DOI: 10.38103/jcmhch.92.9

Original research

EVALUATION OF THE ACCURACY OF IMPLANTS USING 3D PRINTED SURGICAL GUIDES IN IMPLANT PLACEMENT

Nguyen Van Khanh[1], Nguyen Hong Loi[1], Nguyen Dang Khoa[1]

[1]Odonto - Stomatology Center, Hue Center Hospital

ABSTRACT

Background: *The optimal position of the implant in 3 dimensions in space is the most important factor to ensure the long - term success of dental implants. Today, advanced technology can simulate the virtual implant position before surgery. Through 3D printing technology, it is possible to transfer the virtual implant position to the surgical field using a static surgical guide. This study aims to evaluate the accuracy of 3D printed surgical guides when performing implant when performed using 3D printed surgical guides.*

Methods: *The study reports a series of clinical cases with 32 implants placed in the maxilla and mandible. The surgical guide is designed using Blue Sky Implant software. Postoperative CBCT data is combined with preoperative treatment plan data to evaluate deviations in implant position, angle between two implants, and vertical deviation.*

Results: *The study showed implant misalignment when using 3D printed surgical guides: misalignment at the implant neck was 1.11 ± 0.67 mm; at the tip is 1.43 ± 1.053 mm; The angle is 3.01 ± 2.53^o and the vertical is 0.71 ± 0.57 mm. The study noted that angular deviations, cervical, apical and vertical deviations were not statistically significant according to gender, parts of dental archs and implant position.*

Conclusion: *Using a surgical guide can help the implant to be placed more accurately in all 3 dimensions in the maxilla/ mandible. The 3D printed surgical guide has high precision and can be used to support implant surgery.*

Keywords: *Surgical guide, 3D, dental implants.*

I. INTRODUCTION

Dental implants are one of the increasingly popular tooth loss restoration methods due to their superior features compared to traditional tooth restoration ones. The important goal for successful implant placement is the ideal implant position in three dimensions in the maxilla/ mandible, long - term survival, and ensuring function and aesthetics. With the advent of cone beam computed tomography (CBCT) with its increasing availability, low radiation, low cost, preoperative three - dimensional implant planning is becoming more popular. The software enables virtual implant placement using digital data obtained from CBCT scans and intra - oral images of the patient, transferring pre - operatively planned implant positions into surgical guides (SG). 3D printing has improved implant treatment outcomes.

Many authors believe that using 3D printed SG in implant surgery brings many benefits, the implant is placed more accurately in all 3 dimensions in the bone, limiting the need for flap surgery or bone grafting, which leads to the fact that it helps to reduce costs, reduce trauma, and heal quickly [1]. Although implant placement techniques using SG are believed to be capable of achieving more precise and less invasive implant placement, this technique needs to be critically evaluated as it has been established in clinical practice, directly on the patient. Therefore, we conducted this study with the goal: Evaluate the accuracy of 3D printed surgical guides when performing dental implants.

II. PATIENTS AND METHODS

2.1. Patients

Including 10 patients treated with dental implants from February 2022 to August 2023 at

Received: 12/8/2023. **Revised:** 10/9/2023. **Accepted:** 18/9/2023.

Corresponding author: Nguyen Van Khanh. Email: drkhanhrhm@gmail.com. Phone: 0935884886

the Department of High - Tech Dentistry - Odonto - Stomatology Center and Department of Cosmetic Dentistry, Cosmetic Center, Hue Central Hospital. The total number of research samples was 32 implant locations in the maxilla and mandible.

Patients who meet the following 3 criteria were included: (1) Patients aged 18 years and older. (2) The patient has lost teeth in the maxilla and mandible: Bone height ≥ 10 mm (mandible) ≥ 12 mm (maxilla) on CBCT film; Proximal and distal dimensions ≥ 6mm on CBCT film. (3) Patient agrees to participate in the study.

Exclusion criteria were: Having systemic diseases or local conditions that contraindicate dental implant surgery; Smoking > 10 cigarettes/day; The patient's mouth opening is limited to < 40 mm

2.2. Research method

We conducted a case series study on 10 patients with 32 implant positions

Research facilities: CBCT scanner, brand Willdem from Korea; The disk stores the patient's CBCT images as DICOM data (Digital imaging and communication standards in medicine); Trios 3 scanning system to convert function template data into digital data with STL data format (standard template library); Blue Sky Plan software is used to design dental implant surgery guides and evaluate postoperative deviations.

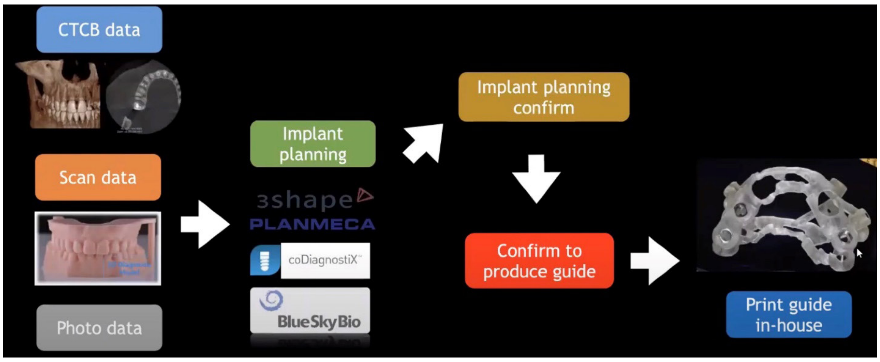

Figure 1: Clinic workflow [2]

Research content: The patient had an initial silicone impression taken before surgery. All plaster maxilla/ mandible samples were scanned using the Trios 3 scanning system to convert surface data of the samples into digital data in STL format (standard template library).

The patient had a CBCT scan before surgery, the data was saved in DICOM format and written to disk.

Using Blue Sky Plan software to combine 2 data including plaster samples and CBCT images of the patient. Then proceeding to plan treatment for the patients directly on this software. After designing a virtual tooth in the position where the implant needs to be placed to simulate the final restorations. Next, proceeding to place a virtual implant based on the final restorations above. From there, the appropriate position, size and direction of implant placement can be predicted. The implant surgery guide is designed based on the simulated implant position. After that, the surgical guides will be sculpted using a 3D printing system.

On the day of surgery, the surgical guide is tried on the patient, then the implant is placed based on the SG. The researcher is the person who directly place implants. All patients had CBCT scans performed after surgery and saved as DICOM data. Postoperative data is combined with simulated implant data when planning the SG design to evaluate accuracy.

2.3. Evaluation criteria

The accuracy of the surgical guide is evaluated by the deviation of the actual implant position after implantation compared to the virtual implant position when planning treatment (Figure 1) [3]. Implant deviations are evaluated including: deviations in the implant neck position (a), deviations in the implant tip position (b), vertical deviations (c) and angular deviations (α).

Determine the reliability and accuracy of the method.

To avoid measurement errors, all measurements were measured by the author under the training of a doctor specializing in reading and measuring CBCT images with many years of experience.

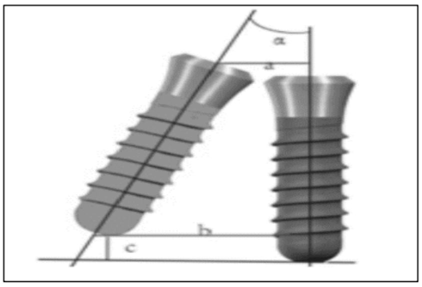

Figure 2: Figure depicting parameters for assessing implant misalignment [3]

Bone density: Misch CE, Kircos LT (1999) [4] classified the bone density into five groups based on number of Hounsfield units (HU). D1 corresponds to values greater than 1250 HU, D2 has 850 - 1250 HU, D3 refers to density within 350 - 850 HU, D4 has 150 - 350 HU and D5 less than 150 HU

Data processing: Data were recorded and analyzed using SPSS 26 software.

III. RESULTS

Table 1: Pattern of tooth loss and implant location

Pattern of tooth loss	Implant location	Ratio (%)	Patient	Ratio (%)
Complete maxilla + mandible	10	31,3	1	10
Complete maxilla	10	31,3	2	20
Complete mandible	4	3,1	1	10
Single tooth loss	8	34,3	6	60
Total	32	100	10	100

10 patients with 32 implant positions, including 01 patient with 10 implant positions in the entire maxilla and mandible, 01 patient with 06 implant positions in the entire maxilla, 01 patient with a full implant of the maxilla with 4 positions and 1 patient with 04 implant positions in the mandible, 01 patient with 2 dental positions R11, R21, 5 patients with 06 implant positions in the posterior mandible.

In the study sample, 15 (46.9%) implants were placed in female patients and 17 (53.1%) implants were placed in male patients.

The overall average age is 52.28 ± 8.95 years old, with no statistically significant difference between men and women

Bone D3 type accounted for the majority with 18 positions accounting for 56.3%; following by D2 type with 13 positions accounting for 40.6% and only 1 position with D4 bone density accounting for 3.1%. Most implant locations had bone widths ranging from 6 - 9mm, accounting for 81.3% with 26 implant locations, and there were 06 locations with bone widths > 9mm with 18.7%.

Table 2. Description of implant diameter and length

Description		Length			
		10	12	14	Total
Diameter	3,6	4 (12,5%)	1 (3,1%)	2 (6,3%)	7 (21,9%)
	4,2	4 (12,5%)	13 (40,6%)	3 (9,3%)	20 (62,4%)
	4,8	2 (6,3%)	2 (6,3%)	1 (3,1%)	5 (15,7%)
	Total	10 (31,3%)	16 (50%)	6 (18,7%)	32 (100,0%)

Based on the bone characteristics of the intended implant areas, all implants selected in this research sample have lengths of 10mm, 12mm, 14mm, of which 10 implant positions are 10mm long, accounting for 31.3 %, 16 locations used 12mm implants accounting for 50% and 6 locations used 14mm implants accounting for 18.7%. In terms of diameter, implants with a diameter of 4.2 mm accounting for the majority with 20 (62.4%) positions, implants with a diameter of 3.6 mm and 4.8 mm have a proportion of 21.9% and 15.7% respectively. The force achieved when implanting the implant recorded the group of 30 - 35 N/cm accounting for the majority with 20 (62.5%) positions, followed by the group > 35 N/cm with 12 (37.5%) positions, there are no cases with force < 20 N/cm.

Table 3: Deviation of real implants with simulated implants when planning to make a surgical guide

Deviation	**Average ± Standard deviation**
Angular deviation	$3{,}01^o \pm 2{,}53^o$
Deviation in apical position 1	1,43 ± 1,05 mm
Deviation in neck position	1,11 ± 0,67 mm
Vertical deviation	0,71 ± 0,57 mm

The actual implant position deviation compared to the computer plan in this study was 3.01^o in angle, 1.43 mm in apical position, 1.11 mm in implant neck position and 0.71 mm to the implant position vertically.

IV. DISCUSSION

Our study sample was performed on 10 patients with an average age of 52.28 ± 8.95 years. It can be seen that this age group is in the 40 - 59 age group, which is the group with the highest implant rate among all age groups (accounting for 57%) compared to the 20 - 39 year old group (accounting for 29%) and the group over 60 years old (accounting for 14%). Compared to other studies by Dam Van Viet (2013) [5] (42.2 ± 14.8 years old), Souza (2022) [6] (58.9 ± 15.1 years old) reported group distribution elder age (all over 40 years old). In the research group, the majority were patients with entire jaw tooth loss, so the majority of patients were 40-59 years old and had entire jaw tooth loss due to periodontal disease. Regarding gender distribution in the study, women accounted for 53.1%, which is more than men, accounting for 46.9%. This result is quite similar to studies by authors Demirkol et al (2019) [7], Bui Viet Hung et al (2017) [8] all reported a higher proportion of women than men. This result can be explained by the fact that women care more about dental and aesthetic issues than men.

Regarding the causes of tooth loss that make patients coming for examination and choosing dental implants, our research shows that periodontal disease is the leading cause, accounting for 71.09%, followed by tooth decay and trauma, with the rates of 18.8% and 9.4% respectively. This result is similar to many previous domestic studies such as the research of Bui Viet Hung et al (2017) [8], Ta Dong Quan (2019) [2]. This is consistent with epidemiology in our country, the rate of periodontal disease in the population is still high and is the main cause of tooth loss in the community. Next, the rate of tooth loss due to tooth decay is higher than due to trauma, while research by Ta Dong Quan (2019) [2] showed that tooth loss due to trauma was up to 25% higher when surveyed in the anterior teeth region.

Bone density is one of the important factors that determine the success of implants and is closely related to the position on the maxilla/ mandible. According to Misch, the distribution of bone density in the upper posterior teeth area is D1: 3%, D2: 50%, D3: 46%, D4: 1%. Bone density affects the decision to choose drill size, as well as the timing of loading the restoration force on the implant. In our study, bone D3 type was common (43.5%). Common in middle - aged and teenage groups, this is consistent with the age group distribution in our study, mainly in the 19 - 39 year old group. Following is bone D2 type, which accounted for 40.6%. These results are similar to the research of Bui Viet Hung (2017) [8]. D2 type bone is the most suitable bone for implant placement. The contact interface between cortical bone and the implant surface helps the implant to have good initial stability. At the same time, the medullary bone has many blood vessels to help increase healing, reduce restoration waiting time. The study only had 1 case of D4 bone (3.1%). D4 bone is a porous bone that is difficult to achieve initial stability, and when drilling bone, special attention should be paid to because the drill is easily deflected.

The study showed that all implant placement areas had bone widths ranging from 6 - 9mm (81.3%), this result is similar to the study of Braut (2014) [1] which recorded average bone width. The average is 7,652 mm at the first molars position and 8,604mm at the second molars position and there are 05 positions with bone width > 9mm, so most of the implants selected in the sample are implants with average diameter.

The force achieved when placing implants was recorded in the 30 - 35 N/cm group accounting for the majority with 20 (62.5%) positions, followed by the > 35 N/cm group with 12 (37.5%) positions. This result is almost similar to the study of Gultekin (2016) [9] with an ISQ value of 70 and the results of Schnutenhaus (2020) [10] with an average value of 63. Because in our study, most of the bone density is D2 and D3, which is a favorable bone density for implants to achieve good initial stability.

When evaluating the accuracy of the implant surgery guide, our study recorded an average deviation of the implant neck compared to the simulated implant with an average value of 1.11 ± 0.67 mm. This result is almost similar to the study of Ta Dong Quan (2019) [2] when conducting research on the anterior teeth group with an average value of 1.06 ± 0.65 mm and the study of Smitkarn (2019) [11] when performing implants for single tooth loss cases (with an average value of 0.9 ± 0.8 mm). However, this value is higher than Kholy's (2019) [12] study on plaster models with the average value when performing trays on 3 teeth being 0.562 ± 0.086 mm. This difference is due to Kholy's (2019) [12] research being performed on a plaster models, so there is no interference with the lips, cheeks, mouth opening or abnormal movements of the patient.

When evaluating the deviation at the implant tip, our study recorded an average value of 1.43 ± 1.05mm; Similar to the research of Smitkarn (2019) [11] with 1.5 ± 0.7 mm and Ta Dong Quan (2019) [2] with 1.29 ± 0.84mm; Similar to the study by Kholy (2019) with an average value of 1.195 ± 0.397mm. Regarding the vertical dimension, the average deviation value in this study recorded was 0.71 ± 0.57mm; relatively higher than the study by Ta Dong Quan (2019) [2] conducted in the anterior teeth area. This is because when performing implants in the aesthetic tooth area, it is often easier to see the position of the implant than in the posterior tooth area, especially in the lower second molars.

For angle deviation in this study, we recorded an average value of $3.01^o \pm 2.53^o$, almost similar to the study of Ta Dong Quan (2019) [2] with an average of $3.04^o \pm 0.97^o$ and that of Smitkarn (2019) [11] with an average of $2.8^o \pm 2.6^o$. This shows that the surgical guide still has some deviation compared to the simulated implant and this deviation is not in any specific direction. The reason for this discrepancy is due to having to go through many stages from treatment planning to the surgical process and collecting post - operative data, including: taking initial impressions, scanning plaster samples, and taking X-rays. CBCT optics, SG printing, tightness of the guide tube, influence of clinical factors (blood, saliva, mouth opening, patient movement during surgery), surgeon experience, and bias of the assessment method [9]. However, 3D printed surgical guidance systems have been proven to help reduce trauma, reduce surgery time, reduce post - operative pain and swelling complications, and have higher accuracy than hand - crafted or implanted systems. Implant grafting does not use SG.

In addition, digital surgical methods can design and manufacture temporary restorations based on the position of the assumed implant when planning, helping clinicians to attach immediate restorations after surgery. This is very significant in preserving and guiding soft tissue, reducing patients' embarassment as well as shortening treatment time. Implant surgery and attaching temporary restorations before and immediately after surgery are also the trends of modern dental implants. Besides, 3D printed surgical guides also have some limitations such as additional costs and pre - operative time.

V. CONCLUSION

Using a surgical guide can help the implant to be placed more accurately in all 3 dimensions in the maxilla/ mandible. The 3D printed surgical guide has high precision and can be used to support implant surgery.

REFERENCES

1. Braut V, Bornstein MM, Kuchler U, et al. Bone dimensions in the posterior mandible: a retrospective radiographic study using cone beam computed tomography. Part 2 - analysis of edentulous sites. 2014;34(5):639-47.
2. Quân TĐ, So sánh hai hệ thống máng hướng dẫn phẫu thuật: in 3d và thủ công trong cấy ghép nha khoa răng trước hàm trên. 2019, Luận văn Thạc sĩ, Đại học Y Dược Thành phố Hồ Chí Minh.
3. Geng W, Liu C, Su Y, et al. Accuracy of different types of computer-aided design/computer-aided manufacturing surgical guides for dental implant placement. 2015; 8(6):8442.
4. Misch CEJID. Contemporary implant dentistry. 1999; 8(1):90.
5. Đàm Văn V, Nghiên cứu điều trị mất răng hàm trên từng phần bằng kỹ thuật implant có ghép xương. 2013.
6. De Souza AB, Kang M, Negreiros WM, et al. A comparative retrospective study of different surgical guide designs for static computer-assisted implant surgery in posterior single edentulous sites. 2022;33(1):45-52.
7. Demirkol N, Demirkol M. A retrospective analysis of anterior single dental implants. 2019.
8. Phạm Hoài Thu, Đỗ Thị Thúy, Nguyễn Văn Hùng. Nghiên cứu áp dụng bộ câu hỏi SF - 36 trong đánh giá chất lượng cuộc sống bệnh nhân viêm khớp dạng. Tạp chí nghiên cứu y học. 2017;106(1):146-150.
9. Gültekin A, Şirali A, Gültekin P, et al. Clinical evaluation of the stability of implants placed at different supracrestal levels. 2016;50(3):21-31.
10. Schnutenhaus S, Brunken L, Edelmann C, et al. Alveolar ridge preservation and primary stability as influencing factors on the transfer accuracy of static guided implant placement: a prospective clinical trial. 2020;20:1-11.
11. Smitkarn P, Subbalekha K, Mattheos N, et al. The accuracy of single-tooth implants placed using fully digital-guided surgery and freehand implant surgery. 2019;46(9):949-957.
12. El Kholy K, Lazarin R, Janner SF, et al. Influence of surgical guide support and implant site location on accuracy of static Computer-Assisted Implant Surgery. 2019;30(11):1067-1075.