

Results from the meta-analyses demonstrated a significant weighted mean difference between the

Table 2 General Characteristics of the Intervention and Results

Study	Fully guided					Half-guided				
	Coronal deviation (SD)	Apical deviation (SD)	Vertical deviation (SD)	Apical angle deviation (SD)	Chair time (SD)	Coronal deviation (SD)	Apical deviation (SD)	Vertical deviation (SD)	Apical angle deviation (SD)	Chair time (SD)
Farley et al[10] (2013)	0.63 (0.37)	1.11 (0.71)	1.24 (0.68)	3.68 (2.19)	NA	1.15 (0.57)	1.84 (0.97)	0.17 (1.09)	6.13 (4.04)	NA
Pozzi et al[9] (2014)	NA	NA	NA	NA	42.68 (21.44)	NA	NA	NA	NA	NA
Vercruyssen et al[25] (2014)	NA	NA	NA	NA	83.01 (17.67)	NA	NA	NA	NA	76.4 (11.8)
Vercruyssen et al[26] (2015)	0.61 (0.54)	NA	0.91 (0.71)	NA	NA	1.42 (1.09)	NA	2.20 (1.44)	NA	NA
Amorfini et al[13] (2017)	NA	NA	NA	NA	38 (2)	NA	NA	NA	NA	47 (6)
Younes et al[12] (2018)	0.55 (0.11)	0.81 (021)	0.43 (0.09)	2.30 (0.92)	NA	0.79 (0.11)	1.14 (0.2)	0.68 (0.09)	5.95 (0.87)	NA
Schneider et al[27] (2018)	NA	NA	NA	NA	127.96 (45.47)	NA	NA	NA	NA	92.88 (39.8)
Tallarico et al[29] (2018)	NA	NA	NA	NA	43.2 (29)	NA	NA	NA	NA	NA
Smitkarn et al[30] (2019)	1.0 (0.6)	1.3 (0.6)	0.7 (0.6)	3.1 (2.3)	NA	1.5 (0.7)	2.1 (1.0)	1.0 (0.8)	6.9 (4.4)	NA
Schneider et al[28] (2019)	0.62 (0.33)	1.02 (0.57)	0.15 (0.82)	3.68 (2.4)	NA	1.25 (0.62)	2.33 (1.24)	0.28 (1.01)	7.36 (3.36)	NA

All reported measurements are in mm except apical angle deviation in grades.
NA = not available.

Study or subgroup	Mean (SD) Fully guided	Half-guided	Mean difference (95% CI)
Fully guided vs half-guided			
Farley et al[10] (2013)	0.63 (0.37)	1.15 (0.57)	−0.52 (−0.94, −0.10)
Vercruyssen et al[26] (2015)	0.61 (0.54)	1.42 (1.09)	−0.81 (−1.12, −0.50)
Younes et al[12] (2018)	0.55 (0.11)	0.79 (0.11)	−0.24 (−0.30, −0.18)
Smitkarn et al[30] (2019)	1 (0.6)	1.5 (0.7)	−0.50 (−0.83, −0.17)
Schneider et al[28] (2019)	0.62 (0.33)	1.25 (0.62)	−0.62 (−0.88, −0.37)
RE model for all studies (Q = 22.46, df = 4, P = .00; I^2 = 74.8%) Test for overall effect: Z = −4.59, P < .001			**−0.51 (−0.73, −0.29)**
Fully guided vs freehand	**Fully guided**	**Freehand**	
Vercruyssen et al[26] (2015)	0.61 (0.54)	2.31 (1.72)	−1.70 (−2.18, −1.22)
Younes et al[12] (2018)	0.55 (0.11)	1.27 (0.11)	−0.72 (−0.78, −0.66)
RE model for all studies (Q = 15.89, df = 1, P = .00; I^2 = 93.7%) Test for overall effect: Z = −2.41, P = .01			**−1.18 (−2.14, −0.22)**

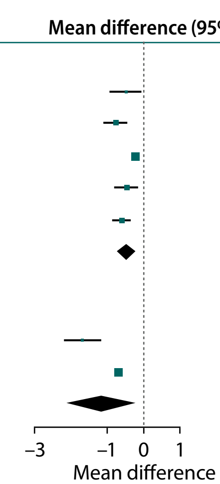

Fig 2 Coronal deviation comparison.

fully guided and half-guided groups (−0.51 mm [95% CI (−0.73, −0.29), P = .007]). The clinical significance of this difference implies a 0.51-mm (95% CI [0.29, 0.73]) benefit in accuracy favoring the fully guided approach. As demonstrated by the forest plots, the improved accuracy of the fully guided approach was further heightened compared to the freehand technique with the weighted mean difference of −1.18 mm (95% CI [−2.14, −0.22], P = .01) between the two groups. Forest plots (Fig 2) illustrate these findings, and funnel plots (Appendix Figs 1a and 1b) confirm the substantial heterogeneity presented as a result of the analyses (I^2 = 74.8%, P < .001; I^2 = 93.7%, P < .001, respectively).

Freehand				
Coronal deviation (SD)	Apical deviation (SD)	Vertical deviation (SD)	Apical angle deviation (SD)	Chair time (SD)
NA	NA	NA	NA	NA
NA	NA	NA	NA	42.31 (23.33)
NA	NA	NA	NA	100 (19.5)
2.31 (1.72)	NA	1.25 (0.95)	NA	NA
NA	NA	NA	NA	NA
1.27 (0.11)	1.97 (0.19)	0.50 (0.09)	6.99 (0.87)	NA
NA	NA	NA	NA	NA
NA	NA	NA	NA	41.5 (32.3)
NA	NA	NA	NA	NA
NA	NA	NA	NA	NA

Study or subgroup	Mean (SD) Fully guided	Mean (SD) Half-guided	Mean difference (95% CI)
Fully guided vs half-guided			
Farley et al[10] (2013)	1.11 (0.71)	1.84 (0.97)	−0.73 (−1.48, 0.02)
Younes et al[12] (2018)	0.81 (0.21)	1.14 (0.2)	−0.33 (−0.45, −0.21)
Smitkarn et al[30] (2019)	1.3 (0.6)	2.1 (1)	−0.80 (−1.22, −0.38)
Schneider et al[29] (2019)	1.02 (0.57)	2.33 (1.24)	−1.31 (−1.81, −0.80)
RE model for all studies ($Q = 17.86$, $df = 3$, $P = .00$; $I^2 = 79.5\%$)			**−0.75 (−1.19, −0.31)**
Test for overall effect: $Z = −3.39$, $P < .001$			

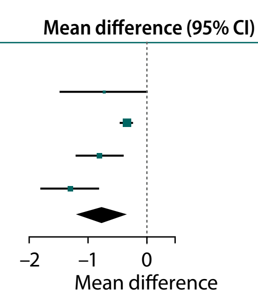

Fig 3 Apical deviation comparison.

Apical Deviation

The meta-analysis revealed a significant weighted mean difference between the fully guided and half-guided approaches (−0.75 mm [95% CI (−1.19, −0.31), *P* = .02]). The forest plot (Fig 3) displays this outcome, and the funnel plot illustrates considerable heterogeneity found in this comparison ($I^2 = 79.5\%$, *P* < .01; Appendix Fig 1c). Nonetheless, for comparison of the fully guided vs freehand techniques, as only one trial[12] could be included, no meta-analysis was performed.

Vertical Deviation

As demonstrated by the forest plots, this comparison did not yield a significant weighted mean difference between the fully guided and half-guided techniques (−0.23 mm [95% CI (−0.90, 0.45), *P* = .51]) and presented considerable heterogeneity ($I^2 = 95.3\%$, *P* < .01). Similarly, the difference for the weighted mean between the fully guided and freehand techniques also lacked statistical significance (−0.17 mm [95% CI (−0.42, 0.09), *P* = .19]) and presented considerable heterogeneity ($I^2 = 71.5\%$, *P* = .19; Fig 4 and Appendix Figs 1d and 1e).

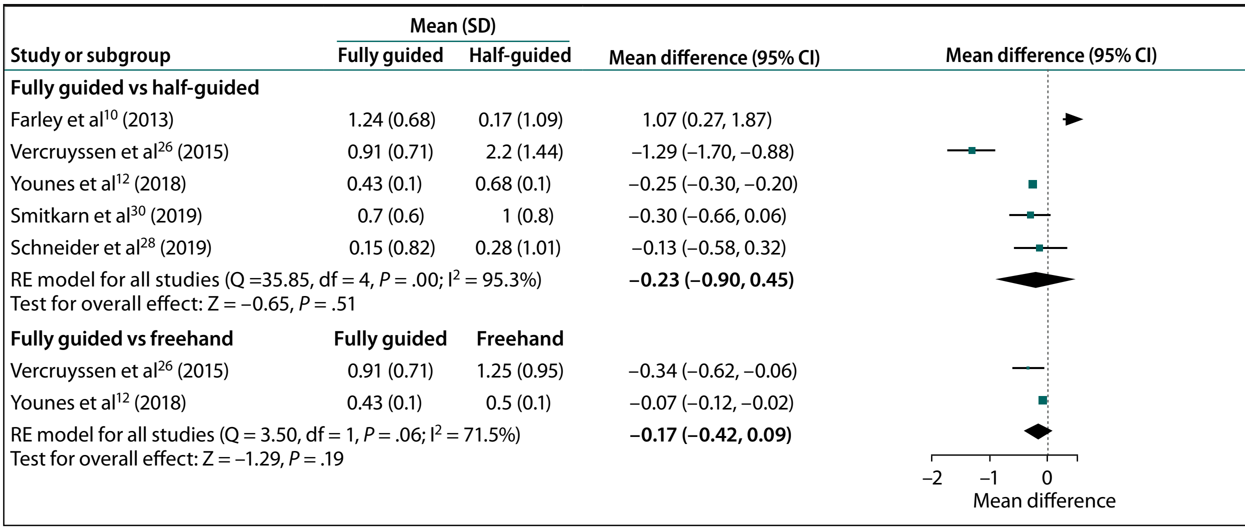

Fig 4 Vertical deviation comparison.

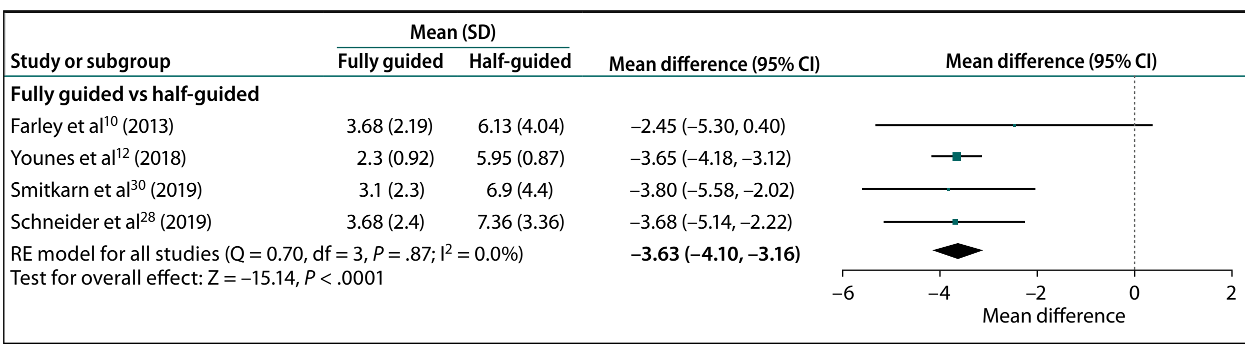

Fig 5 Apical angle deviation comparison.

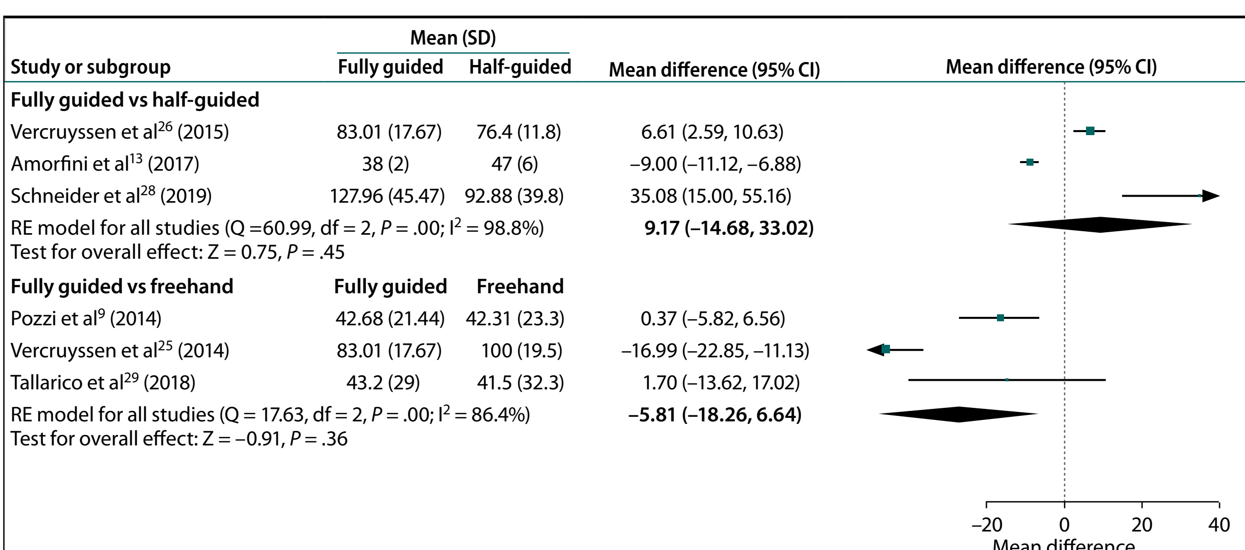

Fig 6 Chair time comparison.

Apical Angle Deviation

The meta-analysis comparing the fully guided vs the half-guided approaches demonstrated a significant weighted mean difference in favor of the fully guided approach (–3.63 degrees [95% CI (–4.10, –3.16), $P < .001$]), presenting low heterogeneity ($I^2 = 0\%$, $P = .87$). These findings are summarized in forest and funnel plots (Fig 5 and Appendix Fig 1f). However, for comparison of the fully guided vs freehand techniques, as only one study[12] had reported this outcome, no meta-analysis could be performed.

Chair Time

The comparison of chair time between the investigated groups did not exhibit a statistically significant difference in any of the techniques. The weighted mean difference between the fully guided and half-guided approaches amounted to 9.17 minutes (95% CI [–14.68, 33.02], $P = .45$), presenting substantial heterogeneity ($I^2 = 98.8\%$, $P < .001$), and the weighted mean difference between the fully guided and freehand approaches amounted to 5.81 minutes (95% CI [–18.26, 6.64], $P = .36$) and presented substantial heterogeneity ($I^2 = 86.4\%$, $P < .001$). These results are illustrated with forest and funnel plots (Fig 6 and Appendix Fig 1).

DISCUSSION

The accuracy in transmitting the presurgical implant positioning planning to the patient is the most studied parameter in the field of implant navigation surgery. Findings from previous systematic reviews are in line with the results of this review.[15,16,18] However, the main focus of the past reviews has been on the outcomes of individual navigation systems, without direct comparison within the individual studies.[15,17,18,32] In the present review, to maximize the clinical relevance, only studies comparing different guiding system approaches have been included and evaluated.

The findings from the meta-analyses revealed that the static fully guided technique provides the most accurate static implant navigation system, while the freehand surgical approach had the least accuracy among the three tested techniques. Additionally, the results of the present review demonstrated a smaller difference in the accuracy between the fully guided and half-guided techniques (weighted mean difference of 0.51 mm for coronal deviation, 0.75 mm for apical deviation, 0.23 mm for vertical deviation, and 3.63 degrees for apical angle deviation), but a larger coronal variation when comparing the fully guided vs the freehand approach (weighted mean difference of 1.18 mm). It is worth mentioning that the only nonsignificant difference in position accuracy was for the vertical dimension, which is consistent with the study of Younes et al.[12] However, the studies by Vercruyssen et al[26] and Farley et al[10] found a greater inaccuracy in the vertical aspect than with the horizontal deviation. The reason for this vertical inaccuracy may be due to the instability of some fully guided stents as described by Farley et al,[10] as some of the templates were seated in a more occlusal position than originally planned. For the study by Vercruyssen et al,[26] the vertical inaccuracy could be due to some fully guided templates that did not have a physical stop, and the depth of the preparation had to be checked visually during the implant drilling. Indeed, the present results demonstrate that the fully guided surgical protocol proved to deliver the highest vertical accuracy; however, when comparing the freehand approach with the half-guided technique, the former provided a higher vertical accuracy. This is explained by the studies of Younes et al[12] and Vercruyssen et al,[26] who both indicated that the half-guided protocol often resulted in a lack of control in the vertical dimension after using the pilot drill or the laboratory-made stent, while the freehand technique often made the clinician more aware of this concern, so the apical placement deviation was reduced during implant placement.[18]

An interesting result of the present meta-analysis was the nonsignificant difference assessed in the operating chair time, reporting different outcomes between studies. While Vercruyssen et al[25] revealed shorter surgical times when using fully guided compared with freehand, half-guided showed the shortest chair time, in accordance with the study of Schneider et al.[27] In contrast, Amorfini et al[13] clearly showed less chair time in the fully guided compared with the half-guided surgery. Interestingly, the trials of Pozzi et al[9] and Tallarico et al[29] did not find a significant difference in the operating time between the fully guided and freehand approaches. This might have been due to both procedures being carried out as a flapless surgical procedure using a soft tissue punch. Schneider et al[27] found a longer duration of the surgery when applying the fully guided approach in comparison to half-guided (conventional laboratory-fabricated stent) when open-flap surgeries were performed in both groups. This tendency of longer chair time associated with the fully guided technique when identical flap design was applied might be related to the time-consuming use of templates with metal sleeves that must be changed for each diameter drill size[25] and mouth-opening limitations that make the procedure more challenging, particularly in posterior areas.[8]

Other factors have been described to influence the implant positioning accuracy outcomes, including the surgical guide support (bone, mucosa, or tooth), which is related to the type of edentulism (fully or partially edentulous patients).[18,26,33] Flapless surgery and teeth/crown-supported guides (partially edentulous patients) have been revealed to achieve the highest implant positioning accuracy,[8,18,34] which was difficult to verify in the present analysis, considering that Verycrussen et al[26] was the unique study to assess implant positioning accuracy in fully edentulous patients, whereas others evaluated partially edentulous patients[28,30] or a combination of fully and partially edentulous patients.[12]

A flapless surgery is often associated with reducing postoperative pain/discomfort, swelling, and analgesic consumption, and with higher patient satisfaction.[9,10,13,25,33,35] A flapless surgical procedure that accompanies the fully guided approach requires 3D planning to ensure adequate bone volume, adequate keratinized mucosa, and computer-guided template fabrication to avoid the needs of flap opening.[10,34]

Otherwise, the experience of the surgeon has been previously described as an important factor related to influencing the outcomes of implant placement.[8] Surgeon experience affects all different surgical approaches, although freehand placement seems to require more surgical experience to overcome its limitations in relation to the least amount of positioning accuracy.[7,13,36–39] Furthermore, surgical experience is also highly recommended when using fully guided or half-guided approaches to prevent any error in presurgical planning or within the guided system that could result in a wrong implant positioning.[8] However, Van de Wiele et al[39] considered that surgical experience has minimum influence on the accuracy of implant placement when a fully guided approach is correctly used together with the supervision of an experienced instructor.

The present systematic review is not without limitations. Although a comprehensive search strategy was employed and complemented through extensive handsearching of the journals for identification of relevant articles, it may still be possible that some grey literature was missed. Considerable heterogeneity arose as a result of some of the analyses. This could have been due to the different implant navigation systems, types of edentulism, the particular flap approach, and the implant distribution. It has also been shown that different implant navigation systems used may also affect the accuracy of the implant positioning, which was an element, along with pain/discomfort and patient satisfaction, that the present review did not have enough standardized information on for analysis.

CONCLUSIONS

Static fully guided implant surgery has the highest accuracy for transmitting the presurgical positioning planning to the patient, followed by static half-guided surgery, while freehand implant placement provides the least accuracy among them. The horizontal coronal and apical deviation, together with apical angle deviation, showed significant differences among the groups, while vertical deviation and chair time failed to show significant differences. Further investigations are needed to verify the clinical implications of these findings.

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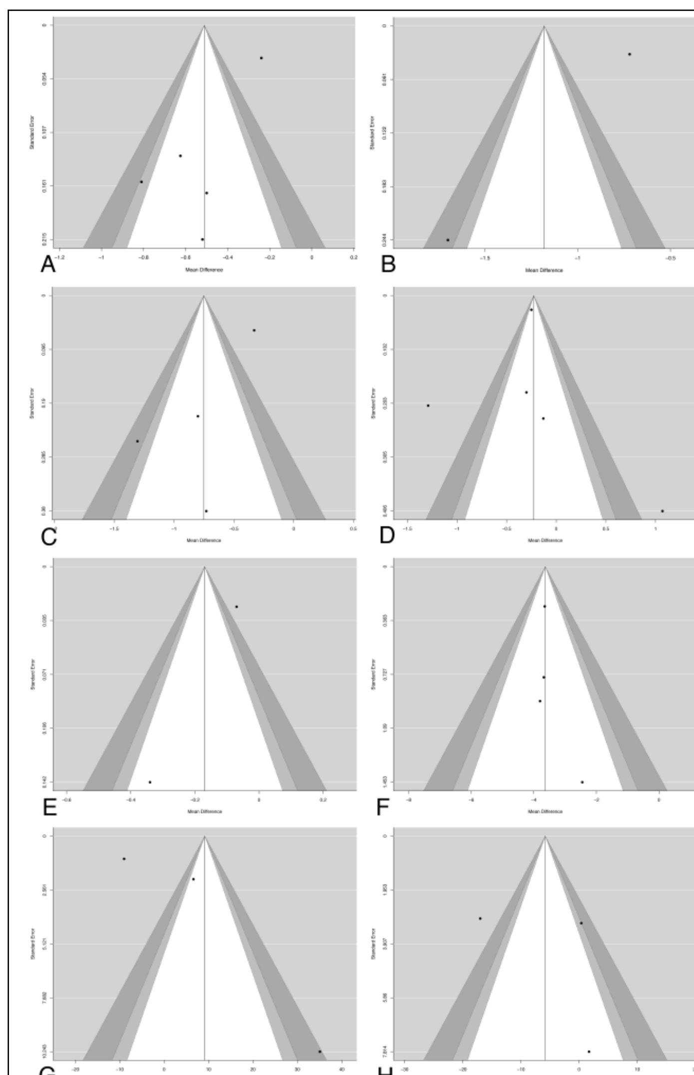
APPENDIX

Appendix Table 1 Bias Risk Assessment for the Included RCTs Using the Cochrane Risk of Bias Tool for Randomized Controlled Trials[23]

Study	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data addresses	Selective reporting	Other bias	Overall risk of bias
Farley et al,[10] 2013	Low	Low	Low	Low	Low	Low	Low	Low
Pozzi et al,[9] 2014	Low	Low	Low	Low	Low	Moderate	Low	Moderate
Vercruyssen et al,[25] 2014	Low	Low	Low	Moderate	Low	Low	Low	Moderate
Vercruyssen et al,[26] 2015	Low	Low	Low	Low	Low	Low	Low	Low
Amorfini et al,[13] 2017	Low	Low	Low	Low	Low	Low	Low	Low
Younes et al,[12] 2018	Low	Low	Low	Low	Low	Low	Low	Low
Schneider et al,[27] 2018	Low	Low	Low	Moderate	Low	Low	Low	Moderate
Tallarico et al,[29] 2018	Low	Low	Low	Low	Low	Low	Low	Low
Smitkarn et al,[30] 2019	Low	Low	Low	Low	Low	Low	Low	Low
Schneider et al,[28] 2019	Low	Low	Low	Moderate	Low	Low	Low	Moderate



Appendix Fig 1 Forest and funnel plot comparison between groups.