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Original Article

Clinical study of dynamic real-time navigation assisted immediate implant without flapping in the esthetic zone

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ABSTRACT

Objective: The purpose of this study is to investigate the clinical effect of Dynamic real-time navigation to assist immediate implant without flapping in the esthetic zone.
Methods: Eight patients who underwent immediate implantation in the aesthetic area were included. A total of 11 implants were implanted using dynamic real-time navigation system combined with non-flap technology. Clinical indicators including implant deviation, initial stability, alveolar bone absorption, implant success rate, pink esthetic score (PES), Papilla index score (PIS), and the thickness of labial side bone plate of the implant were recorded.
Results: The deviation between the actual implant position and the preoperative design was (0.76±0.08) mm at the top, (1.11±0.18) mm at the root, (0.90±0.16) mm at the depth, and (1.48±0.91)°at the Angle. ISO values of all implants were greater than 59. PES was greater than 8. PIS index was 2 or 3. The average alveolar bone absorption was (0.34±0.09) mm and the thickness of bone plate on the lip of implant was greater than 1.6 mm. The success rate of implantation was 100%.
Conclusion: The use of dynamic real-time navigation assisted non-flap implantation in the aesthetic area can effectively reduce implant deviation and improve the aesthetic effect.

1. Introduction

Dental implantation in aesthetic area is one of the common implant types. Immediate implantation is an effective way of dental restoration, that is, implants are implanted at the same time as tooth extraction, which can effectively preserve the potency of bone formation of alveolar socket and maintain the bone volume of tooth extraction. Its clinical efficacy has been gradually recognized [1–2].

However, immediate implantation in aesthetic area had higher requirements for soft and hard tissues, including - intact bone wall of tooth socket and at least 1mm thickness of buccal bone wall. There was no acute inflammation in implanting area. The implant can be implanted in an ideal three-dimensional position, and the amount of bone on the palatal side and the root side of the tooth socket is enough to maintain the initial stability of the implant. The gingival is of thick gingival biological type, and the neck platform of the implant needs to be at least 2mm apart from the inner wall of the buccal bone wall [3].

Traditional oral implantation mostly adopts gingival flapping. During the implantation process, local soft and hard tissues can be effectively observed, but there are problems such as large trauma, postoperative swelling, and pain [4]. Compared with gingival flap operation, non-flap operation has the advantages of less damage and shorter operation time. However, the hard tissue in the planting area cannot be observed without flapping surgery, resulting in implant deviation and lateral puncture [5]. Therefore, it is difficult and highly sensitive to adopt immediate implant without flapping in the aesthetic area.

Therefore, more and more dentists choose to apply digital static guide plate and dynamic real-time navigation system, both of which can achieve minimally invasive and precise implantation to a certain extent, making up for the deficiency of flap implantation [6]. Although the digital static guide plate can improve the precision of implantation [7], it cannot be operated under direct vision after the static guide is in place, nor can it completely avoid the risk of lateral penetration and accurately control the precise implantation in the alveolar bone. Digital dynamic real-time navigation technology is a navigation technology based on computer 3D digital model, so that the operation of the surgeon can be visualized. Therefore, it is a method to effectively avoid lateral penetration and increase the accuracy of implantation in alveolar bone [8–9], thus reducing the damage of hard and soft tissues. In this study, the dynamic real-time navigation system was used to assist the immediate implantation without flapping in the aesthetic area, and a good effect was achieved.

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2. Materials and Methods

2.1. Main equipment and materials

Dynamic real-time navigation and planning software (Iris-100, EPED Group, Taiwan), cone CBCT(beam computed tomography) (I-CAT, USA), CBCT Design Software (In-vivo 5, Anatomage, USA), GOM Inspect Implant Accuracy Verification System (EPED Group, Taiwan), Nobel Biocare and Denton implants, Oral Implant (INTRAsurg 300 Plus, KaVo, Germany).

2.2. General information

8 patients (5 males and 3 females, with an average age of 46.2 years) who received maxillary anterior dental implants in the stomatology department from January 2021 to April 2021 were selected. One to two implants were implanted in each patient, and a total of 11 implants were implanted. This study was approved by the Medical Ethics Committee. Patients were informed of the treatment plan, costs and risks before implantation, and all patients signed informed consent for surgery.

Inclusion criteria :(1) There was no acute inflammation in the implanting area;(2) Preoperative CBCT examination showed sufficient bone mass in the implanting area. The bone height was more than 12mm and the buccal lingual lateral width was more than 6mm; (3) The occlusion relationship of anterior teeth was basically normal.

Exclusion criteria :(1) There are contraindications for tooth extraction; (2) Severe periodontal and other oral diseases; (3) Severe mouth opening restriction, bruxism, heavy smoking, poor maintenance of oral hygiene, etc.

2.3. Clinical Process

2.3.1. Fabrication of registration device and CT data collection

A positioning occlusion plate was prepared cooperatively and used as an intraoperative registration stent. A positioning occlusion plate was placed inside the patient's mouth and CBCT was taken.

2.3.2. Preoperative surgical plan planning

The same physician imported the preoperative DICOM data of patients into the dynamic real-time navigation planning software to mark feature points for intraoperative registration. Implants of appropriate specifications were selected and simulated in the best Three-dimensional position (Fig. 1) to ensure that the thickness of the bone wall on the lip of the implant was more than 1.5 mm, and that there was 3-4 mm of vertical bone mass in the apical area, so as to determine the implant planning scheme.

2.3.3. Dynamic real-time navigation assisted implant surgery

After the patient entered the operating room, the operation area was disinfected and the towels were spread. And the routine preoperative preparation was performed. The navigator was placed at the patient's foot with an infrared tracking device 0.8 to 1.5m away from the operative area, and then connecting the devices. Use an infrared tracking device to calibrate the dental handpiece for implant. An infrared tracking device was used to calibrate the implant handpiece, and a registration device was placed in the maxillary posterior tooth area to confirm the stability of the retainer and register the feature points. After registration, the position relationship between the implant handpiece and the patient's jaw is displayed on the display screen of the navigator. Under the guidance of dynamic real-time navigation system, dental implant surgery was performed by the same physician (Fig 2). Autogenous tooth without retention value was removed with minimally invasive extraction, and implants were implanted without flapping. During the operation, the implant torque was $\geqq$30 N·cm, and the healing abutment was placed. If the implant was more than 1.5mm away from the labial bone plate, bone powder should be implanted in the bone space and then biofilm should be used to close the wound. In the process of implanting, the display screen displays various parameters of implanting path and implanting area in real time. Guided by software, the surgeon dynamically adjusts the placement of the implant in three dimensions to ensure that the implant results are in line with the desired plan.

All patients received routine anti-infective therapy after surgery. Stitches were removed and temporary repair was performed 7 days after surgery, and permanent repair was completed 6 months after surgery.

2.4. Observation indicators and measurement standards

1.4.1 Wound healing in the implanting area was checked 7 days after surgery, and the initial stability of implanting was evaluated by ISQ value. The greater the value, the stronger the stability.

1.4.2 X-ray films were taken 6 months after the operation, and the success rate of implantation and alveolar bone absorption were evaluated. The evaluation criteria for successful implantation were as follows: no loosening of the implant, no significant bone absorption, no obvious bleeding, redness, pain and other adverse reactions after implantation, and no shadow was found around the implant by X-ray examination, and good combination with alveolar bone. Alveolar bone absorption [10]: The product of the data of alveolar bone loss shown on the X-ray and the actual length of the implant, and then divide the length of the implant on the X-ray film.

1.4.3 Accuracy verification: CBCT was taken after surgery, and postoperative CT data and preoperative planning scheme were imported into accuracy verification software. The postoperative 3D reconstruction model was matched with the preoperative model, and the deviation between the actual implant position and the preoperative design position at the top, root, depth and Angle was measured.

1.4.4 The thickness of the labial bone plate of the implant: After the second phase of restoration, CBCT examination was completed, and the thickness of the labial bone plate of the implant neck was measured by the design software.

1.4.5 Aesthetic effect: Soft tissue was evaluated with pink esthetic Score (PES) and Papilla index score (PIS) after secondary remediation [11]. PES index includes 7 indexes, such as proximal middle gingival papilla, distal gingival papilla, marginal gingival level, soft texture, alveolar ridge defect, soft tissue color and soft tissue texture. The score of each index is between 0 and 2, and the higher the score is, the more ideal the condition of soft tissue is. The PIS index ranges from 0 to 4. 0: no gingival papilla; 1: the gingival papilla does not exceed 1/2 of the height of the adjacent space; 2: the gingival papilla filled more than 1/2 of the height of the adjacent space, but did not reach the adjacent tooth contact; 3: the gingival papilla is filled with the entire adjacent tooth space; 4: gingival papilla hyperplasia.

3. Results

2.1 7 days after the operation, the soft tissue in the planting area healed in one stage with good initial stability (Table 1).

2.2 6 months after the implantation, all implants were not loose or detached, and the implant retention rate was 100%. There was no inflammation around the implant and no significant gingiva regression. Imaging examination showed that the implant was well combined with bone and no obvious bone absorption was observed (Table 1).

2.3 All implants were precisely implanted in the alveolar bone without lateral penetration, and the implant location was ideal.

2.4 Implanting accuracy: The deviation between the actual implant position and the preoperative design position at the top, root, depth and Angle were (0.76±0.08) mm at the top, (1.11±0.18) mm at the root, (0.90±0.16) mm at the depth and angle (1.48± 0.91) ° (Table 2).

2.5 Thickness of labial bone plate of implants: 6 months after implantation, the thickness of labial bone plate of all implants was greater than 1.6mm, with an average of (2.31±0.58) mm (Table 1).

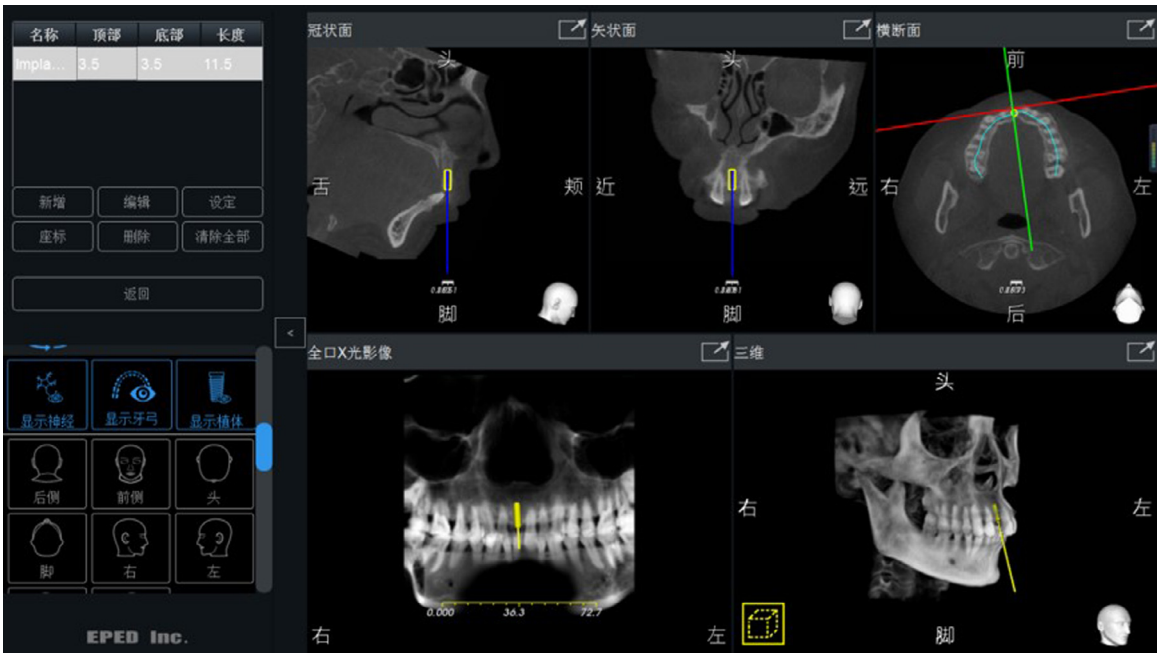

Fig. 1. Stimulation of implantation using dynamic navigation software.

2.6 Aesthetic effect evaluation: 6 months after the second stage of implant restoration, PES of all implants was greater than 8, with the highest score of 14, with an average score of 10.55±1.97; PIS was 2-3, with an average score of 2.45±0.52 (Table 1).

4. Discussion

4.1. Accuracy and error analysis of dynamic real-time navigation system

Dynamic real-time navigation system makes implant surgery more accurately and safely. Through the guidance of the navigation system, the surgeon can realize the real-time positioning of the implantation position, Angle and depth, and effectively avoid the risk of nerve, maxillary sinus and other important anatomical structure damage, and improve the safety of surgery. Some foreign scholars implanted 714 implants with whole-course guide plate, half-course guide plate and free hand respectively, and compared the differences between the post implantation position of each implant and the pre-planned position in the entrance, root and Angle. The results showed that the dynamic real-time navigation system was more accurate for implantation. In addition, some Domestic scholars used dynamic real-time navigation system to perform maxillary double penetration zygomatic implantation, and the results showed that the Angle deviation of 40 zygomatic implants was (2.05+1.02)°, and the operative complications were significantly reduced [12]. In this study, dynamic real-time navigation was used for oral implantation, which was consistent with the above research results. However, dynamic real-time

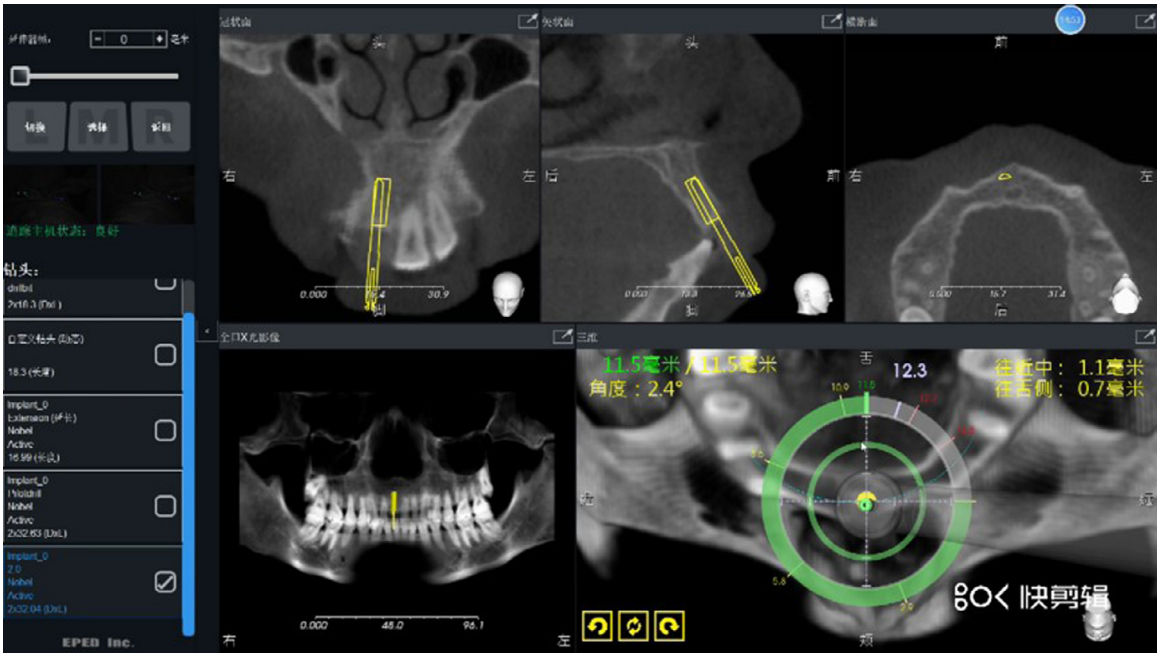

Fig. 2. Real -time monitoring of the position between the drill and the alveolar bone.

Table 1
Implant ISO value and bone absorption, labial plate thickness, PES and PIS

Implant site	ISO(score)	Alveolar bone absorption(mm)	labial plate thickness(mm)	PES(score)	PIS(score)
11	67	0.41	1.86	8	2
12	59	0.25	2.06	11	2
21	73	0.37	2.72	14	2
22	65	0.33	1.64	9	3
11	75	0.24	2.76	13	3
21	61	0.19	2.54	9	2
12	69	0.45	3.61	8	2
21	64	0.26	2.05	11	3
11	72	0.51	1.67	12	2
22	68	0.27	2.18	11	3
11	69	0.31	2.31	10	3
$\bar{x} \pm s$	67.46±4.95	0.34±0.09			
	2.31±0.58	10.55±1.97	2.45±0.52		

Abbreviations: PES: pink esthetic score; PIS: papilla index score

navigation also has errors, mainly including system error, image error, registration error and operational error [13–14]. Systematic error is the inherent software and the hardware error guiding the navigation system to measure position. Image error refers to the influence of CT scanning layer thickness and vowel on the accuracy of 3d modeling data [15]. Registration is the most important step affecting navigation accuracy [16], and different registration methods also determine the accuracy of navigation system [17]. The error mainly depends on the clinical proficiency of the surgeon [18]. Accurate preoperative design and good hand feel are the key points of dynamic real-time navigation technology, and the doctor's operation proficiency is a plus of dynamic real-time navigation surgery.

4.2. Advantages of dynamic real-time navigation technology in implanting in the esthetic zone

Implanting in aesthetic area requires not only accurate three-dimensional location, but also the reduction of soft and hard tissue damage as much as possible, in order to achieve better aesthetic effect [19]. If the traditional free hand implantation is used, the aging and mucous need to be cut and removed, resulting in more inoperative bleeding and affecting the surgical field of vision. At the same time, flapping surgery breaks the structure and position of the original fraternized vaginal, leading to vaginal retraction and alveolar bone absorption on the labial side, affecting the effect of aesthetic restoration [20]. The application of flap less technique in immediate implantation can significantly reduce soft tissue injury and obtain good aesthetic results. In this study, we used the dynamic real-time navigation system for non-flap implantation to obtain a good three-dimensional implant position, avoid side penetration and other complications, minimize the damage of hard and soft tissues in the aesthetic area, and achieve good aesthetic effects. Using dynamic real-time navigation system for oral implantation in aesthetic area has the following three advantages. Firstly, in the preoperative implantation planning process, the dynamic navigation simulation implant software can plan a reasonable implant implantation scheme according to the conditions of the alveolar bone in the implanting area and the requirements of aesthetic area [21]. Secondly, in the process of dynamic real-time navigation assisted implantation, the dynamic navigator can display the position relationship between the implantation path and the labial-palate bone plate and adjacent teeth in real time. The surgeon adjusted the implant path in time according to the prompts to ensure the best implant location and effectively reduce complications such as lateral puncture. Thirdly, dynamic real-time navigation technology overcomes the disadvantages of static guide plate blocking the operation area and difficulty in water cooling, effectively reduces the damage of hard and soft tissues, and effectively ensures the success rate of planting and aesthetic effect [22]. To sum up, dynamic real-time navigation technology provides convenience for the application of immediate planting without flap in aesthetic area.

4.3. Comparison between dynamic real-time navigation technology and Digital guide plate technology

Compared with dynamic real-time navigation system, digital implant guide plate has some limitations in clinical application. First of all, displacement of digital guide plate technology often occurs during the process of implanting. For bone-supported guide plate, due to the difficulty of retention, the guide plates often spontaneously leave the alveolar bone during the process of, especially in areas with high bone density. At the same time, for mucous membrane supported guide plates, retention pins are usually required to assist retainer, which increases the damage to alveolar bone and the risk of

Table 2
Measurement of planting accuracy deviation

Imlant site	Top deviation(mm)	Root deviation(mm)	Depth deviation (mm)	Angle deviation (°)
11	0.136	0.254	0.092	0.26
12	0.085	0.572	0.061	0.79
21	0.136	0.254	0.092	0.26
22	0.190	0.285	0.111	1.09
11	0.544	0.501	0.271	0.96
21	0.268	0.408	0.281	1.60
12	0.451	0.429	0.158	1.77
21	0.938	0.634	0.259	2.38
11	0.825	1.113	0.515	3.21
22	0.143	0.116	0.036	2.07
11	0.148	0.109	0.011	1.92
$\bar{x} \pm s$	0.76±0.083	1.11±0.185	0.90±0.164	1.48±0.912

Fig. 3. Postoperative conical beam CT examination.

Fig. 4. Postoperative photos.

nerve and tooth root damage. Secondly, static guide plates have high requirements for the size of mouth opening. Especially in the implanting area of posterior teeth, dental implant drills are difficult to be cooled by water and invisible in the operation area [23]. However, dynamic real-time navigation has no significant difference with free hand in the requirements of the size mouth opening, water cooling and inoperative area visibility during oral implantation. Finally, compared with the use of dynamic navigation system, it takes more time and cost to make the guide plate. In addition, in the process of making the guide plate, errors may be caused by all factors such as the proportion of modulating materials, method of mold taking, temperature change and model turning [24–25], which ultimately affects the accuracy of planting. Dynamic navigation system is developed on the basis of digital guide plate guiding implant which makes up for the disadvantages of digital guide plate. The combination of dynamic navigation and free hand can simplify and minimally invasive some complicated surgeries.

The preoperative preparation process of dynamic real-time navigation system is complex, and any error in any steps will affect the final implantation effect. At the same time, compared with static guide plate implantation, implantation under dynamic navigation requires higher operation skills for the operator, requiring repeated practice.

In conclusion, the use of dynamic real-time navigation system to assist immediate implantation without flapping in the aesthetic area of anterior teeth can visualize the surgical process and effectively reduce the implantation deviation and damage of hard and soft tissues, which is worthy of clinical application.

Abbreviations

PES: pink esthetic score
PIS: Papilla index score
CBCT`: beam computed tomography

Declaration of Competing Interest

None

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