Navigated Flapless Transmucosal Implant Placement in the Mandible: A Pilot Study in 20 Patients

Gert Wittwer, Dr Med Univ, Dr Med Dent[1]/Wasiu Lanre Adeyemo, BDS, FMCDS, Dr Med Dent[2]/
Kurt Schicho, DSc[2]/Michael Figl, MS DSc[3]/Georg Enislidis, Dr Med Univ, Dr Med Dent, Docent[1]

Purpose: *The aim of this study was to assess whether navigated flapless transmucosal implant bed preparation allows placement of dental implants in edentulous mandibles.* ***Materials and Methods:*** *Each patient was scheduled to receive 4 screw-shaped Ankylos (Dentsply Friadent) implants in the interforaminal region. The VISIT navigation system was used for guided drilling. The mucosa was penetrated without flap elevation. The study protocol did not allow direct visualization of the bone surface during surgery. Data analysis included computed measurements on pre- and postoperative computerized tomographic (CT) images.* ***Results:*** *Twenty patients with fully edentulous mandibles (14 male, 6 female) were included in the study. Computer-based planning for 80 implants was performed intraoperatively. Two implants (2.5%) were not primarily stable because of buccal bone fenestration, which occurred because of uncontrollable shifting of the dental implant drill. These implants were immediately removed. Postoperative CT image evaluation revealed a mean deviation of 0.7 mm in all directions.* ***Conclusions:*** *Navigated flapless transmucosal interforaminal implant placement was found to be a precise, predictable, safe procedure in patients with smooth wide regular mandibular ridges. The technique was less accurate and more complicated in areas where irregular bone existed.* (Clinical Trial) Int J Oral Maxillofac Implants 2007;22:801–807

Key words: *computer-aided navigation, flapless surgery, transmucosal implant*

Implant-supported prostheses have gained wide acceptance in the rehabilitation of fully and partially edentulous patients. The survival of functionally loaded implants is highly dependent on their biomechanical stability.[1] The need to improve the accuracy of the placement of dental implants and their biomechanical stability, and thereby reduce the failure rate after their placement, has led to the experimental application of computer-aided navigation in the field of implant dentistry[1–9]; the risk of damage to the nerves and neighboring teeth can also be avoided by computer-aided navigation.[5,6,10] Computer-aided navigation is a relatively recent technology that allows spatial and temporal linking of the operation site with additional computer-generated information obtained using tracking technology, which continuously registers the position of patients and surgical tools by means of special sensors.[11,12] The use of intraoperative navigation in implant dentistry allows the surgeon to precisely transfer a detailed presurgical implant plan to the patient. This technology for the intraoperative tracking and guidance of surgical instruments also enhances minimally invasive procedures.[8] Clinical and experimental studies have shown that computer-assisted navigation during implant placement is a reliable technique and may be applied in routine dental implantology, even in difficult anatomic situations.[3,7,13,14]

The placement of 4 or more interforaminal implants for the retention of a mandibular overdenture is now a common procedure for the treatment of

[1]Senior Resident, Department of Oral and Maxillofacial Surgery, Medical University of Vienna.
[2]Resident, Department of Oral and Maxillofacial Surgery, Medical University of Vienna.
[3]Center for Biomedical Engineering and Physics, University of Vienna.

Correspondence to: Dr Dr Med Univ Gert Wittwer, AndreasKlinik Cham Zug, Rigistrasse 1, CH-6330 Cham, Austria. Fax: +41 784 08 58. E-mail: gert.wittwer@hirslanden.ch

edentulism.[2,15,16] Traditionally, the surgical site is exposed, and an interforaminal mucoperiosteal flap is elevated and reflected. This procedure may be complicated by postoperative infection and/or dehiscence of the surgical wound.[16] Reflection of the interforaminal mucoperiosteal flap may also jeopardize the mandibular neurovascular bundle. To avoid mucoperiosteal flap elevation and reflection, a novel approach has been developed for mandibular implant placement with the aid of computer-assisted navigation.

The present study was performed to assess whether navigated flapless implant bed preparation allows placement of dental implants in edentulous mandibles.

MATERIALS AND METHODS

All consecutive adult patients who presented with edentulous mandibles and who satisfied the inclusion criteria for the study were operated on using the VISIT navigation system (Vienna, Austria). VISIT consists of software for modular surgical planning and navigation.[2,11] The VISIT implant planning and navigation software was developed at the Department of Biomedical Engineering and Physics (University of Vienna, General Hospital, Vienna, Austria); it is based on AVW 6.0 (Biomedical Imaging Resource, Mayo Clinic, Rochester, MN) and custom-developed routines for registration and visualization.[2,11] It was written for the SGI workstation.[2,11] The planning software included in VISIT allows evaluation of the bony situation based on volume renderings and oblique reformatted computerized tomographic (CT) slices.[7]

Only patients with a sufficient bone height (> 15 mm) in the anterior mandible and without any bone pathology were included in the study. All patients had been completely edentulous in the mandible for at least 1 year prior to surgery. Each patient was scheduled to receive 4 Ankylos implants (Dentsply Friadent, Mannheim, Germany) in locations between the left and the right mandibular mental foramen. Using the planning module of the navigation software, optimal implant position and orientation were defined in respect to the patient's prosthetic requirements.

The workflow within the VISIT software consists of the following steps:

1. Importation of CT data.
2. Drawing of the dental arc and the inferior alveolar nerve.
3. Planning of implant positions and orientations in selected 3-dimensional views.
4. Registration of the patient (by means of a splint or with microscrews directly fixed at the bone).
5. Intraoperative navigation.

Preoperative CT Scanning and Computer-Assisted Navigation

Prior to preoperative CT scans, 3 transitional titanium microscrews 5 mm in length and 1.2 mm in diameter (Martin, Tuttlingen, Germany) were placed under local anesthesia in the anterior and posterior mandibular alveolar crest areas. These screws served as fiducial markers for intraoperative registration of the navigation system. The patients' overdentures were adapted by fixing a metal bar to the incisal edges of the anterior teeth and premolars. The patients' heads were fixed rigidly during high-resolution multislice CT scanning (Philips MX 8000). The imaging data were transferred to the navigation system. The position, length, angulation, and diameter of the implants were determined with the VISIT software (Fig 1).[2,7,17]

Placement of Implants and Surgical Navigation

The implants were inserted under local anesthesia (Articain; Sanofi-Aventis, Berlin, Germany). The navigation system was connected to the patient as well as the surgical drill through a dynamic reference frame (Fig 2). Navigation was performed after matching the patient's CT scans with a point-to-point registration (Fig 2).[18] The position of the drill and the preoperatively determined position of the implant bed were both visible on the monitor.[7] The implant bed was prepared in 3 phases: mucosal penetration, cortical bone preparation, and spongy bone preparation. First, the mucosa was penetrated with a 2-mm pilot drill; cortical penetration was then performed perpendicular to the alveolar crest. Drill shift was avoided. The implant bed was prepared in accordance with the navigation data; definitive preparation of the implant bed was performed using 3.5-mm, 4.5-mm, and/or 5.5-mm drills in ascending order (Figs 3a and 3b). The drilling sequence was followed by tapping and insertion of the screw-shaped Ankylos implants. After the implants had been inserted with a handpiece, a torque wrench was used to complete seating and measure the stability of the implants. Cover and inlet screws were removed, and appropriate abutments (Synecone 1.5 or 3.0, tapered 4 degrees; Dentsply Friadent) were mounted (Fig 4). Implant stability was tested using Periotest values (Siemens, Bensheim, Germany). For each parameter, 5 measurements were performed, and the arithmetic mean was calculated.

Accuracy

The position of the implant tip (apical end) as well as the base (coronal end) was measured on pre- and postoperative CT scans using exactly corresponding axially reformatted slices. Accuracy was assessed postoperatively using the Analyze AVW 6.0 software (Biomedical Imaging Resource, Mayo Clinic,

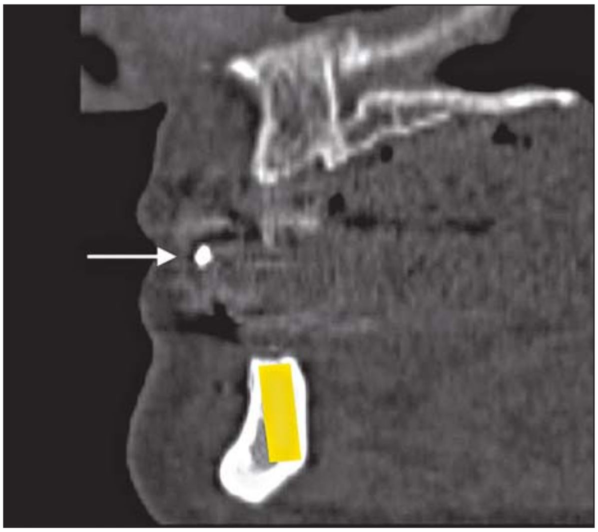
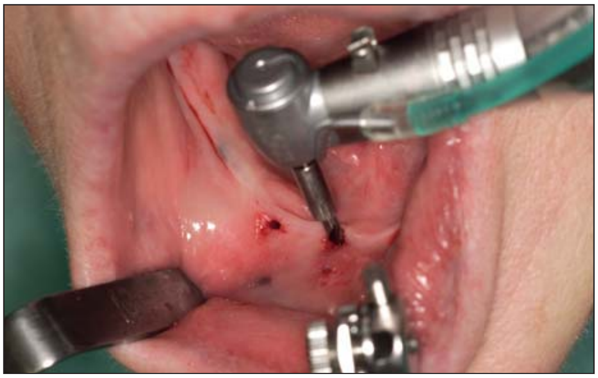
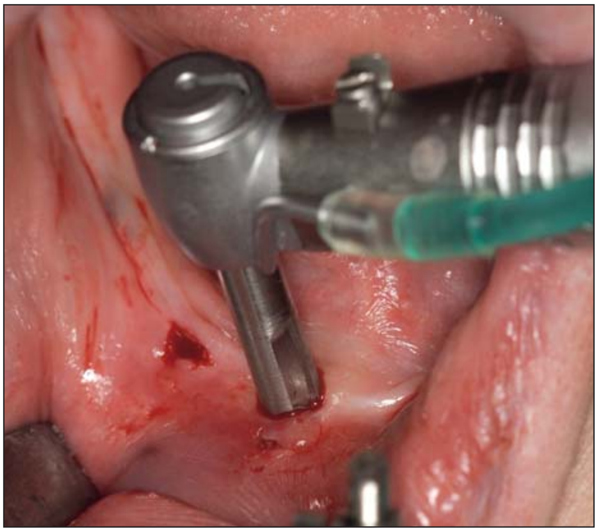


Fig 1 *(left)* Preoperative planning using the VISIT navigation system. The metal bar *(arrow)* indicates the occlusal orientation to define the optimal implant position. The preplanned implant position is shown in a 2-dimensional view according to the incisal edges of the frontal teeth and premolars. The full extent of the available bone was utilized.

Fig 2 *(above)* A dynamic reference frame for tracking the patient's position is mounted in the mental region. Navigation was performed after matching the patients' CT scans with a point-to-point registration using 3 previously inserted screws as fiducial markers.





Figs 3a and 3b *(above)* Start of preparation of the implant bed. The overlying ridge mucosa and bone were penetrated with a 2-mm pilot drill. *(right)* The implant bed was prepared in accordance with the navigation data. Definitive preparation of the implant bed was performed using 3.5-mm, 4.5-mm, and 5.5-mm drills in ascending order.

Rochester, MN). In this procedure, postoperative data were compared with the corresponding preoperative plan. Lingual and buccal deviations at the apical and coronal end of the implants were registered.

Data Analysis

Data was analyzed using the software SPSS for Windows (version 12.0; SPSS, Chicago, IL). Differences between the planned and final implant position in relation to the buccal and lingual mandibular cortices were given as means ± SDs. Results are presented in descriptive and tabular forms.

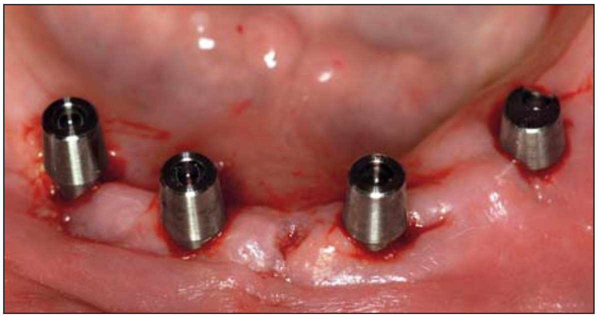


Fig 4 After the implants had been inserted with a handpiece, a torque wrench was used to complete the seating and measure the stability of the implants. Cover and inlet screws were removed, and appropriate abutments (Synecone 1.5 or 3.0, tapered 4 degrees; Dentsply Friadent) were mounted.

Table 1 Type, Length, and Diameter of Implants Used

Type of implant*	Length (mm)	Diameter (mm)	No. of implants
11B	11	4.5	2
14A	14	3.5	16
14B	14	4.5	29
17B	17	4.5	31
17C	17	5.5	2
			80 (total)

*Ankylos; Dentsply Friadent.

Table 2 Types of Implants Used and Periotest Values After Implantation

	Left canine		Left incisor		Right incisor		Right canine	
Patient	Type	PTV	Type	PTV	Type	PTV	Type	PTV
1	14B	−3	14B	−4	14A	−5	14B	−4
2	14B	−4	14B	−4	14B	−3	14B	−2
3	17B	−5	17B	−5	17B	−4	17B	−2
4	17B	−4	17C	−4	17C	−6	17B	−7
5	17B	−3	17B	−4	17B	−4	17B	−5
6	14B*	–	14B	−3	14B	−4	14B	−3
7	14A	−1	14A	2	14A	−4	14A	−4
8	17B	−5	17B	−4	17B	−4	17B	−5
9	17B	−5	17B	−5	17B	−5	17B*	–
10	14B	−4	14A	−3	14B	−5	14A	−4
11	14B	−4	14A	−4	14A	−3	14B	−4
12	17B	−5	17B	−5	17B	−4	17B	−5
13	14A	−3	14B	−4	14B	−2	14B	−3
14	17B	−5	14B	−6	17B	−4	17B	−5
15	14B	−5	14B	−4	17B	−6	14B	−5
16	14B	−4	11B	−4	14B	−3	14B	−5
17	17B	−6	14B	−5	14B	−3	17B	−5
18	14A	−4	14B	−3	14A	−3	14A	−4
19	17B	−7	17B	−6	14B	−5	17B	−5
20	11B	−4	14A	−5	14A	−4	14A	−4

Type = type of implant; PTV = Periotest value.
*Due to insufficient primary stability, the implant had to be removed immediately.

Table 3 Navigation Accuracy for Transmucosal Implant Placement

	Labial deviation (mm)			Lingual deviation (mm)		
	Mean	SD	Range	Mean	SD	Range
Implant tip	0.6	2.0	0.3 to 0.9	0.7	0.3	0.3 to 1.0
Implant base	1.0	0.5	0.3 to 2.0	0.7	0.3	0.3 to 1.2

*Implant tip = apical end; implant base = coronal end.

RESULTS

A total of 20 patients (14 male, 6 female; age range: 56 to 77 years; mean age: 64.3 years) were included in the study. Eighty implants (4 per patient) were placed in the anterior mandible. The distribution of the implants in relation to their length, diameter, and Periotest values are shown in Tables 1 and 2. For 78 implants (18 patients) the preoperative plan could be precisely transferred to the patient intraoperatively by means of navigation. A mean deviation between the preplanned position and the postoperative results of 0.7 mm (error range: 0.3 to 2.0 mm; variance: 0.03 mm^2) was found. Labial and lingual deviations at the tip and the coronal end of the implants are summarized in Table 3. In 2 patients the bony surface caused a deviation of the drilling direction. This caused buccal bone fenestrations during drilling (Figs 5a and 5b). Due to poor stability in 2 patients (patient 6, implant in the left canine region;

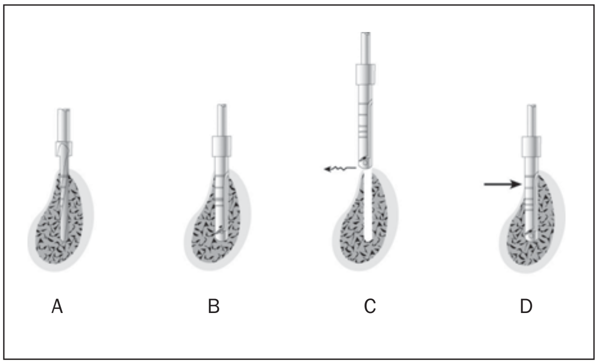


Fig 5a Illustration of the presence of thin buccal and thick lingual cortical bone. A and B show the correct positioning of the pilot and definitive drills. C shows the remaining thin buccal bone after pilot drilling and the resulting shift of the definitive drill in a buccal direction *(arrow)*. This led to a bone fenestration *(D; arrow)*.

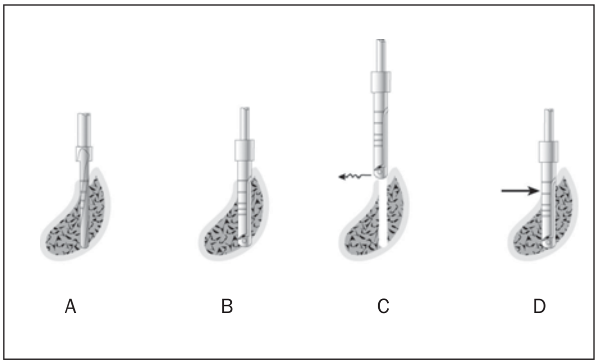


Fig 5b Illustration of the presence of a rim on the ridge. A and B show the correct positioning of the pilot and definitive drills. C shows the rim on the ridge causing a shift of the definitive drill in a buccal direction *(arrow)*. D shows the resultant bone fenestration *(arrow)*.

patient 9, implant in the right canine region; Table 2), the implants were immediately removed. In all other cases the procedure was allowed to progress according to plan and was well tolerated by the patients. Postoperative healing was uneventful in all patients.

DISCUSSION

Computerized navigation surgery is a surgical modality in which the position of the surgical instrument within the surgical field is accurately tracked and displayed as an overlay graphic on the preoperative CT images.[19] In implant dentistry, this feature transforms implant surgery into a fully monitored procedure and therefore facilitates a minimally invasive flapless approach.[8] Several studies have described the value of navigated implant bed preparation for implant dentistry, which is based on the accuracy of the transfer of preoperative planning procedures to the intraoperative setting.[2,4,7–9,13,19] Reducing the risk of damage to anatomic structures such as nerves and vessels is one of the desired outcomes of presurgical planning.[1–8,10,13] The technology has also been employed in other fields, such as neurosurgery, endoscopy, arthroscopy, bone surgery, image-guided biopsy, and removal of foreign bodies.[2,5,6,20] The technology is challenged whenever anatomic structures are not directly visible to the surgeon, as was the case in the current study. A reliable computer-aided intraoperative navigation system should allow accurate transfer of the preoperative plan to the patient with minimal error to avoid complications such as cortical perforation, fenestration, and damage to the inferior alveolar nerve.[13]

This study evaluated a novel approach to the placement of interforaminal mandibular dental implants with the aid of computer-assisted navigation without the conventional elevation and reflection of a mucoperiosteal flap at the surgical site. Implant placement was successful in 78 of 80 attempts. The accuracy of the method appears to be better than that of a similar procedure reported earlier.[7,13] In the present study, a mean deviation of 0.7 mm of the longitudinal axis of the implants from the planned position was recorded. This value is lower than the mean deviations of 1.1 mm and 0.96 mm reported earlier by Wagner et al[7] and Wanschitz et al,[13] respectively. Several factors, including the use of high-resolution CT and intrabony fiducial markers, have been reported to influence the degree of accuracy in computer-aided navigation.[2,9,21] A higher degree of accuracy recorded in the present study might be due to a combination of factors (high-resolution CT, intrabony fiducial markers, and fixation of the patient's head) employed in the study.

The authors of the current study found osseous fixation of fiducial markers to be a more reliable and precise technique. A registration protocol based on external fiducial marker technology has been reported to result in smaller navigation error than one utilizing matching with anatomic landmarks.[22]

Overall, greater mean deviation was recorded at the coronal than at the apical end of the implants on the labial side (Table 3), in contrast to earlier reports.[5,16] This was due to the eccentric shift at the beginning of implant bed preparation; as there was no possibility to smooth sharp bony edges at the alveolar crest, the shifting led to more deviations at the coronal end. Such shifting could not be prevented, because implant bed preparation was accomplished without mucosal elevation and reflection, and the alveolar crest was not directly visible to the surgeon.

Preoperative computer-based planning could be implemented intraoperatively for 78 implants. Two implants (2.5%) had to be removed immediately due to poor stability; this was attributed to 3 factors. First, nonhomogenous cortical diameter at the site of implant placement led to shifting of the drill and subsequent fenestration in cases of thin buccal cortical bone (Fig 5a). Second, irregularities of the alveolar crest surface caused uncontrolled shifting of the second drill, although the pilot drill had been successfully placed as an accurate landmark for subsequent instruments (Fig 5b). To avoid eccentric shift due to bone surface irregularities using standard drilling sets, it is important to analyze the CT slices for bony edges and cortical irregularities, especially if the concave shape of the plate is at risk of fenestration. The third factor that significantly contributed to fenestration was the design of the implant system (Ankylos) used in the study. The relatively wide step between the diameters of the pilot drill (2 mm) and the first definitive drill (3.5 mm) of the Ankylos system might have contributed to the eccentric drilling of the implant bed, leading to fenestration of the buccal plate. The development of a modified set of drills might prevent this problem in the future.

Navigated flapless implant placement offers several advantages. It affords the possibility to optimize implant position relative to prosthetic requirements by engaging more bone, leading to better primary stability for immediate loading. It also enhances intraoperative safety for anatomic structures at risk of accidental injury. As suturing is not necessary, removal of provisional prostheses during early healing can be avoided. The procedure can be safely performed under local anesthesia on an outpatient basis. Avoidance of mucoperiosteal elevation reduces operating time as well as postoperative pain and swelling and eliminates postoperative soft tissue wound infection/dehiscence.

One major limitation of this technique is the cost of CT images and the navigation technology. However, the medical benefit of computer-assisted navigation technology in implant dentistry may outweigh its cost in selected cases.[12] In addition, this technique can be a major surgical problem in cases where the ridge is irregular or a knife edge exists, as is often the case. The use of navigation systems requires additional procedures, such as placement of fiducial markers and a dynamic reference frame for the purpose of referencing CT data and connecting the patient to the navigation system during surgery. However, these additional procedures were easily accomplished and well tolerated by patients.

CONCLUSIONS

Navigated flapless transmucosal interforaminal implant placement is a precise, predictable, and safe procedure in patients with smooth wide regular mandibular ridges. The technique is less accurate and more complicated in areas where irregular bone exists.

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