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# ACCURACY OF TYPE I IMPLANT PLACEMENT USING STATIC AND DYNAMIC GUIDES COMPARED TO THE CONVENTIONAL METHOD – A SYSTEMATIC REVIEW AND META-ANALYSIS

*Naisargi Shah, ** Pratiksha Haveri, ***Rahul Malu, **Anuja Nikam,
**Bhavna Ahuja, **Tejas Nalawade

* Professor and Head of Department, **Lecturer, *** Reader, Department of Prosthodontics and Crown & Bridge, Terna Dental College and Hospital, Navi Mumbai | Corresponding Author: Dr. Pratiksha Haveri, E-mail: haveri.pratiksha57@gmail.com

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## Abstract

***Aim:*** *To evaluate the accuracy of Type I implant placement using static and dynamic guides compared to the conventional freehand method.*

***Settings and Design:*** *This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.*

***Methods and Materials:*** *An electronic search of PubMed (including MEDLINE), EBSCOhost databases, Cochrane Library, and Google Scholar search engine for articles published from 1st January 2013 to 1st March 2023 was conducted. The literature search intended to retrieve all relevant clinical and in vitro studies about the accuracy of type I implant placement using static and dynamic guided surgery and conventional freehand implant placement.*

***Statistical analysis used:*** *Meta-analysis was conducted from the reported quantitative data.*

***Results:*** *A total of 1486 articles were obtained via electronic search, and 2 articles were obtained via manual search; 6 studies met the inclusion criteria and were included in this systematic review. Among the different parameters described, the difference in accuracy between virtual and planned implant positions was evaluated. Accuracy was measured by evaluating the pre- and post-operative CBCT. Three studies comparing the accuracy of static guides with freehand implant placement and two studies comparing the accuracy of static guides with dynamic guided implant placement were included for meta-analysis.*

*The comparison between static and freehand placement showed a statistically significant difference between placement accuracy, favouring static placement, and the comparison between static and dynamic placement favoured dynamic placement.*

***Conclusion:*** *The accuracy of type I implant placement was enhanced using both static and dynamic guided surgery as compared to the conventional freehand protocol. Dynamic guided surgery showed greater accuracy as compared to the static guided system for type I implant placement.*

***Keywords: accuracy, dental implants, computer-assisted surgery, static guides, freehand surgery***

## Introduction

The use of dental implants has become an integral treatment modality in dentistry for the treatment of complete and partial edentulism. Dental implants have several advantages over conventional fixed partial dentures, like a high success rate, improved maintenance of bone, conservation of tooth structure, and decreased sensitivity of adjacent teeth.[1] However, proper positioning and angulation of implants are essential for the success of the surgical and prosthetic treatment.[2]

There are four basic types of implant placement depending on the time required for healing after implantation – Type I: Immediate implant placement which is done at the time of extraction; Type II: Early implant placement which is done 4-8 weeks after implant placement with soft tissue healing; Type III: Early implant placement which is done 12-16 weeks after implant placement with partial bone healing and Type IV: Delayed implant placement which is done after 6 months of implant placement with complete bone healing.[3] The conventional placement method (type IV), which requires 3-6 months for healing before implantation, is the most commonly used. However, in recent times, immediate implant placement (type I) is increasing in demand for its obvious advantages: shortened treatment time, less surgical trauma, and excellent treatment outcomes.[1] However, several studies have demonstrated that type I surgery is highly technically sensitive. Improper position of immediate implants may lead to restoration and aesthetic problems, and even peri-implantitis.[2]

In conventional protocols, implants are placed freehand, but they are unable to reproduce the planned implant position accurately. At present, immediate implant placement depends on preoperative X-ray or cone-beam computed tomography (CBCT) assessment, including bone height at the implant area and position of the lower alveolar nerve and maxillary sinus.[4]

The aim of surgical guides is to reduce the inherent positional uncertainty associated with freehand surgery. Such guides are classified into two main categories: static and dynamic.

The accuracy of template-based static systems is acceptable in most clinical situations. Such templates are mostly fabricated via 3D printing based on digital images (CBCT/intraoral scanner), and the resulting template is either bone-supported, mucosa, or tooth-supported. The success of implant insertion using static systems is based on the surgical guide and the doctor's experience. A study conducted by Shah et al. in the year 2022 demonstrated that in the process of manufacturing static surgical guides, errors can be introduced, which can result in errors in the final implant position.[5] In comparison with the original design, the traditional method can result in an angle or depth that is inconsistent. This is due to a deviation in the thickness of the surgical guide and variation in the surgeon's experience.[6]

Prosthetic-driven implant placement for optimal esthetic restoration has been increasing in demand during the last decades but requires higher accuracy. In recent years, machine-vision (MV) enhanced and artificial intelligence-assisted dynamic navigation (DN), a technology that already has a large number of applications in industry, is gradually being applied to image-guided and minimally invasive surgical approaches and holds great promise for safety and accuracy.[7]

Computer-assisted implant surgery (CAIS), which includes static and dynamic systems, offers reliable results.[6] However, few studies have evaluated this accuracy for type I implant placement, which is in demand due to its

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shortened clinical procedure.

Therefore, this study evaluates the accuracy of static and dynamic guides for type I implant placement. The purpose of this study is to evaluate the accuracy of type I implant placement using static and dynamic guides as compared to the conventional method.

## Material and Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[8] with prior registration in PROSPERO (Registration number CRD42023431317).

The focused question was "Is the accuracy of type I implant placement enhanced using static and dynamic guided surgery as compared to the conventional method?" The PICO, i.e., the Population, Intervention, Comparison, and Outcome format, was used (Table 1).

**Table 1:** PICO Criteria

| PICO | |
|---|---|
| Population | Patients requiring type I implant placement |
| Intervention | 1. Type I implant placement using static guides<br>2. Type I implant placement using dynamic guides |
| Comparison | Type I implant placement using the conventional method |
| Outcome | Accuracy of implant placement |

The inclusion criteria were in vivo and in vitro studies that evaluated the accuracy of type 1 implant placement using computer-guided, static-guided guided and freehand surgery, studies published in peer-reviewed journals, articles appearing in the English dental literature, published between 2013 and 1st February 2023. The exclusion criteria were studies that were not related to type I implant placement and studies in medically compromised patients. Review articles, case series, and case reports were also excluded.

An electronic search of PubMed (including MEDLINE), Cochrane Central, EBSCOhost databases, and Google Scholar search engine for articles published from 1st January 2013 to 1st March 2023 was conducted. The controlled vocabulary terms (i.e., MeSH terms) and free text terms were obtained by searching key concepts in the MeSH database and a thorough evaluation of related articles, thesaurus, dictionaries, and entry terms. The terms such as dental implant, dental implants, type I implant placement, immediate implantation, static guides, surgical guides, computer-assisted surgery, surgical navigation, freehand type I implant placement, conventional type I implant placement, dimensional measurement accuracy, immediate implant placement accuracy, type I placement accuracy were combined using suitable Boolean operators (AND, OR, NOT) (Table 2).

**Table 2:** PICO concept table

| PICO | POPULATION | INTERVENTION | | COMPARISON | OUTCOME |
|---|---|---|---|---|---|
| KEY CONCEPTS | Type I implant placement | Static guides | Dynamic guides | Freehand surgery | Accuracy of implant placement |
| CONTROLLED VOCABULARY TERMS (MeSH TERMS) | Dental Implants<br>Dental implantation | | Surgery, Computer-assisted | | Dimensional measurement accuracy |

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An electronic search was conducted independently by two reviewers (P.H., R.M.). A total of 1488 articles were obtained via electronic search. The articles thus obtained were evaluated for duplicates. A detailed summary of data selection has been put forth in the PRISMA 2009 Flow Diagram[8] (Figure 1).

The study characteristics of each systematic review were extracted, including study details, search details, analysis, and results/findings by two independent reviewers (P.H., R.M)

A third reviewer (N.P.S.) was called in for a final decision if any disagreement persisted between the two calibrated reviewers.

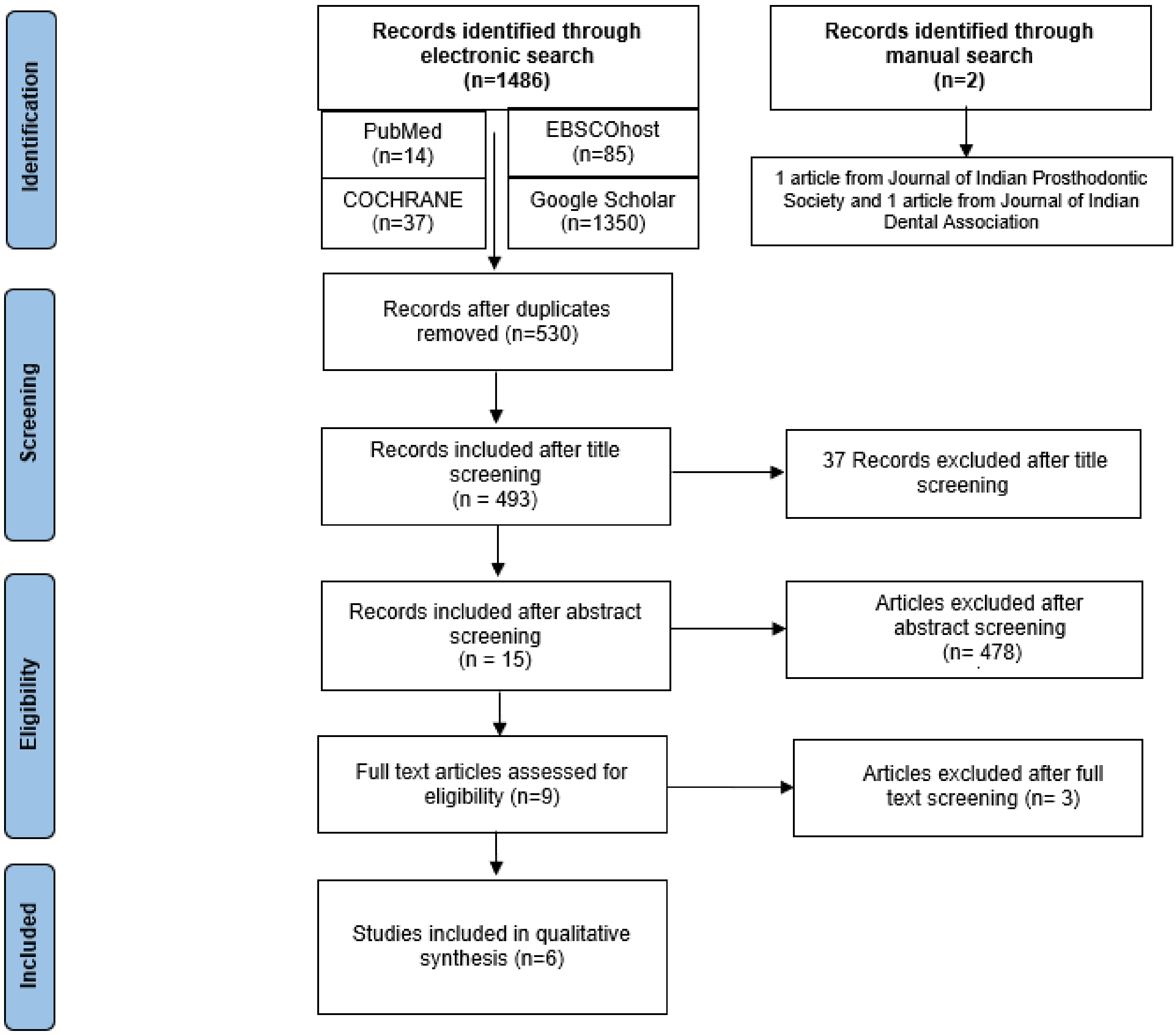


**Figure 1:** PRISMA 2009 Flow Diagram

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## Results

The 1488 articles that were obtained through the electronic searches were compared meticulously concerning the author's name, year of publication, title, abstract, as well as the journal name, issue, and volume number. The articles thus obtained after the electronic and manual searches were evaluated for duplicates using the Mendeley Desktop software (v1.19.6). The 2 articles obtained through the manual search were added manually using the 'add entry manually' feature of Mendeley Desktop software (v1.19.6). The 'check for duplicates' feature of this software was then used to identify and eliminate duplicates. 956 duplicate articles were identified and subsequently eliminated, leaving behind 530 articles. Two calibrated reviewers (P.H., R.M.) independently screened the relevant titles of the studies found through the electronic search. Out of 530 articles, 37 articles were excluded after screening of the title. The articles thus eliminated were either literature reviews, scoping reviews, case reports, case series, or articles not related to type I implant placement. Thus, 493 articles were selected after title screening.

Two calibrated reviewers (P.H., R.M.) now independently screened the abstracts of the studies found relevant during the screening of the titles, and a total of 478 articles were further excluded after abstract screening. The articles eliminated through abstract screening mainly involved different types of implant placement and had no comparison groups. 15 articles were included after abstract screening. Hence, 6 articles were selected after abstract screening and thus were included in this systematic review. The 6 articles included 2 in vitro studies, 3 randomised controlled trials, and 1 prospective study (Table 3).

3 articles were excluded after full-text screening. The reason for exclusion is depicted in Table 4.

A third reviewer (N.P.S.) was called in for a final decision if any disagreement over article selection persisted between the two calibrated reviewers. Inter-reviewer reliability was checked

**Table 3:** Included Studies = 6

| STUDY ID | AUTHOR | YEAR | TITLE |
|---|---|---|---|
| 1. | Chen et al10 | 2018 | Accuracy of flapless immediate implant placement in anterior maxilla using computer-assisted versus freehand surgery: A cadaver study. |
| 2. | Han et al.4 | 2021 | Whole-Process Digitalization-Assisted Immediate Implant Placement and Immediate Restoration in the Aesthetic Zone: A Prospective Study. |
| 3. | Wei et al.7 | 2022 | Does machine-vision-assisted dynamic navigation improve the accuracy of digitally planned prosthetically guided immediate implant placement? A randomized controlled trial. |
| 4. | Wang et al.11 | 2022 | Comparison of Implant Placement Accuracy in Healed and Fresh Extraction Sockets between Static and Dynamic Computer-Assisted Implant Surgery Navigation Systems: A Model-Based Evaluation. |
| 5. | Feng et al.12 | 2022 | Comparison of the accuracy of immediate implant placement using static and dynamic computer-assisted implant system in the esthetic zone of the maxilla: a prospective study. |
| 6. | Ayman et al.13 | 2022 | Effect of implant scan body geometric modifications on the trueness, scanning time of complete arch intraoral implant digital scans |

via Cohen's kappa coefficient.[9] The Cohen's kappa coefficient values obtained for title, abstract, and full text screening were 0.62, 0.68, and 0.75, respectively, indicating moderate inter-reviewer agreement for title, abstract, and full text screening.

The data were subsequently extracted from the 6 included studies and recorded in 2 Excel data extraction sheets as mentioned in the summary table (Table 5).

The data extracted was entered under the following headings: Author and Year of publication, Study design, Study model, Sample size, Comparison groups, Measurement variables, Method of measurement, Software used, Test of Analysis, and Outcome.

Risk of bias assessment of the included studies was done using the Newcastle-Ottawa scale[15] for cohort studies, Cochrane's Collaboration tool[16] for randomised controlled trials, and QUIN tool scale[17] for in vitro studies, by two independent reviewers (P.H., R.M.).

These scales were considered apt for the risk of bias evaluation in this systematic review. The changes made to the scale were validated by the third reviewer (N.P.S.).

All the included studies showed low risk of bias, indicating a high quality of evidence. The scores were categorized as

Low risk of bias (plausible bias unlikely to seriously alter the results); Unclear risk of bias (plausible bias that raises some doubt about the results); or

High risk of bias (plausible bias that seriously weakens confidence in the results) for the in vitro studies and randomized controlled trials; and

Good quality (plausible bias unlikely to seriously alter the results), Fair quality (plausible bias that raises some doubt about the results), or Poor quality (plausible bias that seriously weakens confidence in the results) for the prospective study.

Summarized results indicate an overall high quality of the included studies, with a high risk of bias being present only for specific points (Tables 6, 7, 8).

META ANALYSIS

Six studies evaluating the accuracy of type1 implant placement with the use of static and dynamic guides in comparison with the conventional implant placement were included in the systematic review.

One study, which compared the accuracy

**Table 4:** Excluded Studies = 3

| SR. NO. | AUTHOR | YEAR | TITLE | REASON FOR EXCLUSION |
|---|---|---|---|---|
| 1. | Marrero et al.[2] | 2022 | Accuracy of computer-assisted surgery in immediate implant placement: an experimental study | Only one group considered with no comparison group. |
| 2. | Aydemir et al.[14] | 2020 | Accuracy of Dental Implant Placement via Dynamic Navigation or the Freehand method: A Split-Mouth Randomized Controlled Clinical Trial. | Accuracy of type I implant placement not assessed. |
| 3. | Wei et al.1 | 2021 | Accuracy and primary stability of tapered or straight implants placed into fresh extraction socket using dynamic navigation: a randomized controlled clinical trial | Only one group considered with no comparison group. |

Table 5: Characteristic Data extraction table of included studies

| AUTHOR | STUDY DESIGN | MODEL | SAMPLE SIZE | COMPARISON GROUPS | MEASUREMENT VARIABLES | METHOD OF MEASUREMENT | SOFTWARE USED | TEST OF ANALYSIS | OUTCOME |
|---|---|---|---|---|---|---|---|---|---|
| Chen et al. (2018)[10] | In-vitro study | Eight human cadaver heads | 24 | Computer-guided and Freehand immediate implant placement | Placement accuracy, angular, global, corono-apical, and mesio-distal deviations between virtual and planned implant positions. | Pre- and Post-operative CBCT | Blue Sky Plan3 Software | Independent-samples t test | Computer guided surgery > Freehand surgery Both computer-guided and freehand surgery showed a more buccal placement in immediate implantation. |
| Han et al. (2021)[4] | Prospective study | - | 60 | Whole- Process Digitalization assisted and Conventional immediate implant placement | Implant accuracy, coronal deviation, apical deviation, angular deviation, and depth deviation, were evaluated. | Pre- and Post-operative CBCT | Materialise mimics®, version 20.0 | Independent t test and paired t test. | WD-assisted surgery > Conventional surgery |
| Wei et al. (2022)[7] | RCT | - | 24 | Dynamic navigation-assisted and Conventional freehand immediate implant placement | Implant accuracy, angular, and depth deviations were compared between the groups. | Pre- and Post-operative CBCT | Dcarer dynamic navigation software | Student's two sample t tests and Welch two sample t tests | Dynamic navigation assisted surgery> conventional freehand surgery |
| Wang et al. (2022)[11] | In-vitro study | 20 3D-printed maxillary models | 80 | Static guided and Dynamic guided immediate implant placement | Implant accuracy, apical, depth, lateral and angular deviation | Pre- and Post-operative CBCT | 3Shape software | Independent two-sample t test and Mann–Whitney U test | Dynamic computer-assisted implant navigation showed lower entry and apical errors than static system. |
| Feng et al. (2022)[12] | Prospective RCT | - | 40 | Static system and Dynamic computer-assisted immediate implant placement | Implant accuracy, global deviations at entry and apex and angular deviation. | Pre- and Post-operative CBCT | Mimics software (Materialise NV 2018, Version 21.0) | Student's two sample t-tests and Mann–Whitney U tests | No significant differences in accuracy were found between static and dynamic CAIS groups |
| Ayman et al. (2022)[13] | RCT | - | 22 | Computer-guided and Freehand immediate implant placement | Implant accuracy, global, lateral, depth, mesio-distal and bucco-lingual deviations | Pre- and Post-operative CBCT | Blue Sky Plan3 Software | Independent samples t test | Computer-guided surgery more accurate in buccolingual direction compared to freehand surgery. |

of dynamic navigation-assisted immediate implant placement with the conventional freehand technique (Shi-Min Wei et al., 2022)[7] was excluded from the meta-analysis due to a lack of uniformity in the comparison groups. Three studies comparing the accuracy of static guides with freehand implant placement (Doaa M Ayman et al., 2022; Xiaomei Han et al., 2021; Zhaozhao Chen et al., 2018)[13,4,10] and two studies comparing the accuracy of static guides with dynamic guided implant placement (Miaozhen Wang et al., 2022; Yuzhang Feng et al., 2022)[11,12] were included for meta-analysis.

**Table 6:** Summary of Risk of Bias for Cohort Studies

| STUDY ID | 6 |
|---|---|
| SELECTION | *** |
| COMPARABILITY | * |
| OUTCOME | *** |
| TOTAL SCORE (OUT OF 9) | 7 (GOOD QUALITY) |

**Table 7:** Summary of Risk of Bias for Randomised Controlled Trials

| STUDY ID | 3 | 4 | 5 |
|---|---|---|---|
| Random sequence generation (selection bias) | Low risk | Low risk | Low risk |
| Allocation concealment (selection bias) | Low risk | High risk | Low risk |
| Blinding of participants and researchers (performance bias) | Unclear risk | Low risk | Unclear risk |
| Blinding of outcome assessment (detection bias) | Unclear risk | Unclear risk | Unclear risk |
| Incomplete outcome data (attrition bias) | Low risk | Low risk | Low risk |
| Selective reporting (reporting bias) | High risk | Low risk | Low risk |
| RESULTS | Low Risk | Low Risk | Low Risk |

The Review Manager software (Version 5.4.1) was used to perform meta-analysis. Mean values and standard deviations for coronal and apical deviation were included for the analysis.

The data was tabulated under the headings of study name, group, and effect size. The effect size was calculated on the continuous raw data entered for mean, standard deviation, and sample size. A 95% confidence interval for each effect size was also computed. The heterogeneity of effects was assessed by the Higgin's I2 test.[18] The I2 statistic describes the percentage of variation across studies that is due to heterogeneity rather than chance and is denoted by the formula: I2= 100% x (Q-df)/Q. According to Higgins et al, calculation of heterogeneity is essential in determining the generalizability of the findings of meta-analysis.

**Table 8:** Summary of Risk of Bias for in vitro studies

| STUDY ID | 1 | 2 |
|---|---|---|
| Clearly stated aims/objectives. | 1 | 2 |
| Detailed explanation of sample size calculation | 1 | 0 |
| Detailed explanation of sampling technique | 2 | 2 |
| Details of the comparison group | 2 | 1 |
| Detailed explanation of methodology | 2 | 2 |
| Operator details | 0 | 1 |
| Randomization | 1 | 1 |
| Method of measurement of outcome | 1 | 2 |
| Outcome assessor details | 2 | 2 |
| Blinding | 1 | 0 |
| Statistical analysis | 2 | 2 |
| Presentation of results | 2 | 2 |
| TOTAL SCORE (OUT OF 24) | 17 | 17 |
| FINAL SCORE (%) | 70.83% | 70.83% |

The results of the meta-analysis comparing the coronal deviation between static guided and freehand implant placement showed a greater accuracy of implant placement with static guided surgery. The meta-analysis comparing apical deviation between static guided and freehand implant placement also showed greater accuracy with static guided surgery. The results of the meta-analysis comparing the coronal deviation between static guided and dynamic guided implant placement showed lesser deviation with dynamic guided surgery. The meta-analysis

| Study or Subgroup | static Mean | static SD | static Total | freehand Mean | freehand SD | freehand Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Zhaozhao Chen et al 2018 | 0.85 | 0.38 | 12 | 1.43 | 0.49 | 12 | 32.8% | -0.58 [-0.93, -0.23] |
| Xiaomei Han et al 2021 | 0.74 | 0.21 | 30 | 0.87 | 0.39 | 30 | 41.0% | -0.13 [-0.29, 0.03] |
| Doaa M Ayman et al 2022 | 0.69 | 0.36 | 22 | 1.43 | 1.14 | 22 | 26.1% | -0.74 [-1.24, -0.24] |
| **Total (95% CI)** | | | **64** | | | **64** | **100.0%** | **-0.44 [-0.84, -0.04]** |

Heterogeneity: Tau² = 0.10; Chi² = 9.30, df = 2 (P = 0.010); I² = 78%
Test for overall effect: Z = 2.13 (P = 0.03)

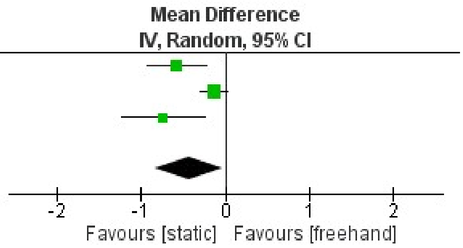


**Figure 2:** Forest plot of results for coronal deviation comparison between static guided and freehand implant placement

| Study or Subgroup | static Mean | static SD | static Total | freehand Mean | freehand SD | freehand Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Doaa M Ayman et al 2022 | 1.26 | 0.42 | 22 | 2.35 | 1.05 | 22 | 32.3% | -1.09 [-1.56, -0.62] |
| Xiaomei Han et al 2021 | 0.81 | 0.16 | 30 | 0.93 | 0.25 | 30 | 35.7% | -0.12 [-0.23, -0.01] |
| Zhaozhao Chen et al 2018 | 0.93 | 0.34 | 12 | 2.2 | 0.79 | 12 | 32.1% | -1.27 [-1.76, -0.78] |
| **Total (95% CI)** | | | **64** | | | **64** | **100.0%** | **-0.80 [-1.65, 0.04]** |

Heterogeneity: Tau² = 0.52; Chi² = 34.30, df = 2 (P < 0.00001); I² = 94%
Test for overall effect: Z = 1.86 (P = 0.06)

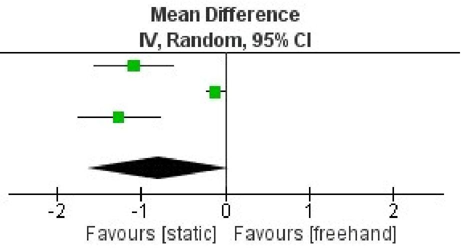


**Figure 3:** Forest plot of results for apical deviation comparison between static guided and freehand implant placement

| Study or Subgroup | dynamic Mean | dynamic SD | dynamic Total | static Mean | static SD | static Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Yuzhang Feng et al 2022 | 1.06 | 0.55 | 20 | 0.99 | 0.63 | 20 | 46.9% | 0.07 [-0.30, 0.44] |
| Miaozhen Wang et al 2022 | 0.6 | 0.29 | 40 | 1.24 | 0.26 | 40 | 53.1% | -0.64 [-0.76, -0.52] |
| **Total (95% CI)** | | | **60** | | | **60** | **100.0%** | **-0.31 [-1.00, 0.39]** |

Heterogeneity: Tau² = 0.23; Chi² = 13.00, df = 1 (P = 0.0003); I² = 92%
Test for overall effect: Z = 0.87 (P = 0.39)

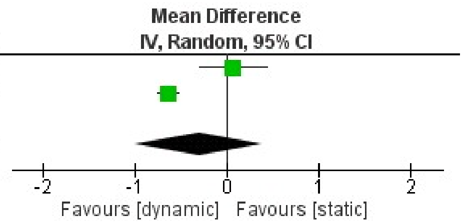


**Figure 4:** Forest plot of results for coronal deviation comparison between static guided and Dynamic guided implant placement

| Study or Subgroup | dynamic Mean | dynamic SD | dynamic Total | static Mean | static SD | static Total | Weight | Mean Difference IV, Random, 95% CI |
|---|---|---|---|---|---|---|---|---|
| Yuzhang Feng et al 2022 | 1.18 | 0.53 | 20 | 1.5 | 0.75 | 20 | 44.7% | -0.32 [-0.72, 0.08] |
| Miaozhen Wang et al 2022 | 0.78 | 0.33 | 40 | 1.69 | 0.34 | 40 | 55.3% | -0.91 [-1.06, -0.76] |
| **Total (95% CI)** | | | **60** | | | **60** | **100.0%** | **-0.65 [-1.22, -0.07]** |

Heterogeneity: Tau² = 0.15; Chi² = 7.29, df = 1 (P = 0.007); I² = 86%
Test for overall effect: Z = 2.20 (P = 0.03)

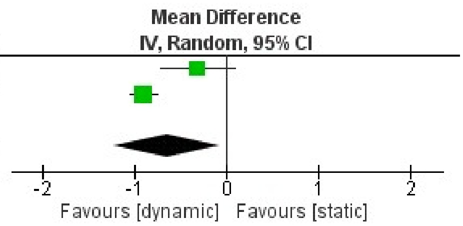


**Figure 5:** Forest plot of results for apical deviation comparison between static guided and Dynamic guided implant placement

comparing apical deviation between static guided and dynamic guided implant placement also showed greater accuracy with dynamic guided surgery (Figures 2, 3, 4, 5, respectively).

## Discussion

The development of immediate implant placement has provided a solution to problems caused by delayed implant treatment. However, accurate transferring of the preoperative implant plan to the surgical site is essential for appropriate restoration to ensure functional and aesthetic outcomes.[19]

The conventional freehand immediate implant placement can lead to irregular extraction socket shape, poor restoration shape, mechanical complications, poor self-cleaning ability, and other issues.[20]

To solve such problems, digital-assisted immediate implant placement has attracted a large amount of attention. The advent of this technology has paved the way for a highly precise and efficient digital workflow.[13] CAD technology can accurately reconstruct 3D models of patients and enables dentists to design implants in 2 or 3 dimensions.[20]

Studies have reported that digital technology helped to determine the optimal 3D position of the implant in the software and helped control implant position precisely.[14] By constructing the 3D whole-process guide plate with CAM technology, the implant can be accurately implemented in surgery. Compared with conventional implantation, digital-assisted implantation was not only more accurate but also preserved the peri-implant bone tissue.[20]

Computer-assisted implant placement nowadays typically contains static and dynamic technological pathways. A significantly higher accuracy of implant placement was achieved with both systems as compared to the freehand protocol, as suggested by clinical evidence.[6]

The studies evaluated in this systematic review compare the accuracy of immediate implant placement with static and dynamic guides and the freehand placement protocol. The difference between the planned and the actual implant positions was measured. The method of measurement used in all the studies was pre- and post-operative CBCT images. The measurements were made for global, coronal, apical, and angular deviations. Among the parameters described were implant placement accuracy, global deviations at entry and apex, angular deviations between planned and postoperative implant positions, and deviation of implant placement at mesial-distal, labial-palatal, and coronal-apical directions.

There were three studies (Ayman et al., 2022; Chen et al., 2018; Han et al., 2021)[13,10,4] comparing the accuracy between static guided and freehand implant placement, two studies (Wang et al., 2022; Feng et al., 2022)[11,12] comparing static guided and dynamic guided implant placement and one study (Wei et al.,2022)[7] comparing dynamic guided and freehand implant placement.

The studies evaluating the accuracy between static guided and freehand groups showed a greater accuracy of implant placement with the static guided placement. The studies comparing static and dynamic guided groups showed a greater accuracy with the dynamic guided implant placement, and the study evaluating the dynamic guided and freehand implant placement showed a more accurate implant placement with dynamic guided implant placement.

The risk of bias analysis was done by the Newcastle-Ottawa scale[15] for cohort studies, the

Cochrane Collaboration's Tool[16] for randomized controlled trials, and the QUIN Tool[17] for in vitro studies.

Five included studies were homogenous in their study design and outcome variables. Hence, a quantitative analysis through a meta-analysis was planned. The results of the quantitative analysis have been provided in the form of forest plots for easy visualization.

The heterogeneity of the primary studies has been evaluated using the Higgins' I2 test.[18] Heterogeneity refers to differences in results between primary studies that are greater than expected by chance alone.

The results of the meta-analysis for the three studies comparing coronal and apical deviation between static guided and freehand implant placement showed a greater accuracy with static guided surgery. The coronal and apical deviation comparison between static guided and dynamic guided implant placement, which was evaluated in two studies, showed greater accuracy with dynamic guided surgery.

Thus, this systematic review reports an overall better implant placement accuracy with static and dynamic guided immediate implantation as compared to the conventional freehand immediate implant placement.

Limitations of this systematic review were; The search for this study was limited to articles published in the English language, grey literature hasn't been searched for relevant literature which could have resulted in mild selection bias and, the results of this systematic review should be applied with caution to the clinical scenario since all the included studies are not clinical studies with some included in-vitro studies.

## Conclusion

The implant placement accuracy is significantly dependent on the method of implantation. Within the limitations of this systematic review, the following conclusions could be drawn:

1. The accuracy of type I implant placement was enhanced using both static and dynamic guided surgery as compared to the conventional freehand protocol.

2. Dynamic guided surgery showed greater accuracy as compared to the static guided system for type I implant placement.

However, more clinical studies are necessary for safer conclusions, since the available scientific evidence is not yet conclusive.

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**LIST OF ABBREVIATIONS:**

| Abbreviation | Definition |
|---|---|
| CBCT: Cone Beam Computed Tomography | IMMEDIATE IMPLANT PLACEMENT: The placement of a dental implant in an extraction socket at the time of extraction or explantation. |
| DN: Dynamic Navigation | COMPUTER-AIDED SURGERY: The process of using computer technology for guiding or performing surgical interventions; to undertake CAS, data regarding the patient's anatomy is required, and can be sourced from ultrasound, radiographs, magnetic resonance imaging (MRI), or conoscopic holography. |
| CAIS: Computer-assisted implant surgery | STATIC SURGICAL GUIDE: A guide used to transfer the location of a virtual implant designed according to the CT data, to accurately guide the preparation and placement of the implant. |
| CAD/CAM: Computer-assisted design/ Computer-assisted manufacturing | DYNAMIC SURGICAL NAVIGATION: A computer-guided free-hand technology that allows for highly accurate procedures in real time through instrument motion tracking, eliminating the need for static guides. |