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# Clinical study of dynamic navigation-assisted immediate implant placement in posterior maxillary alveolar bone defects

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## Abstract

**Objective** To evaluate the accuracy and clinical effect of immediate implant placement(IIP) using real-time dynamic navigation in the posterior maxilla with alveolar bone defects.

**Methods** A total of 55 patients with 72 implants placed in the posterior maxillary region with alveolar bone defects were retrospectively analyzed between January 1, 2021, and October 31, 2024. The study was divided into two groups, navigation group and freehand implant group.The preoperative planning implant data and postoperative CBCT data of the actual implant were imported into the dynamic navigation accuracy verification software, and the deviations of the actual implant neck, root, depth and angle were calculated and reported. Clinical indicators including implant deviation, initial stability, implant success were recorded.

**Results** There were 38 implants in the navigation group and 34 in the freehand group. All implants were successfully placed without serious complications such as perforation of the maxillary sinus mucosa. The initial stability of the implant in the navigation group was (28.53 ± 5.81)N.cm and (18.47 ± 3.64)N.cm, respectively. The initial stability of the implant in the navigation group was higher than that in the free hand group ($P < 0.05$). The deviations in the cervical, root, depth, and angulation of the navigation group were all significantly smaller than those of the free-hand implant group, with statistically significant differences ($P < 0.05$). The median follow-up was 29.6 ± 11.2 months and the implant success rate was 100%.

**Conclusions** Immediate implant placement in the maxillary posterior region with bone deficiency assisted by real-time dynamic navigation can achieve good implant accuracy and satisfactory clinical results.

**Clinical relevance** Dynamic navigation is an advantage for the IIP of an alveolar bone defect in the posterior region of the maxilla.

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**Keywords** Dynamic navigation system, Immediate implant placement, Alveolar bone defect, Precision, Posterior maxillary region

## Introduction

Immediate implant placement(IIP) has received increasing attention due to its potential to shorten treatment cycles, reduce the number of surgical procedures, preserve alveolar ridge volume, and achieve a more esthetically coordinated postoperative outcome [1]. Currently, numerous studies have been conducted on immediate implantation in the anterior or premolar area, which has been demonstrated to have a high success rate for implant placement [2]. Nevertheless, there is a paucity of data regarding the utilisation of immediate implant placement in the maxillary posterior region, and the impact remains inconclusive. This is primarily due to the fact that the extraction of maxillary posterior teeth results in the formation of a large and deep alveolar fossa, which is often accompanied by the challenge of insufficient bone height (RBH) between the maxillary sinus floor and the alveolar ridge [3–4].

IIP in the posterior maxilla is a highly sensitive surgical procedure. Especially in cases with complex bone defects and insufficient bone stock, sinus lift and bone grafting procedures are routinely performed prior to implantation. However, these procedures often involve long waiting times and the efficacy of bone augmentation remains uncertain [5–6]. Therefore, accurate assessment and utilisation of the available bone volume is critical to establishing initial implant stability while avoiding damage to the maxillary sinus mucosa during dental implant surgery.

As computer-aided technology matures, more and more digital technologies are being used in oral implant surgery. The development from traditional implant methods to digital static guides and real-time dynamic navigation has improved the precision, aesthetics and minimally invasive nature of these procedures. In traditional freehand implantation for patients with missing posterior maxillary teeth, the accuracy of the implant site is limited by the surgeon's limited field of view and experience, resulting in significant variations in the angle and depth of the implant site [7]. Dynamic Real-Time Navigation implantation technology uses infrared spatial positioning navigation using preoperative cone beam computed tomography (CBCT) image data and a planned surgical path. This technology allows surgeons to perform implantation procedures with visualisation, displaying adjacent anatomical structures in real time and facilitating timely adjustments to the implantation site and its three-dimensional orientation [8–9]. It is particularly beneficial for posterior teeth, where implant placement is challenging, and for patients who cannot use digital guides due to limited mouth opening and narrow gaps between missing teeth [10]. It also helps to prevent damage to the mucosa of the maxillary sinus [11].

At present, there are few reports on immediate implantation assisted by dynamic real-time navigation in the posterior maxillary region. The aim of this study is to investigate the clinical effect and accuracy of immediate implantation in the maxillary posterior region with bone defect by dynamic real-time navigation, so as to provide reference for the application of clinical navigation implantation technology.

## Materials and methods

### Study population and study design

This was a retrospective study. The study was approved by the Medical Ethics Committee of the First Affiliated Hospital of Sun Yat-sen University (No. [2022]104). Informed consent was obtained from and signed by all of the patients.

Inclusion criteria were as follows: (1) Removal of posterior maxillary teeth that need to be extracted due to trauma or disease. (2) The distance between the alveolar ridge in the maxillary posterior region and the floor of the maxillary sinus should be at least 3 mm, and at least mm of alveolar bone can be used for oblique implantation. (3) There is no acute inflammation at the implant site, and locally controlled chronic inflammation does not absolutely contraindicate immediate implant placement. Exclusion criteria were as follows: (1) teeth with acute infection or uncontrolled chronic inflammation; (2) pregnant or lactating women; (3) history of maxillofacial radiotherapy; (4) uncontrolled systemic diseases such as hypertension, diabetes, etc.; (5) long-term use of glucocorticoids, bisphosphonates and other drugs that affect bone regeneration; (6) failure to maintain basic oral hygiene.

A total of 55 patients (30 males and 25 females, aged between 22 and 75 years, with an average age of $52.31 \pm 16.74$ years) who received dental implantation due to insufficient alveolar bone in the maxillary posterior region in the Department of Stomatology between 1 January 2021 and 31 January 2024 were included in the study. A total of 72 implants (NobelActive System, Nobel Biocare, Sweden)were placed. The selected implant diameters were 3.5 mm, 4.3 mm, and 5 mm. The selected implant lengths were 8.5 mm, 10 mm, 11.5 mm, and 13 mm. The study was divided into two groups: a navigation group and a freehand implant group. The navigation group comprised 38 implants, while the freehand implant group included 34 implants.

## Clinical procedure

(1) Preoperative planning of immediate implant placement.
Cone beam computed tomography (CBCT) was performed on the maxillofacial region of the patients using the iCAT imaging system (Imaging Sciences International, Inc., Hatfield, USA). The CBCT data were imported into the implant design software(Iris-100, EPED Group, Taiwan). The 3D model of the maxilla was reconstructed in the software and the appropriate implant was selected according to the requirements (Fig. 1). The implant placement path was designed to avoid the maxillary sinus and make full use of the residual bone in the alveolar fossa (Fig. 2). Feature points were selected for intraoperative registration. Finally, the type of implant handpiece and drill needle to be used during surgery were selected. The jaw and implant models were saved as STL files.

(2) Surgical procedure.
First, the position of the navigator Iris-100, EPED Group, Taiwan) was adjusted and the device was connected. The implant instruments and landmarks were then registered. After registration, the surgeon performed the implant surgery under the guidance of the navigation system (Fig. 3) to accurately complete the implant hole preparation and implant placement (Fig. 4) and to place the healing abutment or cover screw. During surgery, autogenous bone or bone powder (Geistlich AG, Switzerland)was placed in the area of insufficient bone mass and the incision was sutured. By viewing the dynamic and static views on the navigator, the surgeon can adjust the position, angle and depth of the implantation in real time according to the software's instructions to ensure that the implantation results are achieved as planned.
The procedure for freehand implant placement was as follows: First, minimally invasive extraction of the affected tooth was performed with thorough debridement of the extraction socket. Implant preparation for the extraction socket was then performed step by step. After the socket was formed, the implant was placed. Finally, a healing abutment or cover screw is placed and sutured. Bone grafting was performed as needed.

(3) Postoperative Management.
CBCT was performed immediately after surgery. The restoration was completed 3 to 6 months after implant placement (Fig. 5). The success rate of the implant was evaluated by regular follow-up.

## Indicators of observation

(1) Initial Stability: Implant torque (N.cm) was used to evaluate the initial stability of the implant.

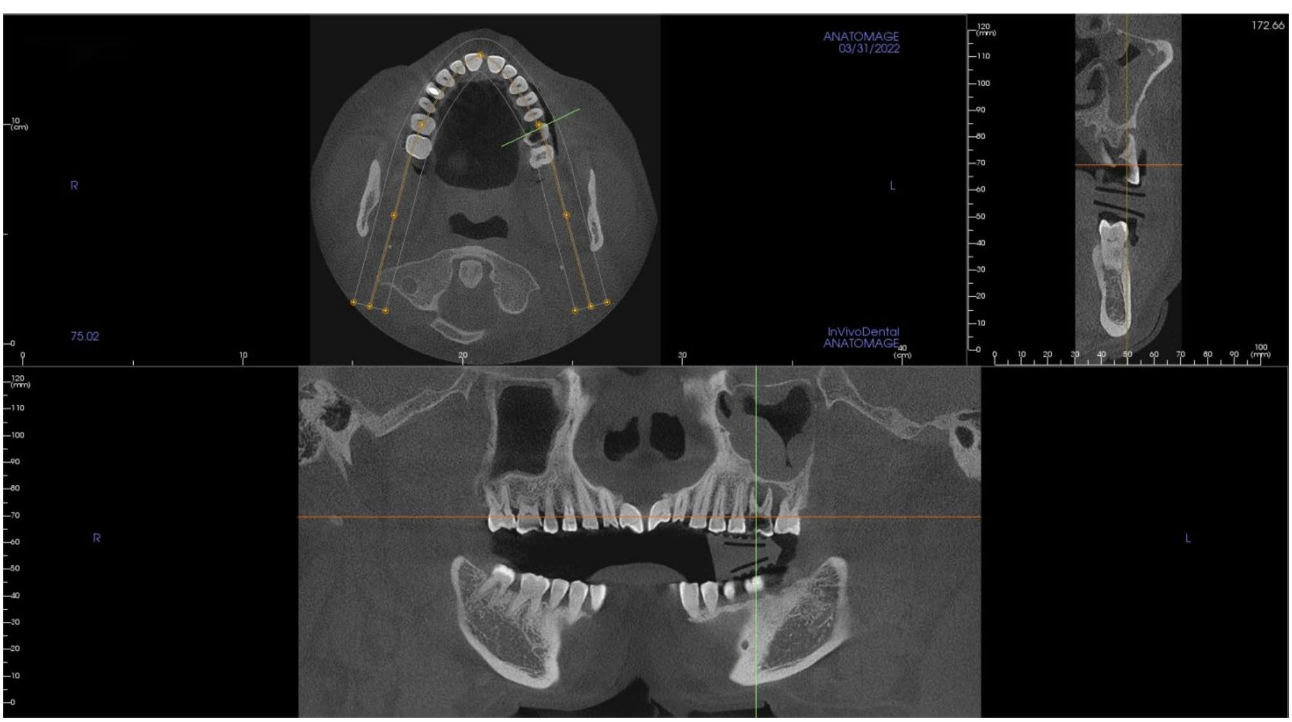


**Fig. 1** Cone-beam CT (CBCT) was performed before implantation

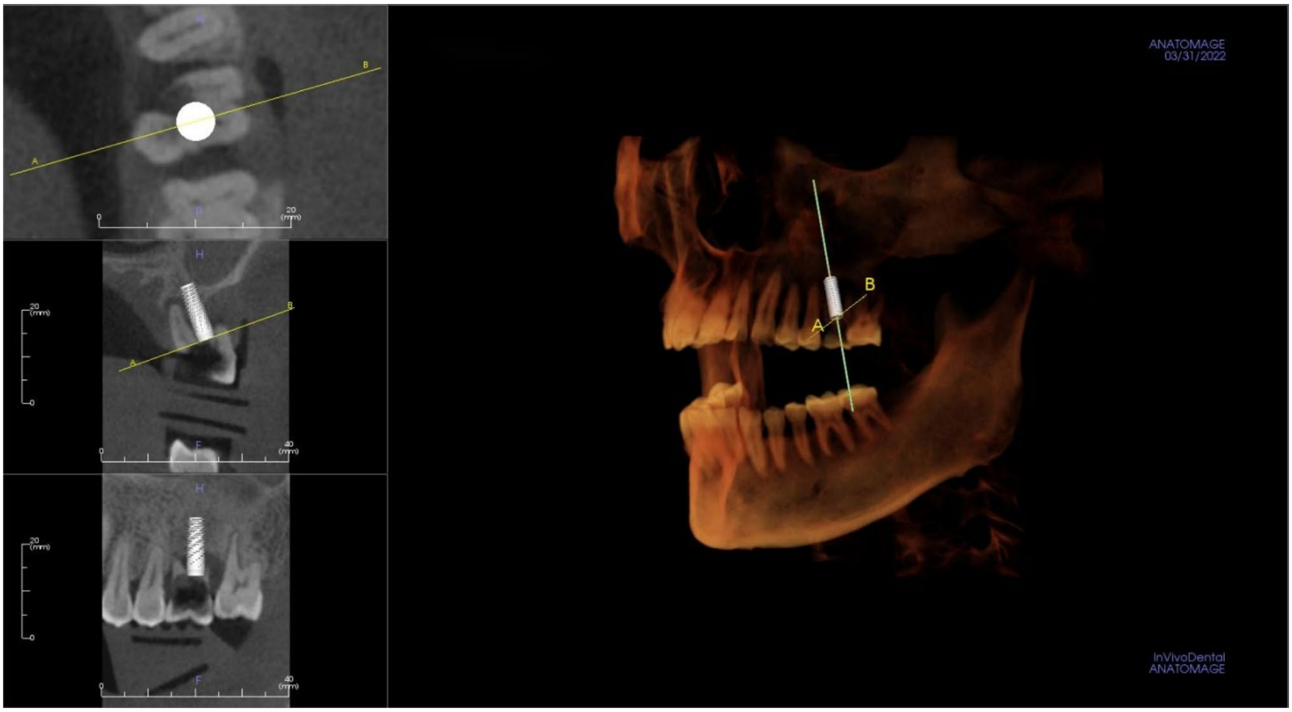


**Fig. 2** Preoperative implant planning was designed

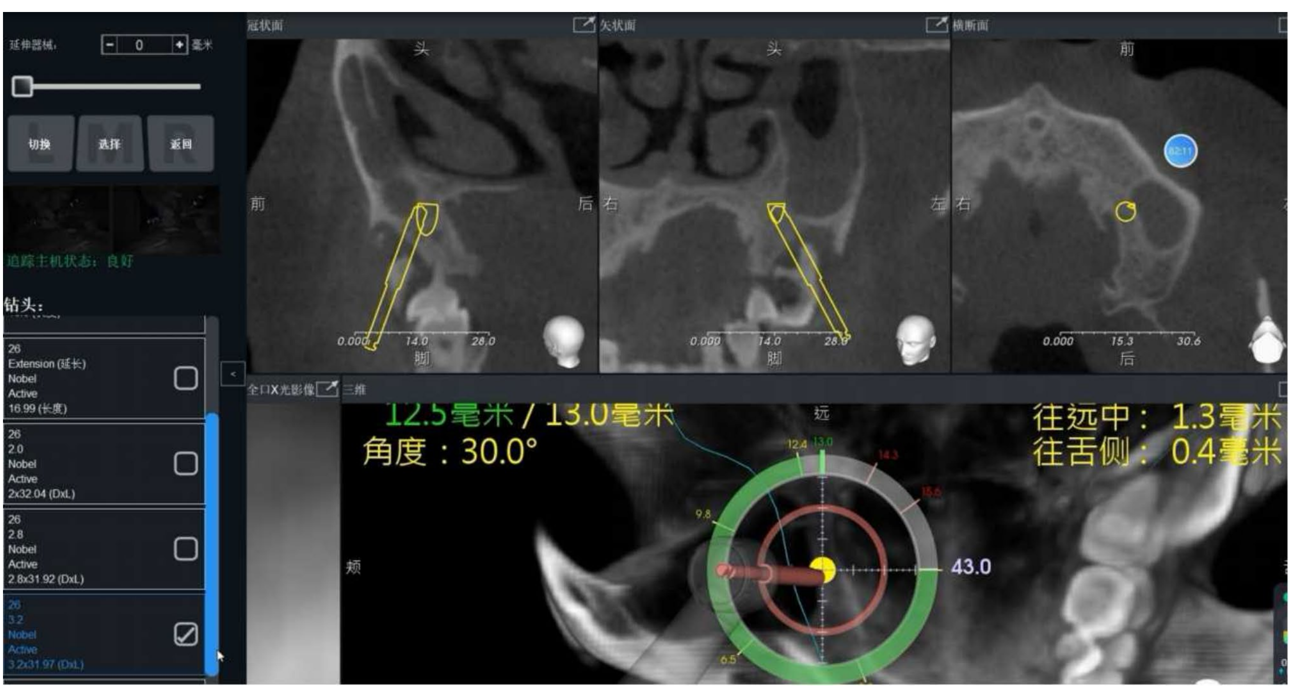


**Fig. 3** Real -time monitoring of the position between the drill and the alveolar bone

Complications such as perforation of the maxillary sinus mucosa were also recorded.

(2) Implant Deviation: The CBCT data before and after surgery were imported into the dynamic navigation accuracy verification software(EPED Group, Taiwan). The deviation between the preoperative virtual implant design and the postoperative actual implant was measured. The actual implant neck, root, depth, and Angle deviations were calculated and reported. The scheme for measuring implant deviation has been referenced in previously published articles [10].

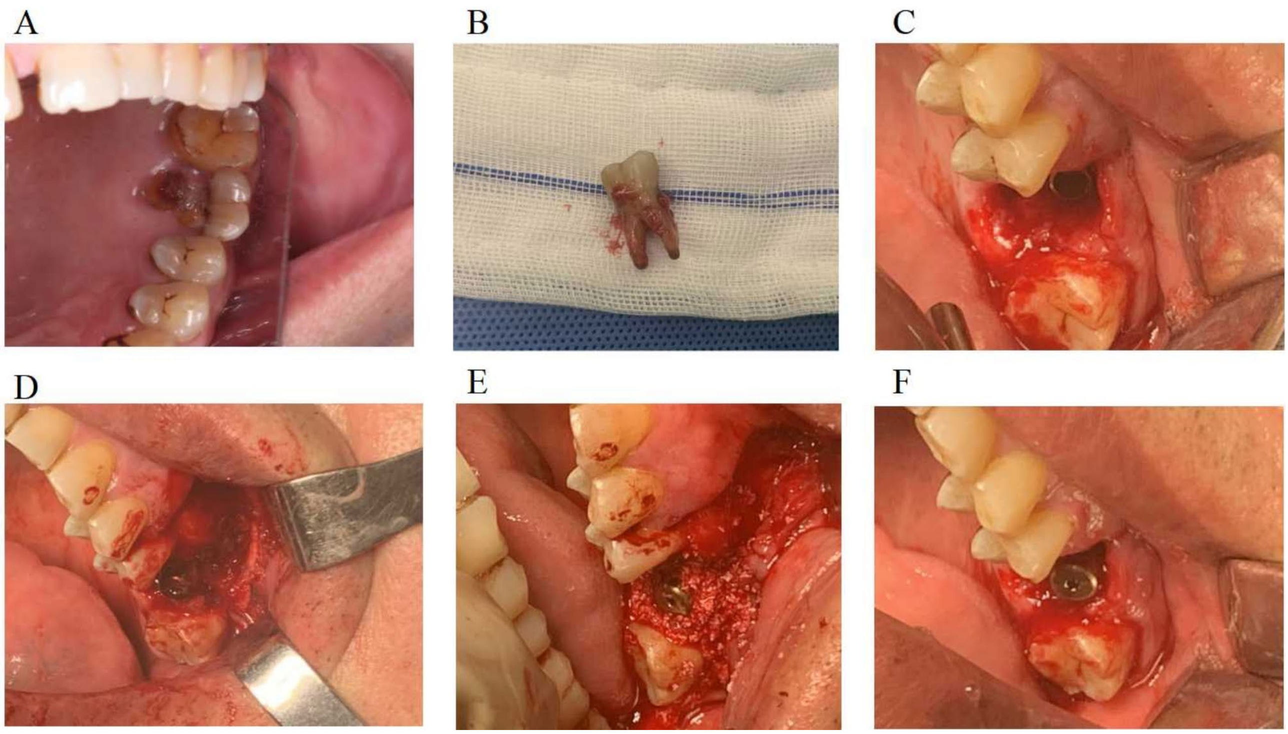


**Fig. 4** Clinical implantation process. **A**: Preoperative image; **B**: Extraction of the tooth; **C**: Placement of dental implants; **D**: Placement of healing abutment; **E**: Implanted bone powder: **F**: The mucoperiosteal flap was reattached; Postoperative Imaging

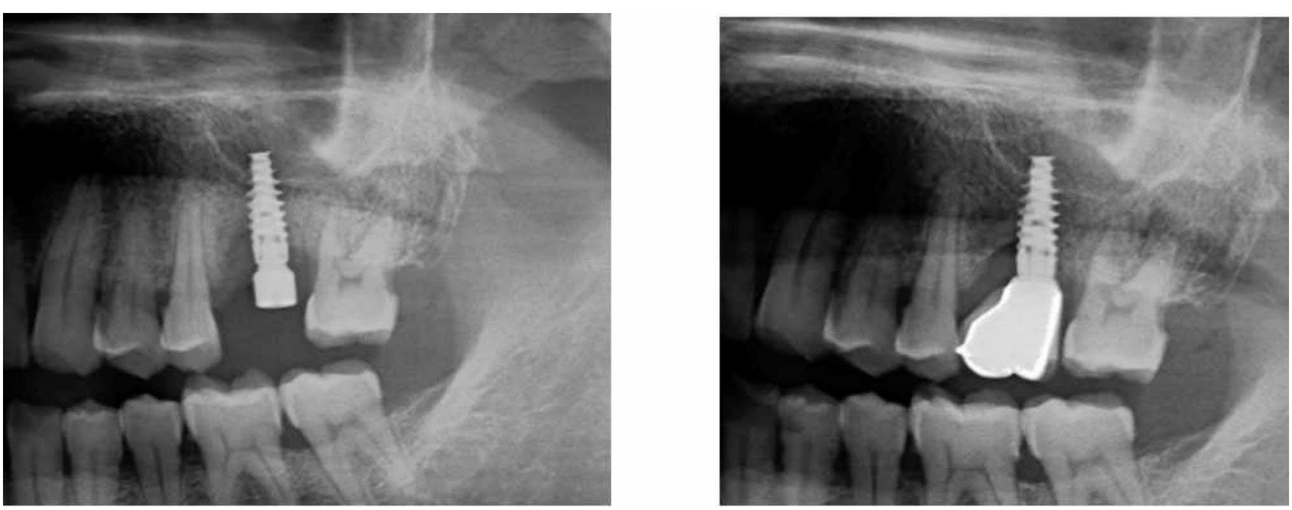

**Fig. 5** Postoperative images. **A**: Panoramic after implantation; **B**: Panorama after restoration

The success rate of IIP: during the follow-up, the implant prosthesis loosening and maxillary sinusitis were checked. The osseointegration of the implants and the radiation around the implants were examined by X-ray film or CBCT. The success rate of implantation was evaluated. The evaluation of implantation success was as follows: (1) Stable implant retention without loosening. Postoperative radiographic examination revealed no radiolucency around the implant. (2) Vertical bone loss at the implant site was less than 1 mm after the first year of implantation and less than 0.2 mm per year thereafter. (3) There was no persistent pain, infection, or irreversible nerve damage.

## Statistical analysis

Statistical processing of data was performed using IBM SPSS 22.(SPSS Inc, Chicago, IL, USA). All data were measured data according to normal distribution and

**Table 1** The demographic and measurement data for the study

| Variables | Navigation group | Free hand group | t | P |
|---|---|---|---|---|
| Number of subjects | 29 | 26 | 0.988 | 0.95 |
| Sex (max/females) | 18/11 | 12/14 | 1.266 | 0.64 |
| Age | 41.7 ± 16.78 | 47.26 ± 19.83 | 1.782 | 0.34 |
| Initial Stability(N.cm) | 28.53 ± 5.81 | 18.47 ± 3.64 | 5.427 | 0.0381* |
| Neck deviation(mm) | 0.43 ± 0.15 | 1.35 ± 0.58 | 19.49 | 0.0025** |
| Root deviation(mm) | 0.77 ± 0.28 | 1.55 ± 1.03 | 23.12 | 0.0017** |
| Angle deviation(°) | 1.45 ± 0.39 | 3.05 ± 1.17 | 14.68 | 0.0044** |
| Depth deviation (mm) | 0.57 ± 0.06 | 0.83 ± 0.51 | 6.339 | 0.0277* |

*: $P < 0.05$; **: $P < 0.01$

expressed as mean ± standard deviation (mean ± SD). Comparisons between the two groups were made using independent samples t-test. $P < 0.05$ was considered statistically significant. Statistical graphs were generated using GraphPad Prism 8.0.

## Result

55 patients were divided into the navigation group and the free hand group, including 29 patients in the navigation group and a total of 38 implants. A total of 34 implants were placed in 26 patients in the free hand group (Table 1). The average diameter of the implants in the free hand implant group was (4.47 ± 1.39)mm, and the average length was (11.87 ± 1.65)mm. In the navigation group, the average diameter of implants was (4.62 ± 1.15) mm, and the average length was (10.93 ± 1.88)mm. There was no significant difference in the diameter and length of implants between the two groups ($P > 0.05$). All 72 implants were successfully placed without serious complications such as perforation of the maxillary sinus mucous.

### Initial stability

All implants were initially stable. The mean torque of the navigation group was (28.53 ± 5.81)N.cm, and the mean torque of the template group was (18.47 ± 3.64)N.cm. The initial stability of the implant in the navigation group was significantly higher than that in the free hand implant group ($P < 0.05$) (Table 1).

Postoperative CBCT showed that implants in the navigation group were surrounded by more alveolar bone and effectively avoided the maxillary sinus than those in the free hand group, indicating the efficacy and safety of immediate implant placement using dynamic navigation.

### Implant deviation

The neck deviation of the navigation group and the free-hand group was (0.43 ± 0.15) mm and (1.35 ± 0.58) mm, respectively. The root deviations were (0.77 ± 0.28) mm and (1.55 ± 1.03) mm, respectively. The depth deviations were (0.57 ± 0.06) mm and (0.83 ± 0.51) mm, respectively. The angular deviations were (1.45 ± 0.39) ° and (3.05 ± 1.17) °, respectively (Table 1). The comparison between the two groups showed that the neck, root, depth and Angle deviations of the navigation group were significantly smaller than those of the free hand implant group, and the differences were statistically significant ($P < 0.05$) (Table 1; Fig. 6).

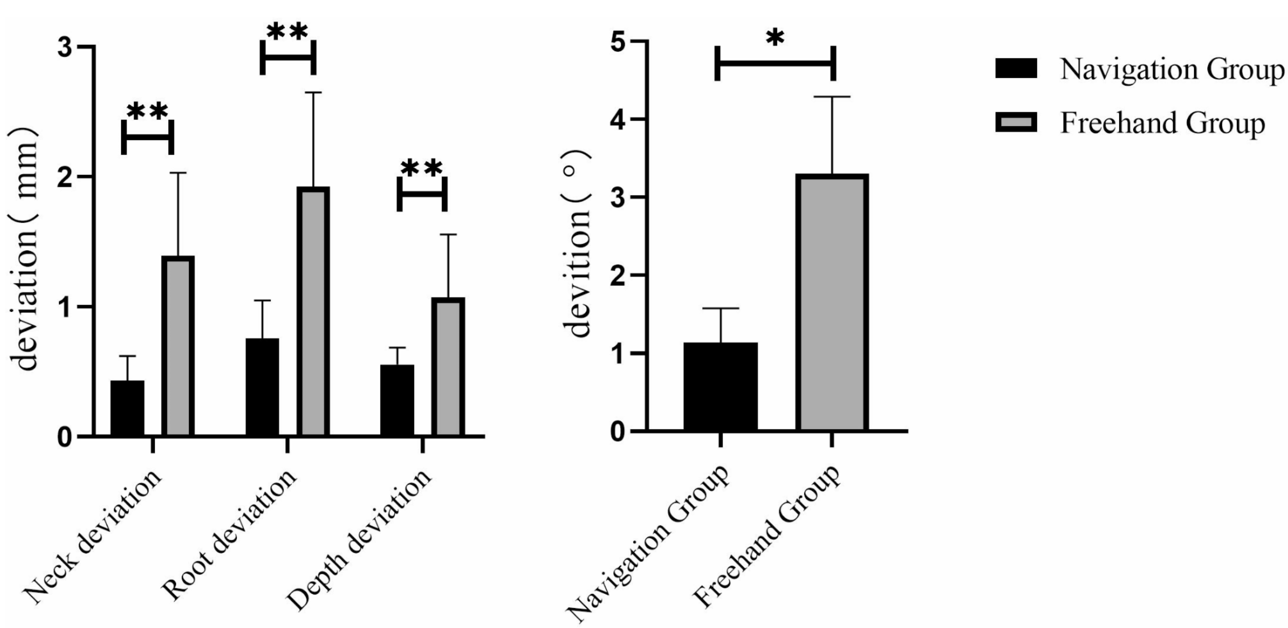


**Fig. 6** Comparison of implant deviation between navigation group and free hand group
*: $P < 0.05$

### Implant survival

The post-operative evaluation indicated that all implants were stable, with no signs of loosening, notable redness, swelling, or pain. There was no evidence of shadowing around the implants, nor any significant bone resorption in their vicinity. The median follow-up period was 29.6 ± 11.2 months, ranging from 8 to 45 months. Radiographic examination revealed no radiolucency around the implants and confirmed good osseointegration. None of the patients experienced maxillary sinusitis. The implant success rate was 100% in both groups.

## Discussion

The root of posterior maxillary teeth is close to the sinus floor, and the vertical height from the sinus floor to the alveolar crest is often insufficient after tooth extraction. As a result, immediate implant placement after maxillary posterior tooth extraction is difficult and the implant often fails to achieve adequate bone embedment, resulting in poor initial stability. Furthermore, the local alveolar bone is frequently characterised by varying degrees of defect and complex morphology following tooth extraction [12]. The freehand implant necessitates a high level of technical proficiency on the part of the surgeon, and instances of implant deviation are not uncommon during the immediate implantation process. It is challenging to achieve the initial stability of the implant following implantation, which can result in implant failure and even the potential for perforation of the maxillary sinus mucosa [11, 13]. Consequently, IIP in the maxillary posterior region with insufficient bone mass is challenging. This study demonstrates that the use of dynamic real-time navigation to assist IIP in maxillary posterior teeth with insufficient bone mass can markedly enhance the success rate of implant placement. The navigation possesses the distinctive attributes of precision and visualisation, which confer unique advantages in the context of maxillary posterior teeth implantation.

The primary challenge associated with IIP is achieving sufficient primary stability. The bone quality in the posterior maxilla is often poor, and extraction sites frequently present with various degrees of bone defects and uneven alveolar bone beds following tooth extraction. This poses a significant challenge for implant preparation, as the implant drill may slip or deflect, leading to a loss of initial implant stability [14–15]. The study employed navigation and freehand IIP in the posterior maxilla. The outcomes demonstrated that all implants were successfully placed with a primary stability exceeding 15 N.cm. The primary stability of the implants in the navigation group was notably higher than that in the freehand group. Ultimately, all implants were successfully implanted. The results suggest that IIP in the maxillary posterior region can achieve a certain degree of primary stability and is a feasible approach. In this study, the implants attained good primary stability due to several factors. Firstly, a conical and deep thread implant design was utilized, which is better suited for implants in areas with poor alveolar bone conditions, such as the maxillary posterior teeth with low bone density. Additionally, this type of implant possesses self-tapping capabilities, which facilitates the attainment of initial stability [16–17]. Secondly, minimally invasive extraction of the affected teeth was chosen to preserve the remaining bone volume of the extraction socket as much as possible, thereby promoting stable implantation of the implants [18].Finally, this study opted for real-time navigation to facilitate IIP. Compared to freehand planting, navigation offers the benefit of visualization. Throughout the planting process, the operator can monitor the condition of the alveolar bone in the implantation area in real-time and make necessary adjustments [19]. However, due to its semi-blind nature, the freehand method does not permit the operator to confidently utilize the remaining bone in the extraction socket for implantation [20].The findings of this study align with those of international research. In a clinical study conducted by Kaewsiri et al. [21] abroad, dynamic navigation and static templates were employed for oral implantation, and all implants achieved an insertion torque exceeding 25 N.cm. Therefore, with the assistance of dynamic navigation and static template, immediate implant placement in the posterior mandibular region can obtain good initial stability. The results suggest that navigation-assisted immediate implantation can obtain better initial stability than free-hand implantation. Therefore, these results suggest that navigation-assisted immediate implantation in the maxillary posterior region can obtain better initial stability than free-hand implantation.

Implant precision is another clinical data to be concerned with in IIP in the maxillary posterior region, especially in cases with insufficient alveolar bone. In this study, we compared the precision of dynamic navigation-guided versus freehand implantation in IIP in the maxillary posterior region. The results showed that cervical, root, depth, and angle deviations were significantly less in the navigation group than in the freehand implantation group. Thus, dynamic navigation-guided IIP in the maxillary posterior region has a significant accuracy advantage. In addition, a previous study by our group compared the accuracy of three different techniques for IIP in the mandibular posterior region: dynamic navigation, static guides, and freehand. The results showed that the implant deviation in the navigated plate group and the static navigated plate group was significantly less than in the freehand group. In addition, the navigation group showed a significant reduction in root and angle deviation compared to the guide plate group [10]. In conclusion, dynamic navigation-guided IIP in the posterior maxilla has a significant advantage in accuracy. In addition, navigation system-assisted oral implant surgery has the advantage of dynamics and visualization [22], allowing the surgeon to use navigation to quickly identify the amount of remaining bone on the palatal and inferior sides of the extraction sockets, resulting in a greater amount of bone around the implant and improved initial stability. In this study, implants in the navigation group were able to utilize more of the remaining bone volume after extraction than implants in the freehand group.

The position of the maxillary sinus floor has a direct impact on the available height of the alveolar bone of the posterior maxillary teeth. During the course of human growth and development, a series of physiological changes occur in the maxillary sinus. The aeration of the maxillary sinus will result in an increase in the volume of the sinus cavity, which will in turn lead to a reduction in the position of the maxillary sinus floor and a subsequent reduction in the bone height that is available for implantation [23]. Therefore, it is technically difficult to perform immediate implant placement in the maxillary posterior region with insufficient bone mass. Many previous reports have selected maxillary sinus elevation to assist immediate implantation, but there is still a risk of maxillary sinus mucosal injury and implant failure [24–25]. In this study, both the navigation group and the freehand group selected the tilted implant placement, thereby avoiding the maxillary sinus. In comparison to maxillary sinus elevation, the technique is less challenging and the clinical outcome is reliable, particularly when performed with the assistance of a dynamic navigation system.

It is also crucial to consider the long-term success of the implant. The success rate of immediate implant placement in the maxillary posterior region was 100% during the follow-up period. It has been demonstrated that when indications are meticulously selected and intraoperative procedures are also conducted with precision, the immediate and long-term success rate in the posterior region is comparable to that of conventional implants [26].

## Conclusion

In conclusion, the dynamic real-time navigation offers the benefits of visualisation and high accuracy for immediate implant placement in the maxillary posterior teeth with insufficient bone mass. It allows for the full utilisation of the remaining bone volume within the extraction socket, thereby reducing the potential damage to the maxillary sinus mucosa and facilitating successful implantation.

### Abbreviations

| | |
|---|---|
| IIP | Immediate implant placement |
| CBCT | Cone beam computed tomography |
| STL | Standard Tessellation Language |

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12903-025-05976-6.

Supplementary Material 1

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Not applicable.

### Author contributions

N.G and H.D: study conception and design. S.Y., X.D., and H. W.: Material preparation, data collection, and analysis. L.H. and S. C. involved in revising it critically for important intellectual content. All authors read and approved the final manuscript.

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### Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

### Ethics approval and consent to participate

This study was approved by the Ethical Committee of the First Affiliated Hospital of Sun Yat-sen University(number: [2022]104) and adhered to the Declaration of Helsinki. All patients signed informed consent for publication.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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