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Different techniques of static/ dynamic guided implant surgery: modalities and indications

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The placement of endosseous implants encounters many constraints: patient movement; limited surgery time related to the use of local anesthesia; a restricted visualization of the operation field; and mental transfer of two-dimensional radiographs (used preoperatively) to the three-dimensional surgical environment, including aspects such as esthetics, biomechanics and functional constraints of the prosthetic treatment. Hence, during a limited time span and with a restricted view, the surgeon must take numerous decisions while nurturing a conscious patient under aseptic conditions. Therefore, thorough preoperative planning of the number of implants to be placed and their size, position and inclination, will free the surgeon's mind, allowing him or her to concentrate on the patient and on tissue handling.

Preoperative planning is ideally performed on three-dimensional images (3). The latter is possible via multislice or cone beam computed tomography (27). The introduction of cone beam computed tomography, offering imaging at low dose and relatively low cost, has increased the applicability and strengthened the justification for three-dimensional-based presurgical planning (20, 35–37). As such, the surgeon can, after consulting the dentist who provides a template representing the planned prosthesis, position the implants correctly in a virtual reality. When the planned prosthesis is incorporated into these computed tomography images, the planning can take into account both the jawbone anatomy and the planned superstructure. This should improve biomechanics and esthetics (50). Moreover, it may optimize the mutual interaction between the 'surgical' and the 'prosthetic' teams.

For each computed tomography brand, specific software exists to support such three-dimensional planning. For example, scans with Siemens spiral CT can be reconstructed with the Dental CT software (Siemens, Erlangen, Germany), whilst computed tomography data acquired by General Electric's MSCT are typically reconstructed with Dentascan software (GE, Medical Systems, Milkwaukee, WI) (26). Similar software is available for cone beam computed tomography companies (e.g. iCat Vision from ISI, Hatfield, PA; and Ondemand 3D from Cybermed, Seoul, South Korea; an overview is listed on www.sedentexCT.eu).

Specific software programs are now available for implant surgery planning (28). This implies that the above-mentioned reformatting programs are no longer needed. The specific software transforms the original data set in a Digital Imaging and Communication in Medicine (DICOM) format. Examples of software programs are given in Table 1 (30). After secondary reformatting of the images, these programs allow implants of different sizes to be 'imported' into the jawbone images. The positioning of the implants in this virtual environment is mostly performed intuitively as is the case during surgery, starting from the coronal part of the jawbone and moving to a more apical location. This is performed on trans-sectional views, to visualize the cortex and the trabecular bone. At the same time, the position of the placed implant is checked in the other planes and in the three-dimensional virtual model. Depending on the software, these views can be displayed either in a split-screen or fully visualized in three dimensions with integrated trans-sectional views. In the latter, without the need for recalculation, the three planes of space are visualized at the same time and within the

Table 1. Example of software programs for static and dynamic systems

Application	Website	Company	Virtual implant planning	Guide	Drill guide production
Static systems (surgical guides)					
3D StendCad	www.implant3d.com	Media Lab, Italy	Yes	None	
Ay Tasarim	www.med.aytasarim.com	Ay Tasarim, Turkey	No	Surgical guide	Sterolithography
Biodental Models	www.med.aytasarim.com/	BioMedical Modeling, USA	Yes	Surgical guide	Sterolithography
EasyGuide	www.keystonedental.com	Keystone Dental, USA	Yes	Surgical guide	Laboratory
GALILEOSImplant	www.sicat.com	SICAT, Germany	Yes	Surgical guide	Laboratory
Guide	www.bioparts.com.br	BioParts, Brazil	Yes	Surgical guide	Sterolithography
Implant 3D	www.med3d.de	Med30, Switzerland	Yes	Surgical guide	Laboratory
ImplantViewer	www.annesolutions.com.br	Anne Solutions, Brazil	Yes	None	
InVivo5	www.anatomage.com	Anatomage, USA	Yes	Surgical guide	?
SICATImplant	www.sicat.com	SICAT, Germany	Yes	Surgical guide	Laboratory
Nobelclinician	www.nobelbiocare.com	Nobelbiocare, Sweden	Yes	Surgical guide	Sterolithography
Scan2Guide	www.ident-surgical.com	I-Dent lmagmg, USA	Yes	Surgical guide	Sterolithography
Simplant	www.materialise.com	Materialise Dental, Belgium	Yes	Surgical guide	Sterolithography
Straumann® coDiagnostiX	www.straumann.com	Straumann, Switserland	Yes	Surgical guide	Laboratory
VIP	www.biohorizons.com	Implant Logic Systems, USA	Yes	Surgical guide	Laboratory
Dynamic systems (navigation)					
IGI	www.image-navigation.com	Image Navigation, USA	Yes	None	Navigation
Ondemand3D Implant	www.cybermed.co.kr	Cybermed, Korea	Yes	None	Navigation
Robodent	www.robodent.com	Robodent, Germany	Yes	None	Navigation
Treon (medical)	www.medtronicnavigation.com	Medtronic Navigation, USA	Yes	None	Navigation
VISIT		University of Vienna, Austria	Yes	None	Navigation
Voxim	www.ivs-technology.de	IVS, Germany	Yes	None	Navigation

same single image. One can compare this three-dimensional condition with images from three cameras that are following the implant, and where the clinician can at any time look at the image on one, two or three cameras, depending on the need.

The use of (cone beam) computed tomography involves the use of a high dose of radiation, however, this should be considered as acceptable in view of the added clinical value provided by the images (29). Moreover, even with the most optimal preoperative planning software, transfer to the surgical field still needs to achieve clinical and medico-legally acceptable accuracy (55). Several options are available for such transfer: computer-guided (static) surgery; or computer-navigated (dynamic) surgery (30). For computer-guided surgery a static surgical guide is used that transfers the virtual implant position from computed tomography data to the surgical site. These guides are produced by computer-aided design/computer-assisted manufacture technology, such as stereolithography, or manually in a dental laboratory (using mechanical positioning devices or drilling machines) (52, 59). With computer-navigated surgery the position of the instruments in the surgical area is constantly displayed on a screen with a three-dimensional image of the patient. In this way, the system allows real-time transfer of the preoperative planning and visual feedback on the screen (4, 48, 71). A workflow of the different systems is presented in Fig. 1.

Static surgical guides

Stereolithography

As mentioned before, besides the bone volume, the ideal tooth position is visualized via a scan prosthesis, so that the implants can be positioned taking both the anatomic and prosthetic aspects into account. As a standard resin prosthesis has a density similar to that of the surrounding soft tissues, it is impossible to segment it easily from the computed tomography images. Therefore, a special scan prosthesis has to be prepared. This can be performed in several ways. The first option is to prepare a copy of the prosthesis in radiopaque resin (Fig. 2A). Only one scan has to be made with the patient wearing the prosthesis in the mouth.

A second method was developed in the mid-1990s by a research team at the University of Leuven. They proposed a double-scan procedure (the patient with the scan prosthesis in the mouth; and the prosthesis alone) followed by integration of the scan prosthesis or radiological template, planned by the dentist, within the craniofacial model (61–63). Therefore, the scan prosthesis contains small gutta percha spheres (diameter ± 1 mm) (Fig. 2B). The craniofacial images show the gutta percha markers with respect to the bone, without visualizing the prosthesis itself. The scan prosthesis is scanned alone, with alerted exposure parameters allowing the denture to be visualized

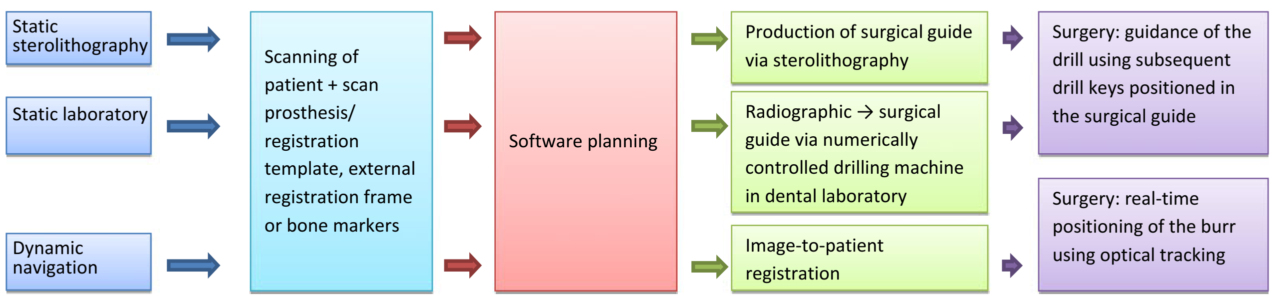

Fig. 1. Workflow of the static and dynamic guided surgery systems.

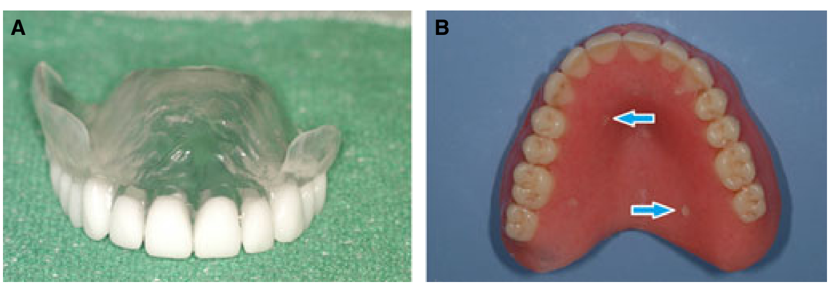

Fig. 2. (A) Radiographic guide with radiopaque teeth. (B) Radiographic guide with gutta-percha markers.

(Fig. 3). As the markers are visible in both sets of scans, they can be transformed and realigned to fuse the prosthesis within the maxillofacial structures. Besides an adequate bone model, derived from scanning the patient with the denture *in situ*, the second scan allows optimal visualization of the prosthesis. Therefore, both models can be presented separately, allowing planning on the bone (Fig. 4A) and/or the prosthetic model. Moreover, by accurate fusion, whilst maintaining excellent image quality, the planning can be carried out and controlled toward the integrated model (Fig. 4B) (27, 58).

Regardless of the method used, correct positioning of the scan prosthesis is very important. Therefore, an index is strongly recommended to position and stabilize the template in the mouth of the patient during the scanning process (Fig. 5). An optimal fit of the scan prosthesis with the patient's soft tissue is crucial. One should determine whether air is visible between the scan prosthesis and the soft tissue. This is especially important for mucosa-supported guides, in which the basis of the future surgical guide will be the same as the basis of the scan prosthesis.

The DICOM images are imported in a software program, fusion of the scan prosthesis via the markers is accomplished and the ideal surgical site and optimal implant dimensions are selected (Fig 4A,B). Once planning is complete and has been approved, the digital plan is sent to the manufacturer for production of the guide using stereolithography. Stereolithography is an additive manufacturing process using a vat of liquid photopolymer resin, curable by ultraviolet light, and an ultraviolet laser that selectively cures resin, layer by layer, into a mass representing the desired three-dimensional object. For each layer, the laser beam traces a part cross-section pattern on the surface of the liquid resin. Exposure to the ultraviolet laser cures or solidifies the pattern traced on the resin and adheres it to the layer below. After a layer is finished (complete pattern has been traced), the object is lowered by one layer of thickness and a new layer of liquid material is applied on top. The subsequent layer pattern is traced by the laser on this new surface and then is joined to the previous layer. This process is repeated until the object is complete. The supports are removed manually after the product is taken from the stereolithography machine (Fig. 6A). After this process, the sleeves for the drill keys are positioned in the guide.

When the guide is finished, it is sent to the surgeon (Fig. 6B). Depending on the system, a list with an overview of the planned implants is included, as well as a patient-specific manual. Before surgery, the surgical guide is fitted in the mouth. After applying some compression, the soft tissues underneath the guide should become pale. The correct position of the guide

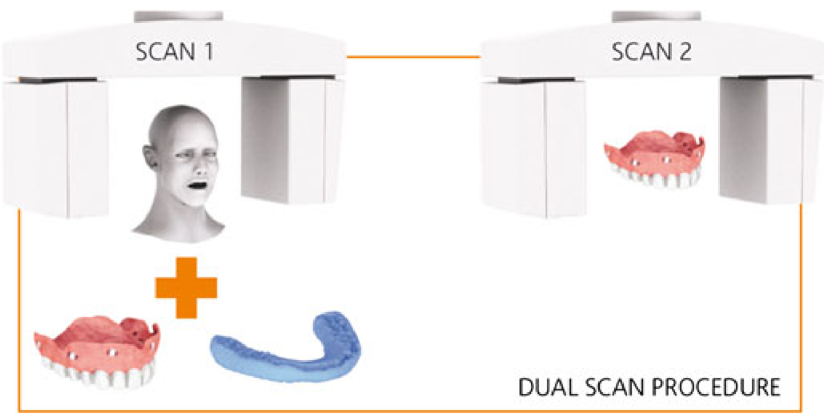

Fig. 3. Example of a dual-scan protocol.

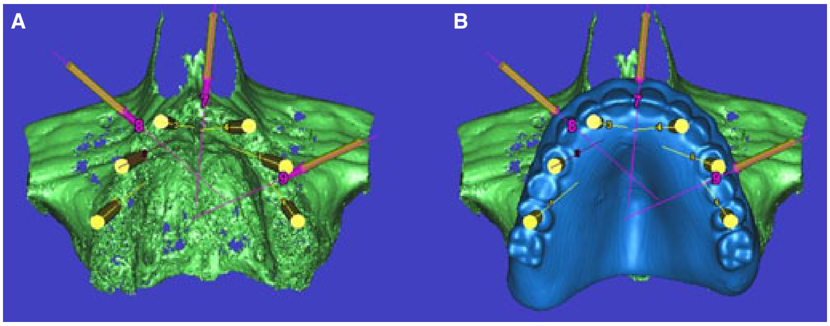

Fig. 4. (A) Example of a three-dimensional model in planning software of the bone. (B) Example of an integrated three-dimensional model of the bone and radiographic guide in the planning software.

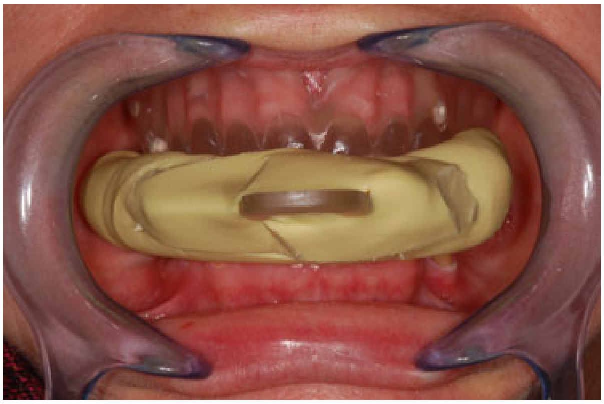

Fig. 5. Patient with radiographic guide and index in the mouth.

is guaranteed by the use of an index. This index is used to stabilize the guide and to allow fixation (Fig. 7). The drilling procedure involves the use of drill keys inserted in the sleeves within the guide, which guide the consecutive drills of different diameters in the correct position and angulation. The drill key can, for some systems, be attached on the drills (Fig. 8) or can be designed as spoons (Fig. 9). Different keys with increasing diameters are available to guide each separate drill. The drills can have a physical or a visual stop. Guidance of the implant is available depending on the system that is used. The tolerance of the drills in the key, of the key in the sleeve or of the implant driver in the sleeve might explain part of the inaccuracy inherent to guided surgery (33, 53).

The protocol can be resumed as follows:

Step 1. Scan prosthesis with radiopaque teeth (one scan) or gutta-percha markers (dual scan).

Step 2. (Cone beam) Computed tomography scan of the patient with the radiopaque guide and radiological index in the mouth. Scan of the scan prosthesis without the index (dual scan).

Step 3. Implant planning in the software.

Step 4. Production of the surgical guide using sterolithography.

Fig. 7. Fixation of the guide with screws. The guide is stabilized with the surgical index.

Step 5. Fit of the surgical guide in the mouth of the patient and preparation of the new surgical index.

Step 6. Surgery. Fixation of the guide using screws. Drilling using subsequent drill keys with increasing diameter.

Different implant companies have their own system, adapted to the specific properties of each implant system (for example: Astra™ – Facilitate® (Mölndal, Sweden); Anthogyr™ – ANTHOGYR Guiding System® (Sallanches, France); Biomet 3i™ – Navigator® (Palm Beach Gardens, FL); Camlog™ – CAMLOG® Guide System (Basel, Swiss); Dentsply Friadent™ – ExpertEase® (Mölndal, Sweden); NobelBiocare™ – NobelGuide® (Goteborg, Sweden); Straumann™ – Straumann Guided Surgery® (Basel, Swiss); and Zimmer Dental™ – Zimmer Guided Surgery Instrumentation, Warsaw , IN). Static guided surgery is difficult when interocclusal space is limited and therefore some guide systems have drill guides with lateral tube openings. These allow entry of the drills from the buccal or lingual side, thereby reducing the amount of interocclusal space required. A guide can be tooth-supported, bone-supported or mucosa-supported. The choice is made by the

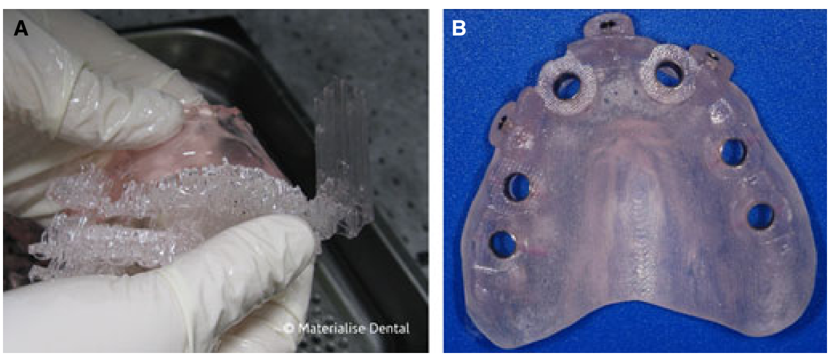

Fig. 6. (A) Finished guide with the supports, which are removed manually (Courtesy of Materialise ™, Leuven, Belgium). (B) Fully developed surgical guide, with the internal sleeves.

Fig. 8. Drill key on drill. The drill is placed with the drill key in the guide, then the drill moves through the key.

number of remaining teeth for support of the guide and on the need/wish for a flapless approach.

This technique was primarily aimed at improving diagnostic, surgical and prosthetic precision, and has achieved relative success (52, 60). However, as the current trend in implant dentistry is to focus mainly

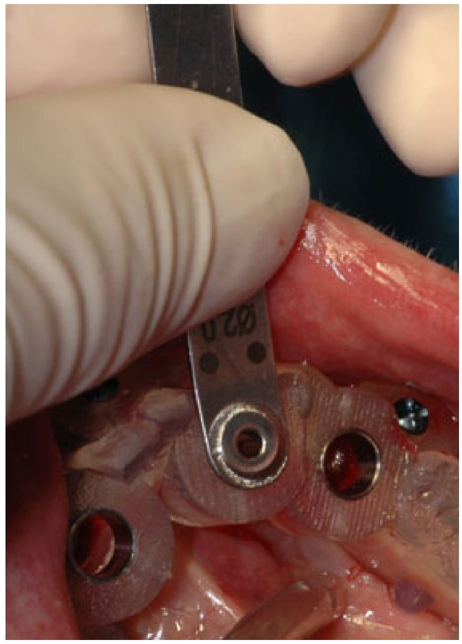

Fig. 9. The drill key placed in the sleeve of the guide, here to guide the 2.0-mm-diameter drill.

on rapid and simplified use, several systems are currently available in which computer-guided implant placement can be implemented in a complete sequence, from flapless implant placement to immediate loading with a 'prefabricated' (Fig. 10A–D) fixed prosthesis (18, 54, 56, 57).

Laboratory

The surgical guide can also be produced in the dental laboratory. Using a mechanical system, the scan prosthesis is transformed into a surgical guide. Fortin

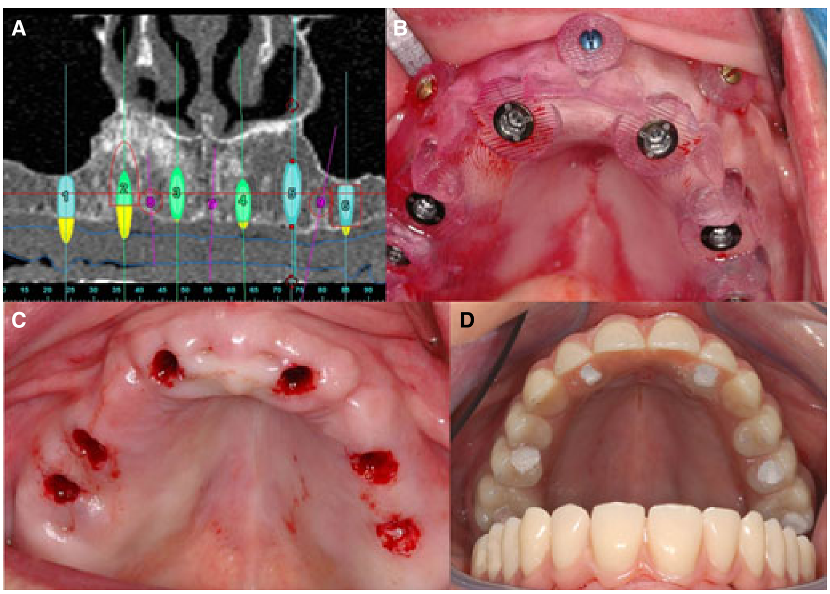

Fig. 10. Clinical case. (A) Software planning. (B) Flapless surgery (punch technique). (C) Surgical guide with implant drivers in the sleeves. (D) Immediate loading with the temporary bridge in place.

and coworkers have published several studies using this technique (15–19).

The restorative dentist makes a study prosthesis on a diagnostic cast, which represents the final restorative prosthesis (Fig. 11A). After satisfactory testing in the patient's mouth, the prosthesis is duplicated in acrylic resin and then serves as a scanning template. To be clearly visible on the (cone beam) computed tomography image, the teeth are made of radiopaque resin. A prefabricated cube, a so-called X-cube (Keystone Dental, Boston, MA), made of acrylic resin, is then attached to the scan prosthesis before computed tomography examination so that when it is in the mouth the cube is outside, in front of the lip (Fig. 11B). The X-cube will be used to transfer the planned implant positions onto the scan prosthesis via a drilling machine. The X-cube includes two tubes of titanium in very precise positions: perpendicular and uncrossed. Computed tomography scans are acquired with the template in the patient's mouth and images are directly input to an imaging personal computer. The implants are planned using custom-designed Easyguide™ software (Keystone Dental). The position is visualized on a three-dimensional view and on three planes: the axial slice and two reformatted views (Fig. 11C).

Once the final positions of implants are defined they have to be transferred to the scan prosthesis. Therefore, the scan prosthesis is firmly fixed to a drilling machine via the X-tube (Fig. 11D). The titanium tubes in the X-cube are used by the system to establish a mathematical link between the computed tomography images and the drilling machine so that the positions of the planned implants are drilled on the guide with high precision at the desired diameter (Fig. 11E). The accuracy is very high, as reported in an *in-vitro* study (17).The X-cube is then separated from the template, which becomes a conventional

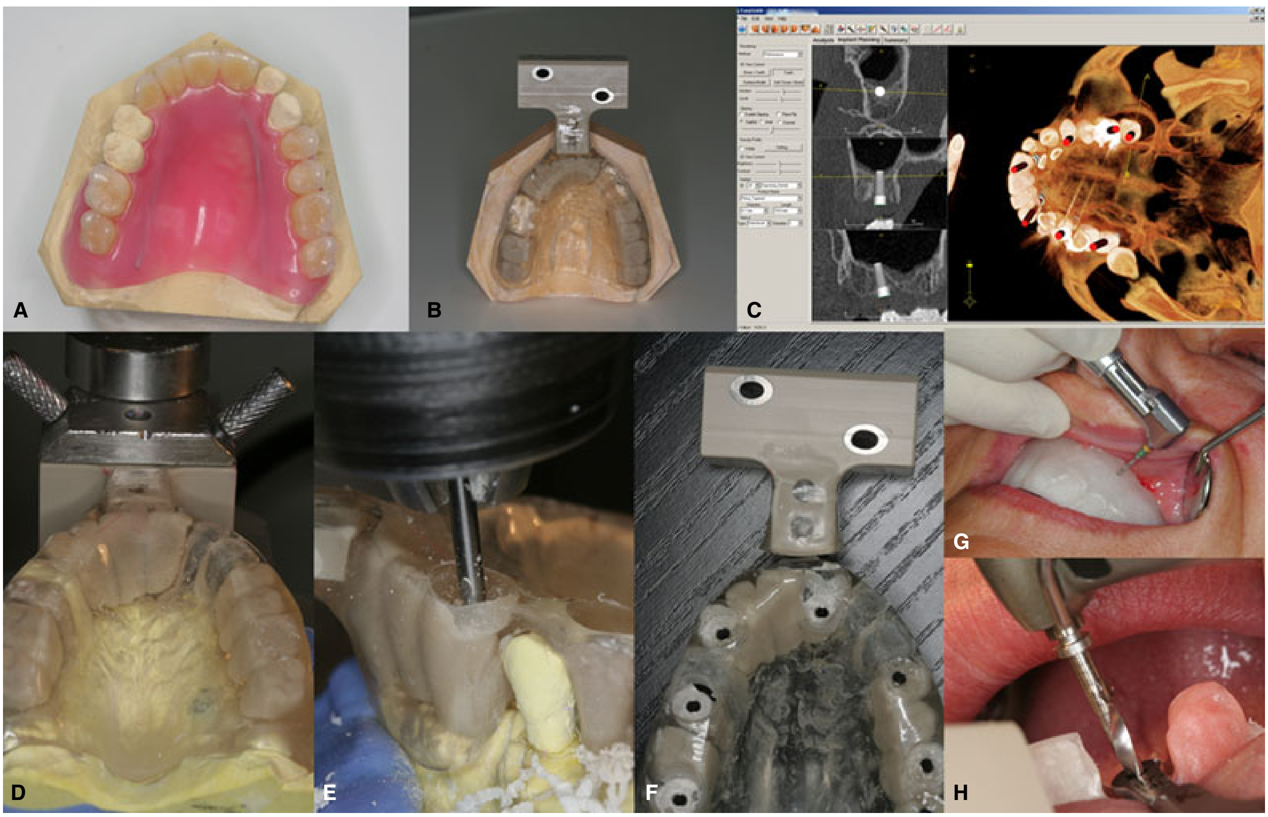

Fig. 11. (A) The study prosthesis is created on a diagnostic cast, which represents the final restorative prosthesis. (B) Duplicate of the study prosthesis in acrylic resin. A prefabricated cube is attached to the scan prosthesis so that when the prosthesis is in the mouth the cube is outside and in front of the lip. (C) Planning software with implant planning on a three-dimensional view and on three planes: axial, tangential and perpendicular. (D) The scan prosthesis is firmly attached to a drilling machine by placing the resin cube on a dedicated device and by passing two metal shafts through the two titanium tubes. (E) The scan prosthesis is drilled according to the planned implant position by a drilling machine. (F) For the surgical procedure, the cube is removed. The scan prosthesis becomes the surgical guide. (G) For completely edentulous patients, the guide is secured, under occlusal pressure, to the bone with fixation screws to avoid movement of the guide. (H) Drilling is performed using subsequent drill keys with increasing diameter.

surgical guide (Fig. 11F). Metal tubes, used as drill sleeves, are inserted through the holes, previously created by the drilling machine, in the surgical guide. Different guides with different diameters are prepared and have to be placed consecutively or one can use drill keys. In partially edentulous patients, the guide is supported by residual teeth. In full maxillary edentulous patients the guide is supported by the mucosa, especially the hard palate area (Fig 11G,H).

The protocol can be summarized as follows:

Step 1. Production of the scan prosthesis with radiopaque teeth + X-cube.

Step 2. Computed tomography scan with the scan prosthesis in the mouth of the patient.

Step 3. Planning using the software.

Step 4. Drilling the implant positions in the scan prosthesis with the numerically controlled drilling machine (fully automatic). The scan prosthesis becomes the surgical guide.

Step 5. Surgery. The guide is then easily replaced in the mouth of the patient, in the same position as during computed tomography examination.

Navigation (dynamic systems)

Surgical navigation systems are able to track a surgical tool relative to the patient, and to dynamically display the position of the surgical tool within the patient's presurgical computed tomography scan, updated in real time (13, 14, 21, 83). Thus, navigation systems allow for: localization of surgical targets and critical anatomical structures; orientation of a surgical tool within the patient's anatomy; and navigation of a surgical tool along a predefined surgical plan.

Tracking technology

Navigation systems for oral and craniomaxillofacial surgery are based on optical tracking technology (13, 83) (Fig. 12A). The technology can be compared with the guidance of cars using the global positioning system. Similarly to the car with the global positioning system device that is tracked by a satellite and guided along a predefined route on a map, the surgical drill with light emitting diodes or passive reflecting tracking elements is tracked by a stereoscopic optical camera and guided along a predefined implant plan on the computed tomography data (Fig. 12B). The accuracy of optical tracking currently lies within a range of 0.1–0.4 mm (31). In order to track the position of the moveable head of the patient, a dynamic reference frame is mounted on the patient (65, 66, 69). The dynamic reference frame can be invasively fixed to the bone or noninvasively mounted on a denture-fixed template (5, 6, 84, 85) (Fig. 12C).

Image-to-patient registration

Before navigation is possible, the physical space coordinates of the patient have to be linked to

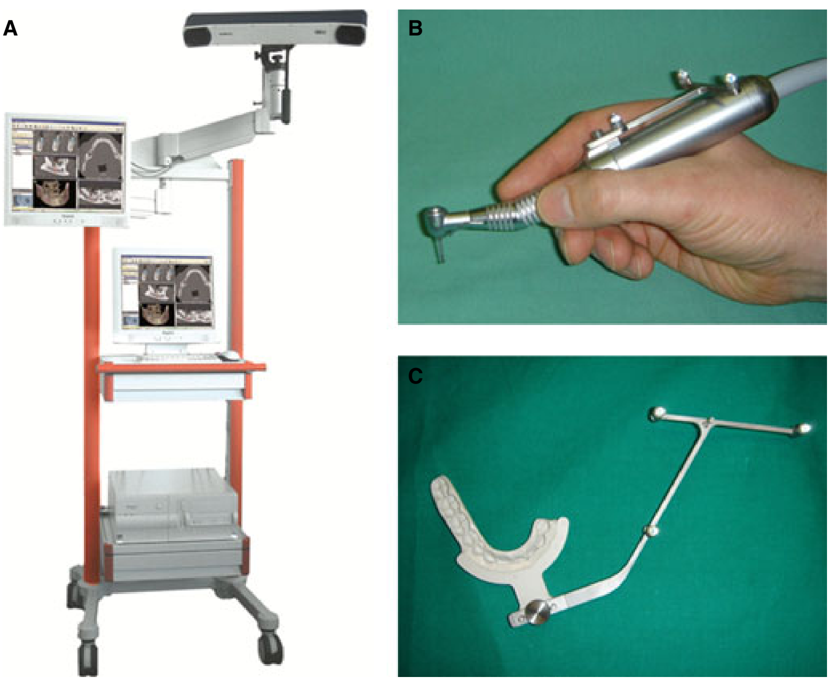

Fig. 12. Navigation system for dynamic surgical guidance. (A) Workstation, graphical user interface and stereoscopic camera (courtesy of IVS Solutions AG, Chemnitz, Germany). (B) Surgical drill with tracking elements (courtesy of RoboDent GmbH, Garching b, München, Germany). (C) Dynamic reference frame mounted to a denture-supported template (Courtesy of RoboDent GmbH, Ismaning, Germany).

the patient's image coordinates, a process called registration (10). In the paired-point technique, the coordinates of corresponding anatomical or artificial (fiducial) points are determined and the geometrical transformation that best aligns these points is computed (77, 80). The corresponding points are defined in the image data and indicated on the patient with a localizer probe of the navigation system. The most accurate method and gold standard are bone markers (e.g. microscrews), which are invasively anchored to the patient's alveolar process or frontal bone (64, 87) (Fig. 13A). These markers are invasive, need additional surgery, may infect and may cause patient discomfort, and therefore should not stay in place for an extended period of time (38). Therefore, noninvasive techniques have been explored (13). Denture-fixed radiographic scan templates may be provided with fiducial markers to serve as registration templates (11, 12). Alternatively, external registration frames (jaw-surrounding frames with fiducials) may be mounted to a scan prosthesis or a vacuum mouthpiece (1, 2, 72, 78, 79) (Fig. 13B).

Under ideal conditions, registration templates or external registration frames may provide registration accuracy similar to that for bone markers, with mean target registration errors of 0.93–0.94 mm for all three methods (82). However, registration templates require a repositioning procedure and thus may become lost or are misfitted at the time of repositioning (71, 75). In edentulous patients, the resilience of the oral mucosa precludes stable and invariant positioning of registration templates or external registration frames (75). The problem may be successfully solved by securing the template to the underlying bone (e.g. via a fixed-reference system, provided by three miniscrews with adapter spheres) (25, 73, 81).

Surgical navigation

After registration, the navigation system is ready for surgical use. The tracked surgical drill and the dynamic reference frame have to be continuously recorded by the stereoscopic camera (Fig. 14A). As visualized on the computer screen or head-mounted devices, special guidance views help to find the location of the planned implant and to follow the implant path into the bone (42) (Fig. 14B).The navigation software indicates the accuracy of the drill's position and angulations but the actual drilling still relies on the manual skills of the surgeon (75) (Fig. 14C).

The protocol can be outlined as follows:

Step 1. Scanning of the patient and the scan prosthesis/registration template, external registration frame or bone markers.

Step 2. Software planning of the implant position.

Step 3. Image-to-patient registration via registration templates, external registration frames or bone markers.

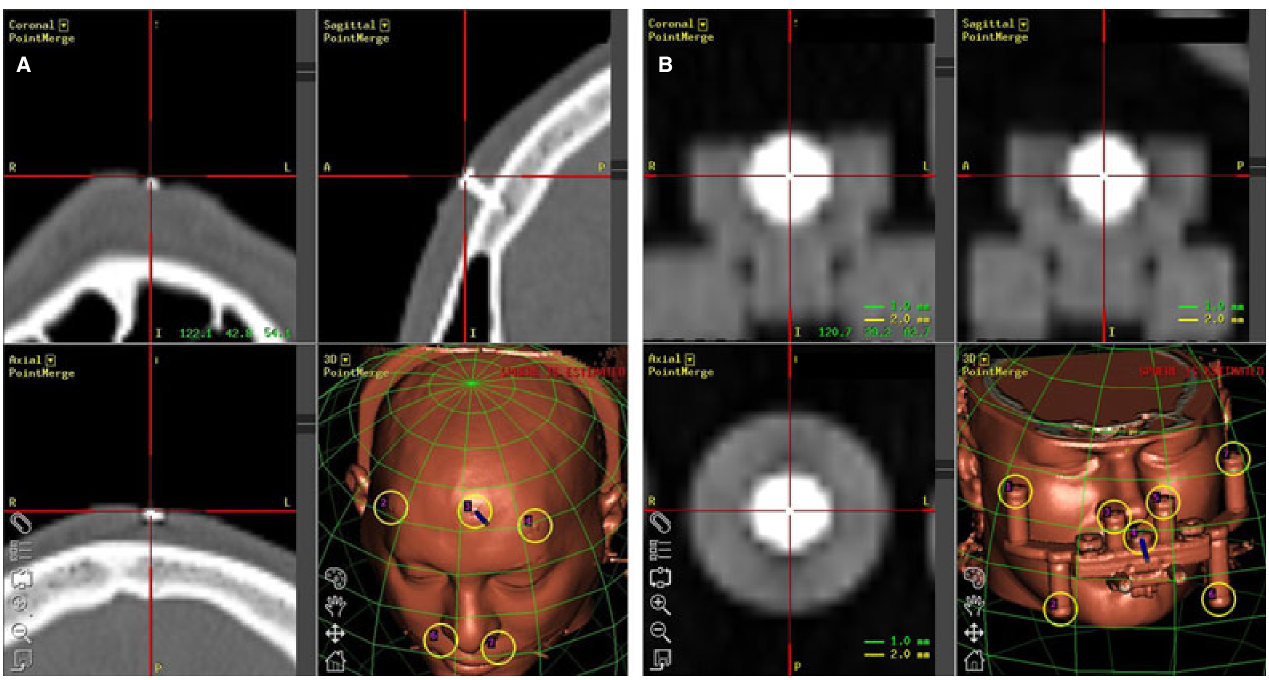

Fig. 13. Image-to-patient registration (marker definition in the image data). (A) Bone marker registration. (B) External registration frame.

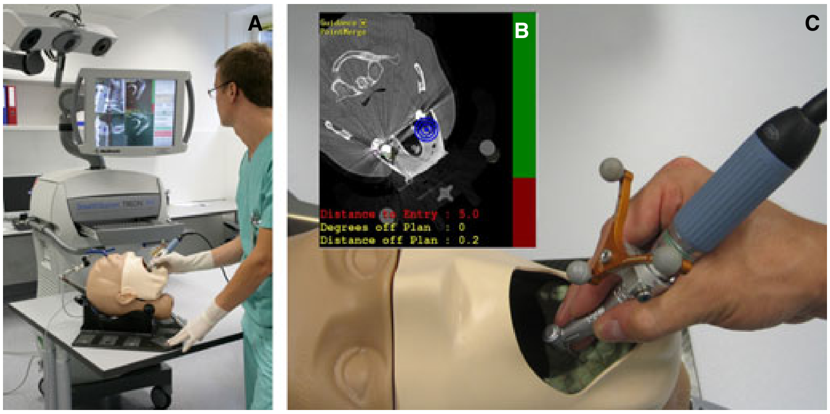

Fig. 14. Dynamic guidance. (A) Simulated implant surgery in a dental dummy. For guidance, the surgeon has to look at the navigation screen. (B) Guidance view indicating location, angulations and drilling depth. (C) Hand-moved dynamically tracked surgical drill.

Step 4. Surgery: navigation of the drill along the predefined surgical plan.

Surgical navigation allows a highly significant improvement in drilling accuracy compared with unguided manual implantation (4, 24, 34). When comparing computer-guided stereolithographic surgical templates with two surgical navigation systems, no statistically significant differences were found (45). In a prospective randomized clinical comparison of two navigation systems, mean lateral errors of 0.7–0.8 mm (maximum: 1.6–2 mm) for the implant shoulder and 1.0–1.2 mm (maximum: 2.4–3.4 mm) for the implant apex were reported (9). Successful clinical applications for oral implant surgery in partially and fully edentulous patients, flapless approaches, difficult anatomic situations and after tumor surgery have been reported (23, 51, 86).

In addition to oral implant surgery, dynamic guidance has proven to be a valuable tool in various surgical procedures, such as zygoma implant surgery (67, 68, 70), removal of tumors and foreign bodies (9, 22, 43, 49), orthognathic and reconstructive surgery (33, 39–41, 44, 46), temporomandibular joint surgery (13, 32, 47), skull base surgery (7, 8) and for education and training purposes (76).

Surgical template fabrication using navigation systems

Surgical navigation systems may also be used for fabrication of surgical templates (78). The navigation procedure is performed on the patient's registered dental stone cast in the laboratory, rather than on the patient (78, 79) (Fig. 15A). The dynamic reference frame can be easily mounted to the base plate of the laboratory set-up (Fig. 15B). A scan prosthesis may not be necessary because the wax-up can be indicated with the navigation probe on the dental stone cast. Unlike dynamic guidance of the tracked drill, a stereotactic targeting device is used (Fig. 15C). The stereotactic targeting device is a tracked adjustable mechanical arm with 6 degrees of freedom, which is aligned with the planned trajectory and allows for rigid drill guidance using an optimal technique (74, 80).

To produce a surgical guide, the dental stone cast is drilled using the stereotactic targeting device (Fig. 16A). Thereafter, metal rods are inserted into the stereotactic drill holes and used to position the surgical bur tubes. The bur tubes are fixed into a resin template in a single session in the dental laboratory. Alternatively, a surgical bur tube may be positioned on the dental stone casts by a metal rod advanced through the stereotactic targeting device and polymerized into prefabricated template using an ultraviolet light-curing resin (79) (Fig. 16B). Preclinical results of the surgical templates on dental stone casts of patients showed mean lateral errors of 0.6 ± 0.4 mm (maximum = 1.4 mm) at the implant shoulder and 0.7 ± 0.4 mm (maximum = 1.4 mm) at the

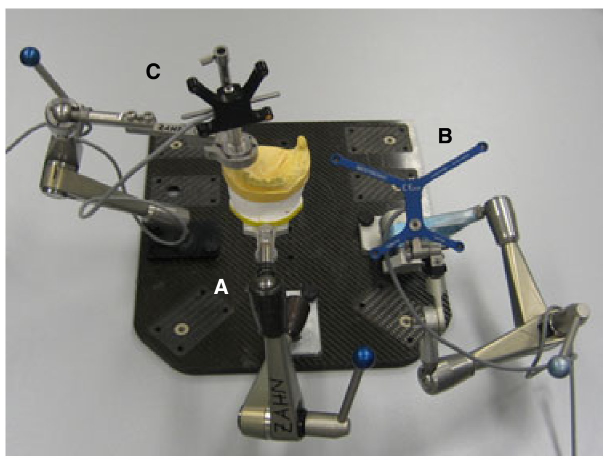

Fig. 15. Stereotactic guidance for surgical template production. (A) Dental stone cast. (B) Dynamic reference frame. (C) Stereotactic targeting device for navigated trajectory alignment.

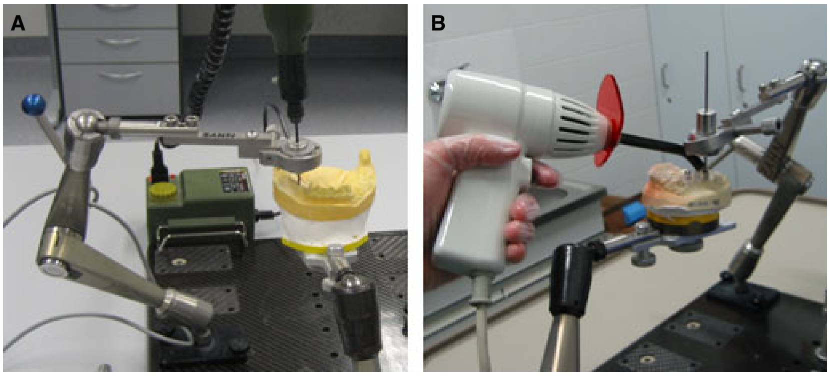

Fig. 16. Surgical template production. (A) Method 1: the dental stone cast of the patient is drilled via a stereotactic targeting device to support metal rods and bur sleeves for surgical template fabrication. (B) Method 2: the stereotactic targeting device is used to support a bur sleeve that is polymerized into a prefabricated surgical template.

implant apex and with angular errors of 1.7 ± 0.6° (maximum = 2.8°) (78). In fully edentulous patients, flapless surgery using similar surgical templates that are mounted via three fixed reference points may provide similar accuracy as reported for tooth-supported surgical templates or surgical navigation (73). In human cadavers, oral implants were placed with mean lateral errors of 0.7 ± 0.5 mm (maximum = 2.0 mm) at the implant shoulder and 0.9 ± 0.7 mm (maximum = 3.1 mm) at the implant apex and with angular errors of 2.8 ± 2.2° (maximum = 9.2°) (81). In contrast to dynamic guidance, the 'static' guidance via surgical templates does not allow changes to be made to the surgical plan at the time of surgery. However, the templates' bur sleeves permit rigidly guided and highly controllable drillings, which may be an advantage in areas of irregular bone. Furthermore, the intraoperative set-up of a navigation system, and the time constraints and potential inconvenience of intraoperative registration and tracking, are not required.

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Abstract

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Abstract

For computer-guided surgery a static surgical guide is used that transfers the virtual implant position from computerized tomographic data to the surgical site. These guides are produced by computer-aided design/computer-assisted manufacture technology, such as stereolithography, or manually in a dental laboratory (using mechanical positioning devices or drilling machines). With computer-navigated surgery the position of the instruments in the surgical area is constantly displayed on a screen with a three-dimensional image of the patient. In this way, the system allows real-time transfer of the preoperative planning and visual feedback on the screen. A workflow of the different systems is presented in this review.