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Original Article

Comparison of the accuracy of implant placement using a simple guide device and freehand surgery

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Abstract *Background/purpose:* In clinical settings, there may be a need for a guide device that is simple and enhances the positioning accuracy of prosthetics. This study aimed to compare the accuracy of implant positioning using two methods: implant placement with a simple guide device (SGD) and freehand surgery.
Materials and methods: A total of 103 patients were randomly assigned to the control or study group. In the control group, implant placement was performed using the freehand technique. In the study group, implant placement was conducted with an SGD. Implant positioning accuracy was assessed by measuring how much the central position, fixture angulation, and fixture position differed from the ideal implant position based on periapical radiographs and cone-beam computed tomography images. In patients with double implants, parallelism between the two fixtures was also measured.
Results: There were 124 subjects, with 84 having single implants (42 in the control group and 42 in the study group) and 40 having double implants (20 in the control group and 20 in the

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study group). Utilization of the SGD for both single and double implant placement improved the accuracy of the central position, fixture angulation, and fixture position ($P < 0.05$). Additionally, in double implantation cases, it significantly enhanced parallelism between the two fixtures ($P < 0.001$).
Conclusion: These findings suggest that use of an SGD leads to more accurate implant placement compared with freehand surgery taking into account the final prosthetic restoration.

Introduction

Implant therapy is an increasingly successful treatment option for patients with partial or complete tooth loss. Recently, there has been a growing emphasis on prosthetic-driven implantology, which highlights the importance of placing implants at ideal positions and angles.[1] This approach offers advantages such as minimization of implant screw loosening, efficient occlusal force loading, a realistic cervical emergence profile, and simplified oral hygiene due to correct implant positioning.[2–4] Numerous studies have explored various guide devices to achieve accurate implant placement.[5]

Traditionally, dental surgical stents were primarily designed based on soft tissue levels rather than on bone levels, leading to challenges in achieving accurate fixture placement during surgery. Computer-guided implant surgery has become indispensable for creating more precise and patient-specific surgical guides.[6,7] These advanced technologies can visualize both soft and hard tissues in three dimensions, significantly improving the accuracy of the planning and placement of dental implants. However, this approach involves multiple X-ray sessions, additional patient visits, a fabrication period for the surgical guide, and associated costs, making it less practical for short-span implants such as single or double implants.[8] While readily available kits, such as the Osstem Parallel Guide Kit (Osstem Implant, Seoul, Korea), are designed to assist in aligning the spacing and direction of implant placement, they do not present the final prosthesis shape during the operation stage.

In this study, we developed a simple guide device (SGD) that not only considered the relationships with adjacent teeth but also anticipated the final prosthesis to be restored. This SGD is designed to be easily attached to a surgical handpiece, taking into account the final prosthesis size selected to meet the individual needs of the patient. The objective of this prospective study was to compare the accuracy of dental implantation using this SGD and freehand surgery.

Materials and methods

Patient selection

The present study was designed as a prospective, blocked-randomized clinical trial. The study participants attended the Department of Oral and Maxillofacial Surgery at Seoul Metropolitan Government-Seoul National University (SMG-SNU) Boramae Medical Center in Seoul, Korea for implant therapy from April 2020 to April 2021. Patients younger than 19 years with incomplete jaw growth were excluded from this study. The inclusion criteria were as follows: (1) patients who required implant treatment in the premolar and molar regions and (2) patients who had lost one or two teeth. Patients were randomly assigned to the control or study group. Patients in the control group underwent implant installation using the freehand technique. Patients in the study group underwent implant installation using an SGD. All surgical procedures were conducted by a single experienced surgeon who specialized in oral and maxillofacial surgery (YS Han, corresponding author).

Ethical approval was obtained from the institutional review board of SMG-SNU Boramae Medical Center, Seoul (IRB No. 16-2017-58). The study was conducted in accordance with the Declaration of Helsinki, 2000 revision and followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Written informed consent was acquired from all patients prior to inclusion in the study.

The design of the simple guide device

The SGD utilized in this study comprises three main components: a cap, a connector, and a tooth template (Fig. 1). The connector is securely attached to the head of the surgical handpiece and is designed to connect various sizes of tooth templates to its lower part. Depending on the location of the edentulous jaw and the size of the space, a suitable tooth template is selected (Table 1). The cap is used to firmly fix the selected template onto the mount of the implant fixture.

All the devices used in this study were designed and manufactured using CAD-CAM technology. The connector is made of resin, while the tooth template is made of zirconia material. The tooth template is specifically designed to be compatible with the Osstem TS III (Osstem Implant) mount type implant fixture, allowing it to be tested in the oral cavity after implant placement. This allows clinicians to assess the appropriateness of the path and position of the implant before the final restoration is fixed.

Surgical procedures

Implantation was conducted based on the surgeon's perspective using the conventional freehand method in the control group. If necessary, a minor bone graft was

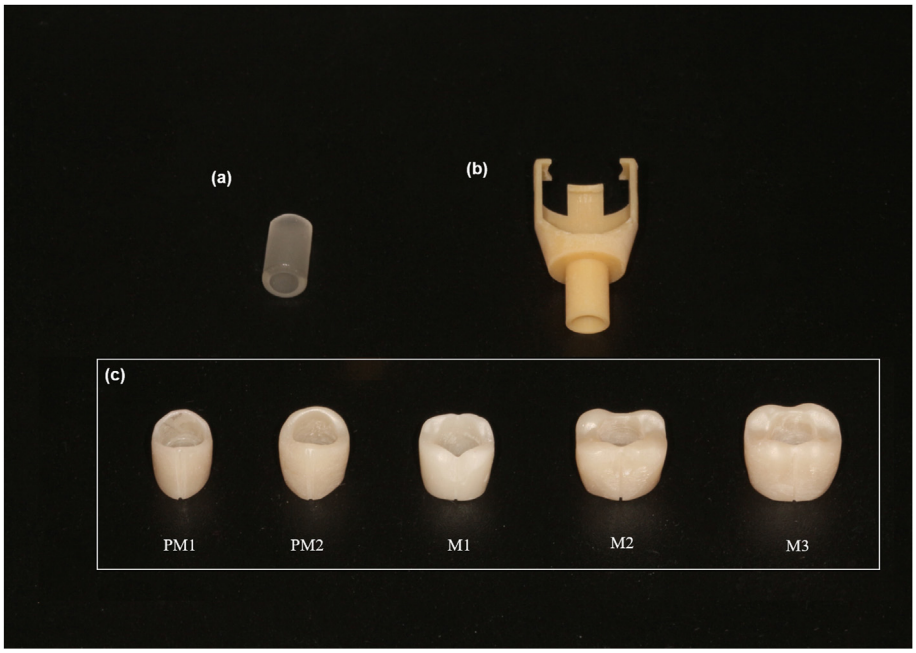

Figure 1 Components of the simple guide device. (a) Cap, (b) connector, and (c) tooth template. The details of the tooth templates are provided in Table 1. PM, premolar; M, molar.

Table 1 Specification of tooth templates.

	PM1	PM2	M1	M2	M3
Mesio-distal width, mm	6.5	7.5	8.5	9.5	10.5
Bucco-lingual width, mm	7.5	8	7.5	8	8
Height, mm	6.5	6.5	6.5	6.5	6.5

PM, premolar; M, molar.

performed. The surgical procedures in the study group are summarized in Fig. 2. After local anesthesia, the full-thickness flap was elevated. Thereafter, the connector was attached to the implant handpiece, and a tooth template appropriate for the size of the edentulous space was mounted on the connector. After drilling, insertion of the implant fixture was completed. When placing two implants, alignment was guided by the tooth template connected to the pre-installed implant.

Measurements

The ideal position and angulation of the implant were defined as follows: (1) the screw hole is located in the central pit of the implant prosthesis; (2) mesio-distally, the fixture of the implant is located on a line that vertically bisects the occlusal surface of the implant crown; and (3) bucco-lingually, the implant fixture is located on a line passing between the midpoint of the alveolar crest and the functional cusp of the opposite tooth. Based on this, the differences in angulation and position between the actual and ideal implants were measured. The measurements were taken by one examiner (YS Han). The parameters for assessing the accuracy of implant placement are listed below. (1) Central position: in the implant crown fabrication model, the degree of deviation of the screw hole from the central pit of the occlusal table was measured using a caliper (Fig. 3A). (2) Fixture angulation: the difference of angulation between the actual (blue line) and ideal (red line) long axes of the implant fixture was measured. Mesio-distal angulation (MDA) and bucco-lingual angulation (BLA) were measured on periapical radiographs and the coronal plane of cone-beam computed tomography (CBCT) images, respectively (Fig. 3B and C). (3) Fixture position: the distances at two points where the long axes of the actual (blue line) and ideal (red line) implants met the alveolar crest were measured. Mesio-distal distance (MDD) and bucco-lingual distance (BLD) were measured on periapical radiographs and the coronal plane of CBCT images, respectively (Fig. 3B and C). (4) Parallelism between two fixtures: in the double implant group, mesio-distal parallelism between the two implant fixtures was evaluated.

Data analysis

Statistical analyses were performed using SPSS 27 (SPSS Inc., Chicago, IL, USA). The Shapiro-Wilk test and Levene's test were used to assess the normality and homogeneity of variance, respectively. Student's t-test was used to compare the control and study groups. All statistical results were considered significant if the *P*-value was less than 0.05.

Results

A total of 103 patients (54 males and 49 females) were included in the present study. The patients' mean age was 63.15 ± 13.15 years. The total number of subjects was 124: 84 had single implants (42 in the control group and 42 in the study group) and 40 had double implants (20 in the control group and 20 in the study group). All prosthetic treatment was

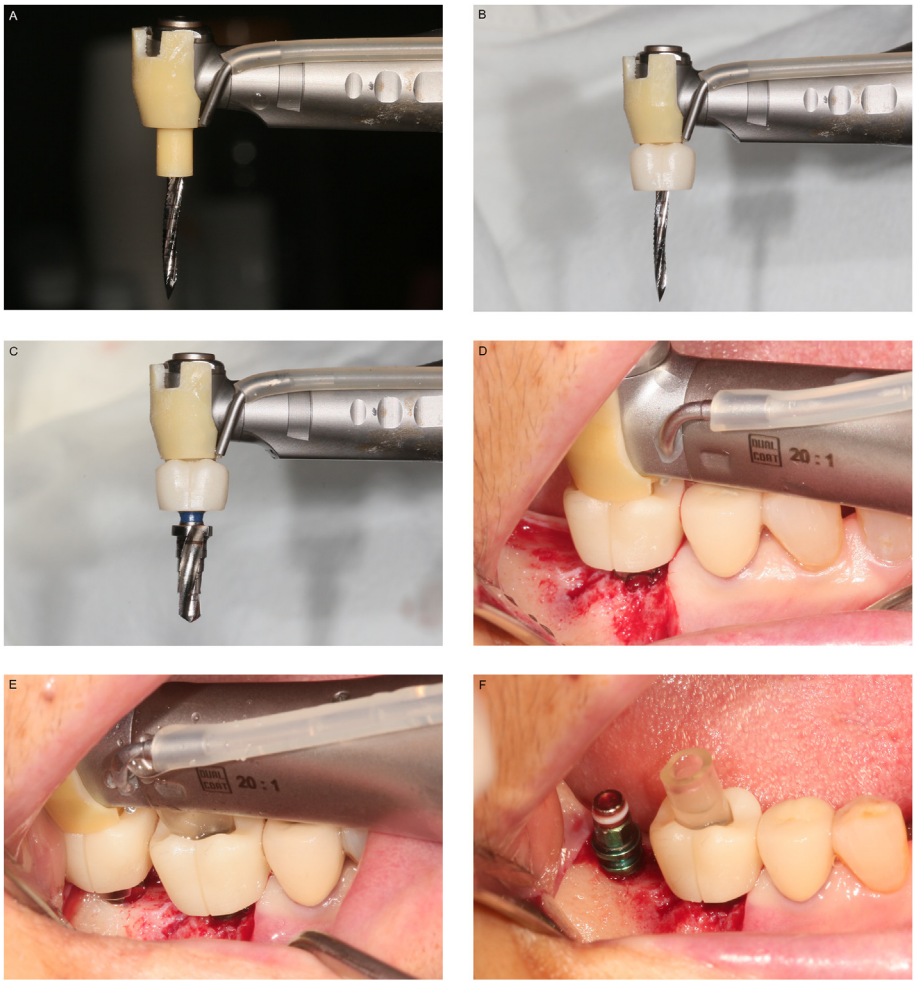

Figure 2 Implantation with a simple guide device (SGD) in the study group. (A) The connector was attached to the implant handpiece. (B) The tooth template was mounted to the connector corresponding to the final prosthesis size. (C) The SGD was capable of guiding up to the full-size drill. (D) Drilling with the SGD on the lower right first molar. (E) Additional implantation on the lower second molar using the SGD. (F) The cap securely attached the chosen template to the mount of the implant fixture.

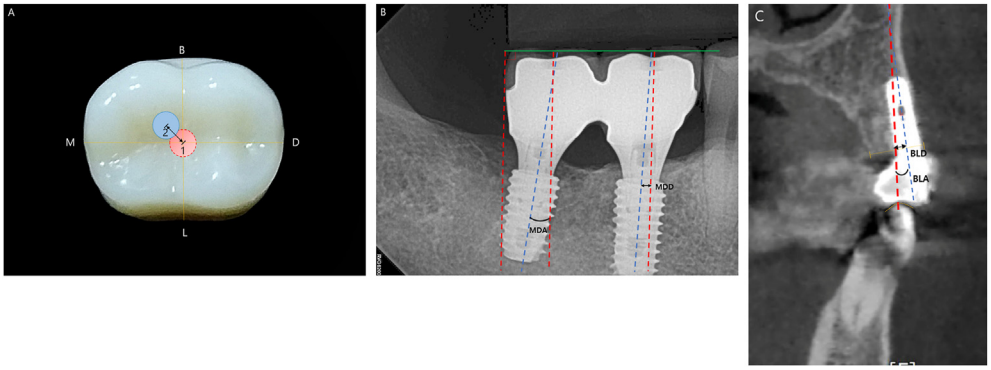

Figure 3 Measurement of positional accuracy. (A) Occlusal view of the implant prosthesis. The central position was measured. (B) Mesio-distal view on periapical radiographs. MDA and MDD were measured. (C) Bucco-lingual view on cone-beam computed tomography images. BLA and BLD were measured. Red circle, position of ideal screw hole; blue circle, position of actual screw hole; green line, occlusal plane; red line, ideal long axis; blue line, actual long axis; MDA, mesio-distal angulation; BLA, bucco-lingual angulation (or bucco-palatal angulation); MDD, mesio-distal distance; BLD, bucco-lingual distance (or bucco-palatal angulation).

Table 2 Comparison of the accuracy of single implant placement between the study and control groups.

	Control group (N = 42)	Study group (N = 42)	*P*-value[a]
Central position, mm	1.05 ± 0.55	0.47 ± 0.26	<0.001
Fixture angulation, °			
MDA	8.03 ± 4.34	3.00 ± 1.65	<0.001
BLA	5.35 ± 2.39	2.71 ± 1.77	<0.001
Fixture position, mm			
MDD	0.75 ± 0.39	0.35 ± 0.23	<0.001
BLD	0.54 ± 0.30	0.30 ± 0.19	<0.001

MDA, mesio-distal angulation; BLA, bucco-lingual angulation (or bucco-palatal angulation); MDD, mesio-distal distance; BLD, bucco-lingual distance (or bucco-palatal distance).
[a] Result of Student's t-test.

completed with a screw-and-cement-retained prosthesis (SCRP).

The results of the Shapiro–Wilk test and Levene's test confirmed the normality and homogeneity of variance ($P > 0.05$). Accuracy of all factors (central position, fixture angulation, and fixture position) in single implant cases significantly differed between the control and study groups ($P < 0.001$), as assessed by measurement of the central position (1.05 ± 0.55 mm in the control group and 0.47 ± 0.26 mm in the study group), MDA (8.03 ± 4.34° in the control group and 3.00 ± 1.65° in the study group), BLA (5.35 ± 2.39° in the control group and 2.71 ± 1.77° in the study group), MDD (0.75 ± 0.39 mm in the control group and 0.35 ± 0.23 mm in the study group), and BLD (0.54 ± 0.30 mm in the control group and 0.30 ± 0.19 mm in the study group) (Table 2).

Even when two implants were placed, all factors, including parallelism between the two fixtures (4.26 ± 2.17° in the control group and 0.19 ± 0.08° in the study group), significantly differed between the control and study groups ($P < 0.001$ for most measurements and $P = 0.003$ for BLD) (Table 3).

Discussion

From the perspective of prosthetic-driven implantology, several studies have explored various guide devices aiming to achieve precise implant placement. Traditional dental surgical stents are noted for their drawback of diminished accuracy, whereas computer-guided implant surgery is associated with drawbacks including elevated costs and increased time requirements. Additionally, guide kits have limitations in accurately reflecting the final prosthetic restoration.

Using an SGD is time-saving and cost-effective because it eliminates the need to customize a stent for each patient. Even when establishing multiple implants, a tooth template is connected to the reference implant, allowing selection of additional templates for implant placement. After inserting a single implant, alignment of the next implant is guided using the tooth template connected to the implant fixture mount, ensuring it is perpendicular to the occlusal surface. This allows verification and ensures proper placement during implant surgery. Most importantly, guide devices are characterized by their accuracy. The purpose of our study was to assess whether an SGD can enhance the precision of implant placement in comparison with freehand surgery. This study showed that when an SGD was used for implantation, accuracy of the central position, fixture angulation, and fixture position was improved ($P < 0.05$), and in particular, parallelism between the two fixtures was improved upon double implantation ($P < 0.001$).

Various factors contribute to the accurate placement of implants, which can be categorized into patient and practitioner factors.[9,10] Clinical radiographic assessments are conducted to precisely understand patient factors, and based on this information, the surgical skill and experience of the dentist performing the implantation significantly impact its accuracy. Surgeon experience is especially critical in freehand implantation, where implants are placed without a surgical guide. This approach involves envisioning

Table 3 Comparison of the accuracy of double implant placement between the study and control groups.

	Control group (N = 20)	Study group (N = 20)	*P*-value[a]
Central position 1st, mm	1.00 ± 0.52	0.45 ± 0.17	<0.001
Fixture angulation 1st, °			
MDA	7.09 ± 4.00	2.20 ± 1.44	<0.001
BLA	5.32 ± 2.27	2.77 ± 1.53	<0.001
Fixture position 1st, mm			
MDD	0.66 ± 0.37	0.30 ± 0.17	<0.001
BLD	0.52 ± 0.28	0.20 ± 0.14	<0.001
Central position 2nd, mm	1.11 ± 0.47	0.53 ± 0.23	<0.001
Fixture angulation 2nd, °			
MDA	9.29 ± 3.11	2.16 ± 1.39	<0.001
BLA	6.03 ± 2.55	2.81 ± 1.67	<0.001
Fixture position 2nd, mm			
MDD	0.99 ± 0.50	0.40 ± 0.20	<0.001
BLD	0.53 ± 0.28	0.30 ± 0.16	0.003
Parallelism between the fixtures, °	4.26 ± 2.17	0.19 ± 0.08	<0.001

MDA, mesio-distal angulation; BLA, bucco-lingual angulation (or bucco-palatal angulation); MDD, mesio-distal distance; BLD, bucco-lingual distance (or bucco-palatal distance); 1st, proximal implant of two implants; 2nd, distal implant of two implants.
[a] Result of Student's t-test.

the final crown during the procedure.[11] In our clinical study, we introduced an SGD to facilitate placement of the fixture perpendicular to the occlusal surface and the screw access hole (SAH) in the center of the occlusal plane. Use of an SGD diminishes the reliance on surgical expertise and minimizes potential deviations during the drilling process. Consequently, it has the potential to result in more prosthetic-driven implant positioning.

Three types of implant prostheses are currently utilized in clinical practice: a screw-retained prosthesis, a cement-retained prosthesis, and a SCRP. Among these, a SCRP is preferred by clinicians due to its easy retrievability, passive fit, ability to completely remove excess cement, and straightforward maintenance and management.[12] In our study, all restorations were fabricated using a SCRP. However, successful SCRP rehabilitation requires careful consideration of both the position and angulation of the implant fixture and the shape of the prosthesis during the planning phase. Specifically, the fixture should be placed perpendicular to the occlusal surface in order to allow a straight abutment and ideal SAH orientation. Additionally, the SAH should be located in the center of the occlusal plane.[13] An SGD can be considered as a tool to achieve these objectives.

Several studies have investigated the benefits of implant placement perpendicular to the occlusal surface. Studies involving finite element analysis reported that implants experience higher stress under oblique load conditions than under vertical load conditions.[14–16] Another study reported that mechanical effects vary based on the loading directions and contact points, indicating that stress can increase when vector directions are unfavorable.[2] These findings suggest that positioning implants vertically can help to reduce complications associated with prosthetic restorations, providing stability and positive treatment outcomes.

A limitation of this study is that accuracy was only assessed following placement of single and double implants. In the case of multiple implantations, the accuracy of the SGD has not been confirmed. It is necessary to recruit a larger number of patients in order to validate the effectiveness of the SGD in cases with multiple implants.

In light of our results, an SGD may offer clinicians improved accuracy over freehand surgery at the fixture and prosthesis level when performing single and double implantation.

Declaration of competing interest

The authors have no conflict of interest relevant to this article.

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