An Open System Approach for Surgical Guide Production

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Purpose: Surgical guides for oral implantology were made with a new open system independent of implant planning software based on a universal computed tomography/cone beam computed tomography (CBCT) scan plate for fiducial markers.

Materials & Methods: For this in vitro study, CBCT scans were taken of 18 models based on a universal computed tomography/CBCT scan plate (Bego Medical, Bremen, Germany) for fiducial markers. The models were made from radiopaque composite with several integrated radiopaque gutta-percha points used as a reference. The coDiagnostiX (Institut Straumann, Basel, Switzerland) and implant 3D (med3D, Heidelberg, Germany) software programs were used for virtual implant planning. Coupling devices on the scan plate allowed for the precise connection to a special transfer plate (Bego Medical), which transfers the implant position to the drill guide. The horizontal distance of the final implant position to the gutta-percha markers was compared with the implant planning values.

Results: Planning of 18 implants was performed with the Institut Straumann system and 18 with the med3D system. The horizontal deviation of the final implant placement compared with the implant planning made with the med3D system showed a mean error of 0.33 mm for implants 1 and 2. The difference between the CBCT measurements of the Institut Straumann models was larger than that of the med3D measurements. The mean error for implant 1 was 0.65 mm and 1.13 mm for implant 2.

Conclusion: The reduction in the dental laboratory costs, the freedom to use different implant planning software programs, and the easy handling might facilitate the distribution of guided surgery and provide significant benefits for the clinician and the dental laboratory.
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Computerized implant planning based on 3-dimensional (3D) tomographic data (computed tomography [CT] or cone beam computed tomography [CBCT]) followed by image-guided surgery has recently been introduced to improve the accuracy of prosthodontic-driven implant positioning, thus minimizing the risk of damage to anatomic structures and allowing the full utilization of available bone for maximum implant stability.[1,2] After CT-based evaluation of an implant site,[3] planning of dental implants is performed virtually on the computer screen. The virtual treatment planning can then be transferred to the patient through insertion of implants by use of a surgical template,[4] computer-assisted navigation,[5] or a combination of both methods.[6] Guided surgery with drill guides has been reported to increase the precision of implant placement and is suitable to transfer 3D implant planning to patients.[7-9]

This report discusses the use of surgical guides in oral implantology made with a new open system approach based on a universal CT/CBCT scan plate for fiducial markers. Two different guided surgery systems, coDiagnostiX (Institut Straumann, Basel, Switzerland) and implant 3D (med3D, Heidelberg, Germany), were used for virtual implant planning. The implant position was then not transferred to the drill guide with the Institut Straumann or med3D systems; instead, it was transferred with the open Bego Guide system (Bego Medical, Bremen, Germany). The final drill guide was still produced in the dental laboratory. The research purpose of this study

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was to evaluate the use of a universal CBCT scan plate that works independent of an implant planning software program.

Materials and Methods

For this in vitro study, CBCT scans of 18 models were performed with a Planmeca ProMax 3D system (Planmeca Oy, Helsinki, Finland). The implants were placed in the left or right maxilla in the premolar and first molar regions. To avoid processing artifacts, the models were made from radiopaque composite without any metallic components. To be able to compare the implant planning with the final drilled position, a radiopaque gutta-percha point was inserted as a reference in the canine and second molar regions on each side (Fig 1).

From these models, scan prostheses were produced. On top of these scan prostheses, special universal scan plates (Bego Medical) were glued. This prefabricated scan plate contained integrated fiducial markers for most popular implant planning systems. Coupling devices on the scan plate allow for the precise connection to a special transfer plate (Bego Medical) (Fig 2).

Metal-based Institut Straumann markers were placed according to the manufacturer's protocol, and a CBCT scan of the 9 models was performed. The brick necessary for the med3D system was made out of radiopaque composite as well, because a regular Lego Brick (Lego, Grasbrunn, Germany) could not be accurately detected on the Planmeca CBCT scan (Fig 3).

Nine models were scanned by use of the med3D fiducial markers. DICOM (Digital Imaging and Communications in Medicine) data sets were used for implant planning purposes in the Institut Straumann and med3D software programs. The registration procedure was based on the software-specific reference markers. The axes of the 2 implants were planned exactly parallel to the gutta-percha markers placed in the canine regions. The implant planning data were transferred to Bego Medical. On the basis of the implant position, a special transfer plate with integrated sleeves was produced. The transfer plate was sent to the dental laboratory for attachment to the scan plate. The dental technician then used a special drill to transfer the planned implant positions through the sleeves in the transfer plate into the scan prostheses (Fig 4).

After removal of the transfer plate, as well as the partial or complete removal of the scan plate, guide sleeves were integrated into the scan prostheses. The scan prostheses were then transformed into a drill

FIGURE 2. Prefabricated scan plate glued to scan prostheses.

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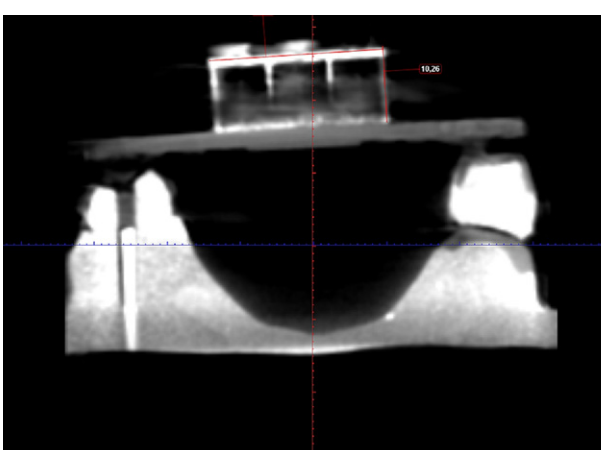

FIGURE 1. Radiopaque gutta-percha point inserted as reference in model.

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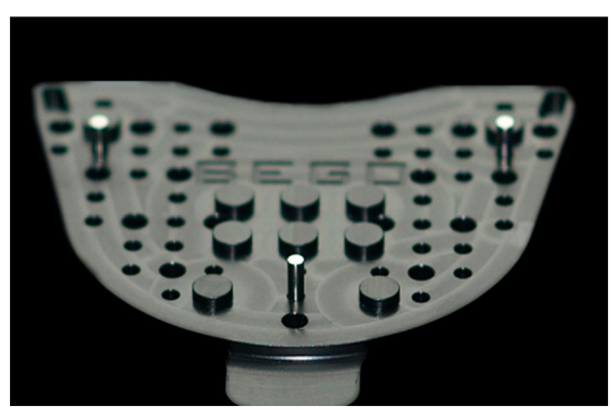

FIGURE 3. Scan plate with Institut Straumann reference marker integrated.

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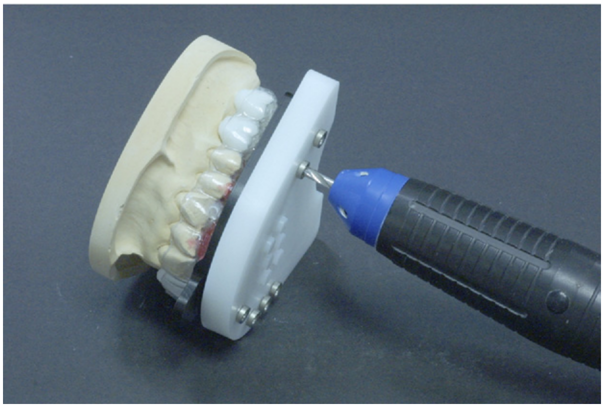

FIGURE 4. Scan plate with attached transfer plate.

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guide that was used to drill holes into the models according to the implant planning (Figs 5, 6).

MEASUREMENT OF DISTANCE

During the CBCT scans, all the models with the integrated gutta-percha markers and the system-specific fiducial markers were positioned in the same way to obtain comparable images of the region of interest. By use of cross-sectional and axial views, as well as 3D re-formations of the data, the radiopaque gutta-percha markers were easily identified. The measurement tool of the Planmeca software was used to make measurements on the CBCT slices by using a computer mouse to position the measurement tool cursor on the markers of interest. The planned implant positions were exactly parallel to the gutta-percha markers. The distances were then calculated, displayed, and recorded. The distance of the final implant osteotomy in the models, related to the gutta-percha markers, was compared with the implant planning values. The horizontal deviation of the coronal and apical implant positions was then measured (Fig 7).

FIGURE 5. Removal of attached scan and transfer plate.

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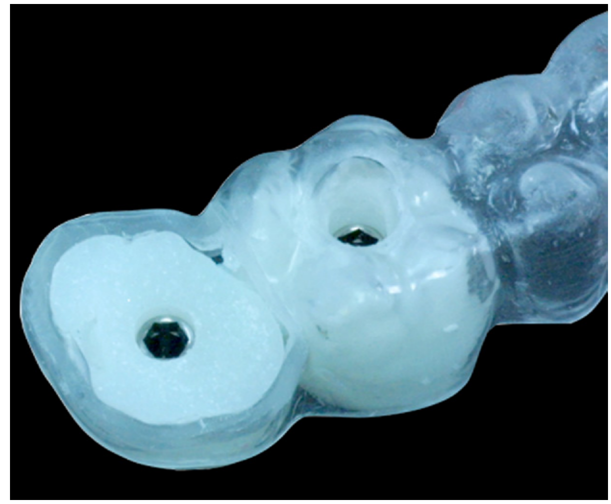

FIGURE 6. Scan prostheses transformed into drill guide.

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Results

Thirty-six implants were virtually planned based on the CBCT data acquired with the universal scan plate.

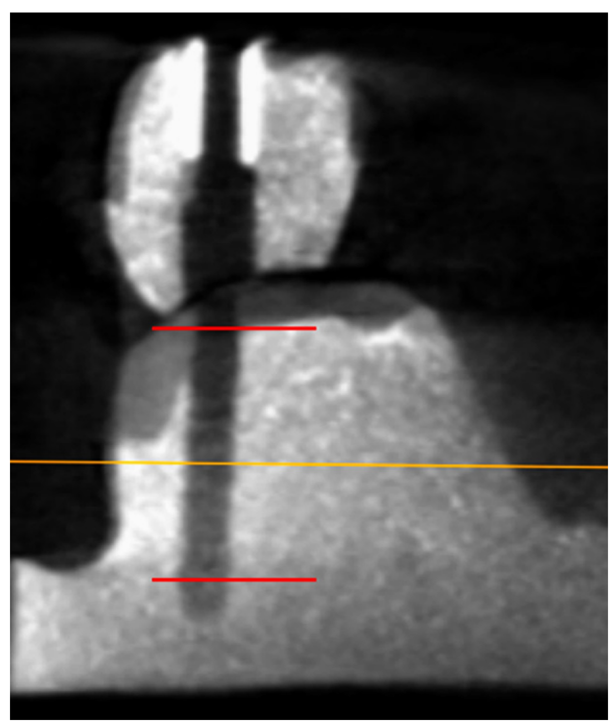

FIGURE 7. Implant osteotomy in model.

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FIGURE 8. Distance measurement between final implant osteotomy and reference marker displayed on CBCT scan.

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Planning of 18 implants was performed with the Institut Straumann system and 18 with the med3D system. Finally, the implant planning was transferred to the models with fabricated drill guides. Each implant had 2 measurement points to calculate the horizontal deviations.

The horizontal deviation of the final implant osteotomy compared with the implant planning made with the med3D system showed a mean error of 0.33 mm for implants 1 and 2. Measurement error was found to range from 0.07 to 0.79 mm on the images produced by CBCT.

The difference between the CBCT measurements of the Institut Straumann models was larger than the difference between the med3D measurements. In comparison, the CBCT data of the Institut Straumann models showed differences in the horizontal implant deviation from 0.12 to 2.78 mm. The mean error was 0.65 mm for implant 1 and 1.13 mm for implant 2 (Fig 8).

Discussion

The results support the hypothesis that it is possible to work with an open drill guide system, based on a universal scan plate, that is independent of an implant planning software program and a CBCT scanner. The guide is used to achieve an accurate transfer of the implant position from virtual reality to physical reality comparable with what is reported for other implant procedures for the same indication. It should be noted that for both test groups, the exact same radiographic and planning protocol, implant system, instrumentation and drilling protocol, and processes for the fabrication of the final drill guide were used in this study. The only difference was the implant planning software and the related radiopaque reference markers.

Both surgical templates were sufficiently clinically accurate in transferring the planned implant positions to the surgical field. CBCT-guided surgery with drill guides is known to enhance safety in dental implant placement compared with the "freehand" technique[10,11] while being compatible with all aspects of implant surgery including flapless techniques.[6] At this time, no CBCT-guided drill guide technology is available with absolute precision. All articles written on surgical guides show deviations between virtual planning and actually obtained implant positions in all dimensions.[12] In our series we recorded a mean horizontal deviation of 0.33 mm for the med3D group and between 0.65 and 1.13 mm for the Institut Straumann group. This is comparable to other reports on immediate loading of dental implants. Komiyama et al[10] reported positional deviations of implant replicas between preoperative and postoperative plaster models both at the coronal implant hex and at the apex. The geometric mean of the deviation at the apex was 0.59 mm in the maxilla and 0.4 mm in the mandible. At the hex, it was 0.59 mm in the maxilla and 0.39 mm in the mandible. Statistically significant differences were observed between the implant position in the preoperative plaster models and the implant position in the postoperative plaster models. Van Assche et al[13] used CBCT data to produce accurate implant planning with a transfer to surgery by means of stereolithographic drill guides. Preoperative CBCT images were subsequently matched with postoperative images to calculate the deviation between planned and placed implants. The placed implants showed a mean linear deviation of 1.1 mm (SD, 0.7 mm; range, 0.3-2.3 mm) at the hex and 2.0 mm (SD, 0.7 mm; range, 0.7-2.4 mm) at the tip. The results are also comparable to different types of guide systems using optical tracking technology. A study from Wagner et al[11] showed a mean deviation of 1.1 mm (range, 0-3.5 mm).

The Institut Straumann coDiagnostiX is a system designed for the planning and placement of implants fully guided to yield accurate position, depth, and angulation with immediate loading of implants if desired. The med3D system and coDiagnostiX are designed as software systems for use with all major implant systems. This feature increases their functionality, but at the same time, it is a limitation for med3D users because this system is not perfectly adapted to 1 implant system. The coDiagnostiX system is nicely adapted to the Institut Straumann implant system. Other non-stereolithographic drill guide technologies are available for the fabrication of surgical guides as well (eg, IDent [IDent Imaging, Foster City, CA] and EZ Guide [Keystone Dental, Burlington, MA]). These technologies also fabricate a surgical guide by milling the radiographic prosthesis according to a digital CT/CBCT-based treatment plan.

Drill guide technologies available today do have some limitations. Clinicians should be aware of the inherent additional costs involved in the use of these proprietary software programs and drill guide processing technologies. These costs limit the utilization of these technologies. CBCT technology helps us to determine the proximity of vital structures at the site of the planned implants, the amount of available bone in an area, and the potential need for bone augmentation and grafting procedures.[14] However, only a cost-effective and accurate drill guide system with advanced handling will finally transfer these advantages to the clinical site. Many dental laboratories have only 1 implant planning system with which they work. Necessary dental laboratory software and hardware can be very expensive. Most dental laboratories cannot work with clinicians who use different implant planning software programs. Therefore an open drill guide system that is independent of the implant planning software program that is used makes sense. The clinician can continue using his or her preferred software regardless of which systems are used by the dental laboratory. Additional expenses for software and hardware are eliminated. The use of prefabricated scan plates allows for reasonable pricing along with high accuracy, easy handling in the dental laboratory, and more flexibility for the dentist and dental technician.

The data transfer can be achieved by e-mail because the necessary file size needed to produce a transfer plate based on the scan prostheses is extremely small. Complex file transfers or the more time-consuming task of physically sending cast models is not necessary. Because the workflow in the dental laboratory is very simple and efficient, the universal scan plate can be transformed into a drill guide within a few minutes.

The differences in the 2 test groups were rather large. Because the only difference was the implant planning system, the error found can be reduced to system-specific characteristics. The detection of the Institut Straumann metal reference markers was clearly not as precise as the radiopaque brick detection of the med3D system. The brick was made with radiopaque composite especially made for CBCT scanning. This is an advantage of the med3D system, which enhanced the accurate registration procedure of the system and, in the end, resulted in more accurate implant positions.

It is well known that there are questions as to the resolution and accuracy of specific CBCT machines related to the "gold standard" of medical-grade CT scanners.[13] This may be a problem for all implant planning systems using geometric reference markers, because the CBCT data that are used to plan implant positions are ultimately incorporated into the surgical drilling guide that is fabricated from those data and that plan. This problem will be addressed in a separate article.

In this study, only drill guide systems produced in dental laboratories were used. The other common technology used is the production of a stereolithographic surgical guide or model, whose manufacturing technology involves the reproduction of the digitally planned dimensions of the surgical guide or model by selectively solidifying an ultraviolet-sensitive liquid resin by use of a laser beam. Stereolithographic materials have inherent potential problems in their fabrication that can lead to light sensitivity and expansion and/or shrinkage of the material over time. However, according to D'Haese et al,[15] it is unlikely that the production process of the guide has a major impact on the total accuracy of a mucosa-supported stereolithographic guide. Sterilization and handling of stereolithographic materials also can present problems. High-temperature autoclaves will distort the material. There is sterilizable composite material available for the production of drill guides made in the dental laboratory.

Although the results of this in vitro study show excellent results, it is important to emphasize that the clinical outcomes may be dependent on good patient selection, pretreatment planning, and diagnostic procedures.

The in vitro data from this study indicate that a new open drill guide system, independent from the interactive planning software and CBCT technology used, provides significant benefits for the clinician and the dental laboratory. This technology seems to provide clinicians with a prosthetic-based surgical technique that results in efficient, highly predictable, and comfortable patient treatment. The reduction in the dental laboratory costs and the easy handling might facilitate the utilization of guided surgery. Proper case selection and attention to guided surgery principles are still extremely important and will increase case success.

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