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Accuracy of dynamic implant navigation surgery performed by a novice operator

A preliminary study in a cadaveric model

Abstract

Aim: The main objective was to evaluate the accuracy of dynamic navigation-guided surgery (DNGS) for implant positioning performed by a novice operator. The secondary objectives were to analyze the operator's learning curve and identify possible complications deriving from the technique.

Materials and methods: Twenty-five implants were placed in eight partially edentulous human heads. Preoperative CBCT scans were imported to planning software to determine the implant positions. Implants were placed using a dynamic navigation system. Postoperative CBCTs were superimposed onto the implant planning images. Discrepancies between the virtually planned implant positions and the postoperative positions were evaluated by measuring horizontal platform deviation, apex deviation, apicocoronal (vertical) deviation, and angular deviation.

Results: Mean platform, apex, vertical, and angle deviations were 1.55 ± 0.81 mm, 2.45 ± 0.84 mm, 1.59 ± 0.70 mm, and 5.56 ± 4.03 degrees, respectively. No significant differences were found between the maxilla and mandible or between anterior and posterior sites. A flat learning curve was observed, with the exception of the implant platform, where a tendency toward improvement in accuracy was observed between the 8th and the 17th implant placed. No complications were reported.

Conclusions: Based on the results of a study performed by a novice operator on a cadaveric model, DNGS allows accurate implant placement within a 2-mm safety margin in terms of implant platform and vertical positions, and a 3-mm margin in apical vicinities. The technique requires practice to learn the required eye–hand coordination. (*Int J Comput Dent* 2022;25(4):1–9; doi: 10.3290/j.ijcd.b2588207)

Keywords: computer-assisted surgery, computer-guided surgery, dynamic navigation, accuracy, dental implant, dental navigation

Introduction

Poor dental implant positioning compromises the functional and esthetic outcomes of implant-based treatments and increases the risk of long-term biologic and/or biomechanical complications^{1,2}. Implant positions will be determined by the characteristics of the prosthetic restoration they are to support and the adjacent anatomical structures. Detailed consideration of these two parameters will be the starting point of any implant-based treatment.

The combination of the implant planning software with the 3D images makes it possible to plan and visualize the prosthetic outcome beforehand. It also facilitates the communication between the prosthodontist, the surgeon, and the patient³.

In computer-assisted implant surgery, the static guided surgery (SGS) method employs surgical guides to transfer virtual implant positions, decided by means of digital presurgical planning, to the surgical site, aiming to reproduce the virtual treatment plan as precisely as possible. SGS has been reported to be a reliable technique for transferring planned implant positions to their clinical locations and achieves high levels of precision and predictability³⁻⁷. However, there are certain limitations regarding SGS^{2,7,8}. Firstly, the technique demands a wider range of mouth opening, which can present a problem when treating posterior regions. The template must be kept stable, which is more difficult in edentulous patients. Then, the guide itself presents an obstacle to proper visualization of the surgical field and obstructs bone irrigation^{9,10}. Lastly, it is not possible to modify the guide once it has been printed^{7,11}.

Alternatively, with DNGS, the position of the handpiece in relation to the patient's CBCT is tracked in real time and displayed on a screen, showing a predefined implant plan superimposed onto computerized tomographic data^{3,12,13}. During DNGS, optical cameras align the scan volume with the operative field volume and track the handpiece, which is



equipped with a tracking sensor. In this way, the technique is somehow comparable with the global positioning system (GPS) used in the transport industry. Any deviation in the drill direction and/or implant position from the presurgical plan can be detected as soon as it occurs, so that the operator can immediately respond by readjusting the drilling depth, drilling angle, or drill position^{2,14,15}. It would appear that DNGS does not suffer the same limitations of SGS described above, as the device does not obstruct the visualization of the surgical field, does not affect bone irrigation, and does not require excessive mouth opening. It has been demonstrated in the literature that DNGS constitutes a reliable technique that may be applied in routine implant dentistry^{11,13-16}.

The aim of the present study was to evaluate the accuracy of implant positioning obtained when DNGS was used by a novice (non-experienced) operator (in a cadaveric model). As secondary objectives, the study aimed to describe the learning curve involved in mastering the technique and identify any possible complications deriving from DNGS.

Materials and methods

The study protocol was approved by the Research Ethics Committee of the Faculty of Dentistry at the International University of Catalonia (Sant Cugat del Vallés, Barcelona, Spain; Registration code: CIR-ECL-2018-09).

Twenty-five Vulkan (Vulkan Implants, Barcelona, Spain) internal hexagon tapered implants of 3.3-mm diameter and 10-mm length were placed in eight fresh human cadaver heads provided by the Department of Anatomy at the International University of Catalonia (Barcelona, Spain).

After harvesting from human donors, these specimens had been frozen to prevent structural changes to the tissue. The cadaver heads were completely defrosted for a period of 3 days at room temperature prior to the study. Manipulation of the specimens was carried out with a maximum level of respect.

Eligibility criteria

Specimens were selected according to the following criteria: partially edentulous maxilla and/or mandible with minimum edentulous span of one tooth; bone width ≥ 4 mm and bone length ≥ 11 mm. Exclusion criteria were: completely edentulous maxilla and/or mandible; completely dentate maxilla and/or mandible; bone width < 4 mm and bone length < 11 mm.

CT scan guide preparation

Firstly, bimaxillary alginate impressions were taken of the specimens and used to create a study cast. Secondly, a stent made from thermoplastic material (Navident; ClaroNav, Toronto, Canada) was warmed with hot water (boiling water left to cool for 3 min) and molded over the entire alveolar arch of the study cast (excluding the teeth distal to the implantation area), then left to harden. The spaces where implants were to be placed were then cut out. An extension piece made of the same material was connected to the central anterior area of the stent, connecting the stent to the CT marker, which contained fiducial markers.

CBCT data acquisition

CBCT scans (i-Cat; Imaging Sciences International, Hatfield, PA, USA) of the specimens were captured. To standardize data acquisition, the exposure volume was set at 102-mm diameter and 102-mm height. The voxel size was 0.2 x 0.2 x 0.2 mm. Scanning followed the settings recommended by the manufacturer (80 kV and 5 mA). The Frankfort plane was used for cranial reference. The CBCT scans were taken with the stent holding the CT markers in place.

Implant planning

DICOM files were imported to the implant planning software (Navident). Prosthetic planning was performed, placing virtual crowns to simulate the ideal prosthetic rehabilitation. The implants were then introduced virtually according to the prosthetic plan, respecting the adjacent anatomical structures. Then, a generic implant of 3.3-mm diameter and 10-mm length was selected from the software's implant library to match the macro design of the Vulkan implants (Fig 1).

Both prosthetic and implant planning were performed simultaneously by two experienced operators (JMG and RRB). During planning, any discrepancies that occurred in the virtual positioning of a crown or implant were resolved by discussion.

Surgical procedure

A DrillTag (Navident) was attached to the handpiece and a JawTag (Navident) to the remaining cadaver teeth. Both these attachments (DrillTag and JawTag) have specific printed patterns designed for visualization by the system's optical cameras to identify and capture their relative positions. Thereaf-

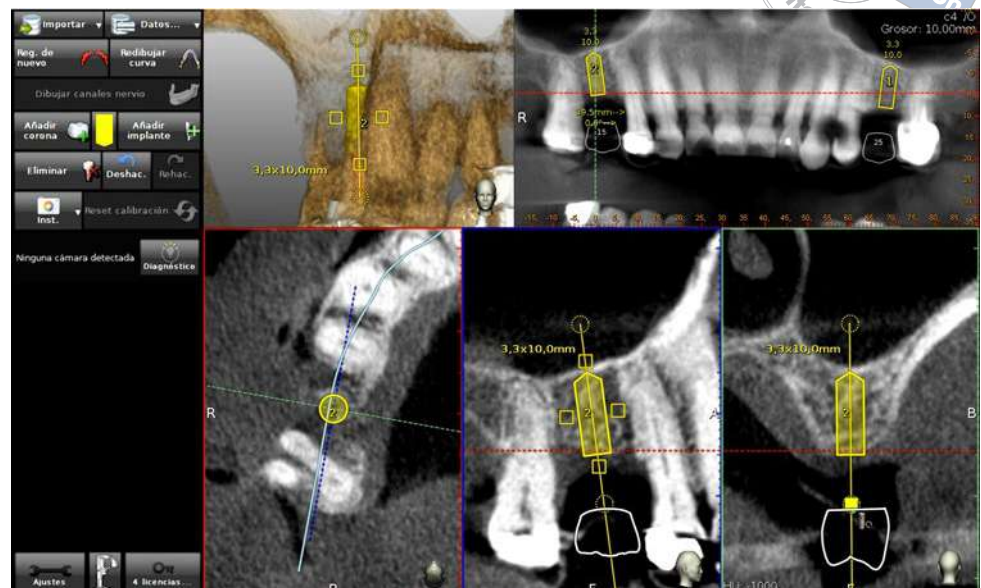


Fig 1 Prosthetic planning and virtual implant positions determined by anatomical and prosthetic requirements.

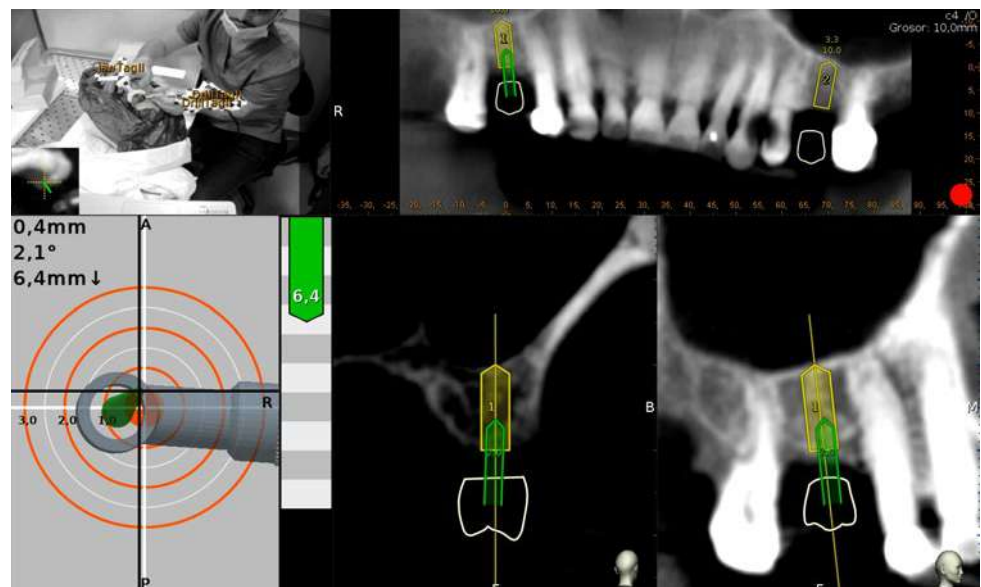


Fig 2 Surgical guidance in real time: vertical, mesiodistal, and buccopalatal orientation is displayed as well as current platform and angular deviations.

ter, two novice operators (RRB and CI), both without any previous experience in DNGS and each with similar experience in conventional implant dentistry (advanced knowledge of how implants should be placed and restored and advanced clinical experience in conventional implantology but no previous experience in DNGS) placed the first 17 implants and the following 8 implants, respectively. The procedure was repeated for each specimen, as follows:

A midcrestal incision was made in the edentulous space, combined with intrasulcular incisions on each side of the edentulous span to raise a full-thickness flap. After that, the

axis of the handpiece was calibrated, and implant drilling was performed following the manufacturer's (Vulkan Implants) recommendations. Each implant drill was calibrated prior to use so that it would be recognized and registered by the DNGS. The computer screen displayed an image of the planned implant positions superimposed over an image captured in the CBCT and showed, in real time, the bone drilling and the implant placement, indicating any discrepancy between the planning and the surgery as it happened (Fig 2). Finally, interrupted monofilament 5/0 sutures were placed for wound closure, simulating an in vivo clinical situation.

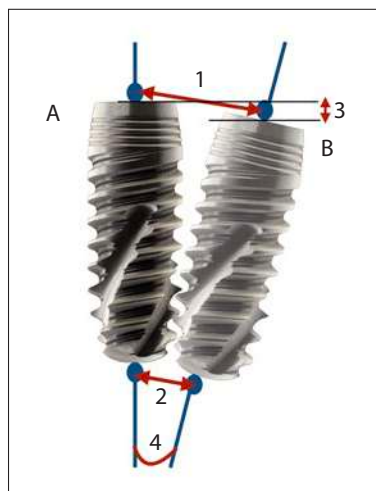


Fig 3 Illustration of the planned and placed implant (A and B, respectively). Disassembly of the total errors into horizontal at the platform and apex level, vertical, and angular.

- 1) Deviation at the implant platform.
- 2) Deviation at the apical part of the implant.
- 3) Vertical deviation.
- 4) Axial deviation of the implant, expressed in degrees.

Accuracy evaluation

Postoperative CBCT scans were captured applying the same standardization method described above. The resulting DICOM files were imported to EvalNav (Navident) software. Each postoperative CBCT was superimposed over the presurgical implant planning image. The accuracy evaluation procedure was as follows:

Firstly, any irrelevant anatomical structures present in the CBCT image were eliminated using 3D sculpting tools. Secondly, the planning and the postoperative CBCTs were aligned manually using relevant anatomical landmarks such as the mental foramen, infraorbital foramen, nasopalatal foramen, and greater palatine foramen. This was complemented by automatic alignment to achieve optimal registration. Then, three different methods were used for assessing the quality of the superimposition: a checkerboard that interleaves the pre- and post-images, a magenta/green blending image, and a flip back and forth between planning and postoperative CBCTs. In any poorly matched areas, the checkerboard shows misalignment of the anatomical structures such as teeth or buccal or lingual perimeters, etc. The magenta/green marks misalignments in magenta or green; well-matched areas appear as a gray color. The flip back and forth technique produces an oscillating motion between anatomical structures when they are not correctly aligned. At this stage, whenever the superimposition could not be considered perfect, the process was terminated and repeated from the beginning. If the superposition was approved, an implant model was creat-

ed by the software from the postoperative scan matching the real implant positions. In cases in which implant alignment could be improved, the examiner adjusted the model to match the real position of the implant in the postoperative scan. When this process was completed, the following data were recorded (Fig 3):

1. Platform deviation: deviation at the implant platform, expressed in millimeters.
2. Apex deviation: deviation at the apical part of the implant, expressed in millimeters.
3. Apicocoronal: vertical deviation, expressed in millimeters.
4. Angular deviation: axial deviation of the implant, expressed in degrees.

This process was performed by two examiners independently (MSN, JGA), referred to as examiner 1 and 2, respectively.

Statistical analysis

Firstly, a paired *t* test was performed to evaluate interexaminer reproducibility with a 95% confidence interval (CI). Statistical analysis was performed for the data recorded by each individual examiner as well as all data produced by both examiners together.

The following descriptive statistics were calculated: mean, standard deviation, minimum and maximum values, and median. Confirmatory results ($P > 0.05$) were obtained for most of the measurements applying the Kolmogorov-Smirnov test so that parametric analysis could be performed. Inferential analysis included the estimation of 95% CI for each deviation. A *t* test for independent samples was applied to determine whether the mean deviation values depended on the maxillary or mandibular location. The learning curve was analyzed using the non-linear Spearman's correlation coefficient. Implants were divided into two subgroups according to surgeon (1st to 17th, and 18th to 25th). The significance level used was 5% ($\alpha = 0.05$).

Results

A total of 25 implants were placed uneventfully in eight fresh human cadaver heads. Most implants were placed in the posterior region (98%) and in the mandible (76%). Implant distribution is summarized in Table 1. There were no statistically significant differences in implant accuracy between arches (maxilla and mandible) or between anterior and posterior implant positions.



Implant accuracy

Mean implant deviation at platform, apex, vertical, and angular were 1.55 ± 0.81 mm, 2.45 ± 0.84 mm, 1.59 ± 0.70 mm, and 5.56 ± 4.03 degrees, respectively. All implant deviation data recorded by each examiner and both examiners together are shown in Table 2.

Interexaminer evaluation

Accuracy measurements at angular ($P = 0.004$) and at apical ($P = 0.020$) deviations were influenced by the individual examiner, while at the implant platform and at the vertical implant position, no statistically significant differences between examiners were found ($P = 0.397$ and $P = 0.054$, respectively). Differences between examiners are shown in Table 2 and Figure 4.

Learning curve

The non-linear Spearman's correlation coefficient analysis found no significant correlation between positioning accuracy and the order in which the implants were placed for any of the parameters studied when analyzed globally. Nevertheless, a tendency toward improvement in accuracy was

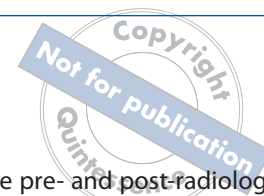
Table 1 Implant distribution

Jaw	Implant location (FDI)	N 25	% 100
Maxilla	16	2	8.0
	14	2	8.0
	25	1	4.0
	26	1	4.0
	Total	6	24.0
Mandible	37	3	12.0
	36	4	16.0
	35	2	8.0
	34	2	8.0
	32	1	4.0
	41	1	4.0
	45	3	12.0
	46	2	8.0
	47	1	4.0
	Total	19	76

observed at the implant platform between early (8th implant) and late (17th implant) implant placement. Moreover, the data showed a statistically significant relationship between the order of the implants and accuracy ($P = 0.013$): the later the implant was placed, the more accurate its position.

Table 2 Platform, apical, vertical, and angular deviations obtained by individual examiners and overall mean values obtained by both examiners

	N	Mean	Standard deviation	Confidence interval (CI) 95%	Minimum	Maximum	Median
Platform deviation, examiner 1	25	1.48	0.90	1.11–1.85	0.01	3.29	1.24
Platform deviation, examiner 2	25	1.63	0.94	1.24–2.02	0.01	3.18	1.86
Mean platform deviation	25	1.55	0.81	1.22–1.89	0.33	3.24	1.53
Apical deviation, examiner 1	25	2.18	0.88	1.82–2.55	0.00	3.65	2.18
Apical deviation, examiner 2	25	2.71	0.99	2.30–3.12	1.38	4.89	2.47
Mean apical deviation	25	2.45	0.84	2.10–2.79	1.21	3.87	2.46
Vertical deviation, examiner 1	25	1.36	0.87	1.00–1.72	0.00	3.10	1.23
Vertical deviation, examiner 2	25	1.83	0.95	1.44–2.22	0.11	4.17	1.72
Mean vertical deviation	25	1.59	0.70	1.30–1.88	0.36	3.31	1.67
Angular deviation, examiner 1	25	4.78	4.26	3.02–6.54	0.00	15.01	3.38
Angular deviation, examiner 2	25	6.34	4.38	4.53–8.15	0.00	17.30	5.26
Mean angular deviation	25	5.56	4.03	3.90–7.22	0.68	14.70	4.00



Discussion

Although DNGS presents several advantages over the static method^{7,11,14,15,17}, it has not been applied in clinical practice to the same extent, probably because it has more complicated handling systems, is technically more sensitive, and is more expensive. In addition, evidence in support of this newly developed field is lacking^{14,15,18}.

The present study obtained mean accuracy values within the 2-mm safety margin recommended for SGS¹⁹ (except for apex deviation, which can reach 2.45 mm safely). Nevertheless, maximum and minimum deviations ranged considerably, which could lead to iatrogenic lesion, although no anatomical structures (such as the alveolar nerve canal, maxillary sinus floor, or disruption of the buccal and/or lingual bone wall) were injured in this study.

Only a few studies have compared the accuracy of DNGS with the static method, and these have failed to find significant differences between them^{2,17,21}. Nevertheless, SGS is clearly influenced by the type of surgical guide support: tooth- and mucosa-supported guides in partially edentulous patients show greater accuracy than bone-supported guides in completely edentulous patients^{20,22}. However, DNGS appears to present fewer differences in accuracy between partially and completely edentulous patients, with no differences deriving from surgical guide support-related factors¹⁴. Moreover, when the dynamic method is compared with the classic freehand method, implant positioning accuracy is much greater with DNGS^{15,18,22}.

Evaluating vertical implant positioning, Younes et al found no differences in a comparison between the freehand approach and the SGS approach²³. However, Jorba-García et al found greater accuracy with the dynamic method than with the freehand method, except for vertical deviation¹⁸. This might be explained by the fact that, in the freehand method (unlike the dynamic method), the surgeon's gaze is directed at the implant placement underway rather than at the screen, and the surgeon may be able to visualize the implant insertion more clearly. Likewise, when SGS is employed, the surgeon's view is obstructed by the surgical guide.

Implant deviations from planned positions, as well as their evaluation, are the sum of several potential sources of error. These are numerous and cumulative: the capture of pre- and postoperative CBCT images, followed by the planning software, surgical execution, and even the evaluation method²⁴. The literature attributes a mean error of < 0.5 mm to the image processing software, a value that is not clinically relevant but should be taken into consideration when analyzing out-

comes^{6,25}. In the present study, the pre- and post-radiologic study of all specimens was conducted by the same trained operator, and a reduced voxel size was used to increase image resolution, so the imaging process may be considered reliable.

Regarding surgical execution, implant placement with DNGS demands good eye–hand coordination, as the surgeon is guided by looking at the computer monitor rather than directly at the surgical field. Any hand tremor or individual perception of a deviation as well as the subsequent effort to correct it in response to live feedback makes DNGS technically sensitive. Therefore, the operator's eye–hand coordination plays a central role in achieving accurate implant positioning. In the present study, implants were placed by two right-handed surgeons with the same background in conventional implant dentistry but with no previous experience of DNGS. These operators were chosen to eliminate any bias deriving from left- or right-handedness or from difference in clinical experience of the technique, as recommended in previous studies^{2,11,18,26}.

Block et al reported slightly better positioning accuracy than that found in the present study (1.16 ± 0.59 mm mean deviation at the implant platform, and 2.97 ± 2.09 degrees angular deviation)¹⁵. In another cadaveric study model treated with SGS²⁰, the deviations were comparable with those found in the present study (platform 1.18 ± 0.12 mm, apical 1.52 ± 0.18 mm, and angular 2.82 ± 0.40 degrees). In the same systematic review²⁰, deviations reported in the clinical studies analyzed were – surprisingly – slightly less than those found in the present cadaveric study model, apart from angulation (platform 1.10 ± 0.09 mm, apical 1.40 ± 0.12 mm, and angular 3.98 ± 0.33 degrees)^{11,26,18}.

Although the variables are supposedly easier to control in an *in vitro* study than in a clinical model, the cadaveric study model is not free of obstacles. Defrosted heads are only an imitation of a real patient, presenting limitations to radiologic pre- and postoperative evaluation as well as the entire surgical procedure, with a greater stiffness of the soft tissue such as the cheeks and tongue. Worse ergonomics must be adopted when working on a laboratory table rather than in a dental chair. The above limitations and obstacles, taken together with the fact of non-experienced operators, might be some of the reasons why the deviation value obtained in the present cadaveric study were similar to or higher than the Bock et al¹⁵ clinical study mentioned above, a fact that has also been seen in SGS studies²⁰.

Most studies of implant positioning accuracy use CBCT scans for postoperative evaluation^{17,18,20,23,25,27–29}. However, the limitations of CBCT superimposition are clear: the method involves multiple steps and can be subject to variability. For



this reason, in the present study, two examiners performed the evaluation process independently. The accuracy of measurements at the implant platform and vertical position did not differ significantly between the examiners, while apical and angular evaluations showed statistically significant differences between examiners. Nevertheless, these differences (mean difference of 0.53 mm and 1.56 degrees) are clinically irrelevant. Mean values of evaluations obtained by both examiners were calculated together for all the variables to prevent bias deriving from choosing the results obtained by one examiner rather than the other.

DNGS would appear to achieve acceptable implant positioning accuracy. In addition, no surgical guides are needed, which constitutes an advantage over SGS, whether fully or semi-guided, and reduces planning time and chair time because DSGS eliminates the process of fabricating the surgical guide. With no guide over the area of interest, the surgeon's view of the surgical field is not obstructed, and bone irrigation is not affected.

However, every drill needs to be calibrated by the camera, and a natural and ergonomic position of the handpiece is not always possible because of interference with the sight of the camera, then interrupting the guidance.

When analyzing the learning curve, none of the variables investigated in the present study underwent significant improvement in accuracy as the surgeons gained experience, except for implant platform deviation. This variable showed a significant reduction in deviation from the 8th to the 19th implant placement. This can be described as a practically flat learning curve. In an *in vitro* study with a significantly higher sample size, Sun et al concluded that the learning curve for dentists with no previous experience of DNGS reaches a plateau after 30 implants²⁶.

In a clinical study, Block et al reported that surgeons with prior experience in DNGS achieved greater implant accuracy with a flat learning curve compared with surgeons with experience in implant dentistry but with no prior experience in DNGS¹¹. Although the differences between surgeons were not significant, the inexperienced operators in the present study needed to perform the procedure 20 times before differences in comparison with experienced surgeons decreased to a minimum. In line with these results, Pellegrino et al stated that the difference in terms of implant placement accuracy between operators with different surgical experience in both conventional implantology and DNGS were clinically irrelevant³⁰. However, experience in DNGS seems to have an influence on drilling time. In addition, Jorba-García et al showed that extensive experience in conventional implant dentistry

did not necessarily lead to significantly greater accuracy in DNGS¹⁸.

A potential explanation for the fact that there was no significant improvement in accuracy as the surgeons gained experience in the present study might be due to it being a preliminary study with a small sample size.

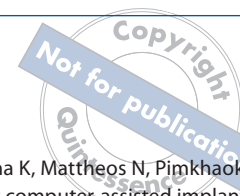
In the present study, DNGS achieved acceptable implant positioning accuracy with a practically flat learning curve. This is a potential reason for the considerable range between the maximum and minimum values (but not the mean values). When planning an implant placement, it is suggested to not only take into consideration the accuracy and the range between maximum and minimum values of accuracy, but also additional factors such as the role of the implant length in the implant accuracy³¹, and the necessity for a novice to start training on a non-human model first.

Conclusions

DNGS implant placement is an accurate guidance method. It would appear to be safe as no surgical adversities were experienced. Nevertheless, for the sake of caution, relatively high safety margins of up to 2 mm in the implant platform and the vertical position, and 3 mm in the apical area, must be respected by novice surgeons until there is less variation between the maximum and minimum deviation values, which might be obtained with more experience in this technique. DNGS training is highly recommended to prepare the surgeon to adapt to the loss of direct vision and to learn how to perform implant drilling and implant placement watching a screen, which demands better eye–hand coordination than conventional implant placement. Further studies are needed to quantify the deviations derived from each step in the DNGS technique, to properly assess its cost-effectiveness, to describe and understand more precisely the learning curve, and to directly compare the technique with other guidance methods.

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Disclaimer

The authors declare that they have no conflicts of interest.

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Genauigkeit dynamisch navigierter Implantatinserktion durch einen chirurgischen Novizen Eine Präliminarstudie am Leichenmodell

Zusammenfassung

Ziel: Primäres Ziel dieser Studie war es, die Positionsgenauigkeit von Implantaten zu untersuchen, die von einem chirurgischen Novizen mittels dynamisch navigierter Implantatchirurgie inseriert wurden. Sekundäre Ziele waren eine Auswertung der Lernkurve des Operators und die Identifikation potenzieller aus dieser Technik resultierender Komplikationen.

Material und Methode: In 8 teilbezahnten humanen Leichenköpfen wurden 25 Implantate eingesetzt. Die Planung der Implantatpositionen erfolgte jeweils nach dem Import einer präoperativen digitalen Volumentomografie in die Planungssoftware. Die Implantate wurden unter Verwendung eines dynamischen Navigationssystems eingesetzt. Um die Genauigkeit zu analysieren, wurde eine postoperative DVT mit den Implantatplanungsdaten überlagert. Die Bewertung der Diskrepanz zwischen der virtuell geplanten und der postoperativen Implantatposition erfolgte durch Bestimmung der horizontalen Plattformabweichung, der Abweichung des Implantatapex, der apikokoronalen (vertikalen) Abweichung und der Winkelabweichung.

Ergebnisse: Die mittlere Plattform-, Apex-, vertikale und Winkel-Abweichung betrugen $1,55 \pm 0,81$ mm, $2,45 \pm 0,84$ mm, $1,59 \pm 0,70$ mm bzw. $5,56 \pm 4,03^\circ$. Signifikante Unterschiede zwischen Ober- und Unterkiefer bzw. zwischen Front- und Seitenzahnbereich fanden sich nicht. Insgesamt war eine flache Lernkurve zu beobachten. Eine Ausnahme hiervon bildete die Implantatplattform, für die sich zwischen dem 8. und dem 17. inserierten Implantat ein Trend zur Verbesserung der Genauigkeit zeigte. Komplikationen wurden nicht beobachtet.

Schlussfolgerung: Die Ergebnisse dieser von einem chirurgischen Novizen an einem Leichenmodell durchgeführten Studie zeigen, dass mittels dynamisch navigierter Implantatchirurgie eine genaue Implantatsetzung innerhalb eines Sicherheitsabstandes von 2 mm für die Implantatplattform und die vertikale Implantatposition und eines Sicherheitsabstandes von 3 mm für den Bereich des Implantatapex möglich ist. Der Erwerb der für die Technik nötigen Auge-Hand-Koordination erfordert Training.

Indizes: computergestützte Chirurgie, computergeführte Chirurgie, dynamische Navigation, Genauigkeit, Dentalimplantat, dentale Navigation



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