Accuracy of a Laboratory-based Computer Implant Guiding System

Joseph Nissan, Eitan Barnea, Ido Alt, Roni Kolerman

Department of Oral Rehabilitation, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel-Aviv University Tel-Aviv, Israel

Private practice, Tel-Aviv, Israel

Department of Periodontology, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel-Aviv University Tel-Aviv, Israel

Correspondence: Joseph Nissan, Department of Oral Rehabilitation, School of Dental Medicine, Tel-Aviv University, Tel-Aviv Israel, Fax: +972-3-5357594, e-mail: nissandr@post.tau.ac.il

Abstract

Purpose: Computer guided implant placement is a growing treatment modality in partially and totally edentulous patients, whereas data about the accuracy of some systems for computed guided surgery is limited. The purpose of this study was to evaluate the accuracy of a laboratory computer guided system.

Materials and Methods: A laboratory-based computer guiding system (M Guide, MIS technologies, Shlomi, Israel) was used to place implants in a fresh sheep mandible. A second CT scan was taken after placing the implants. The drill plan figures of the planned implants were positioned using assigned software (Med3D, Heidelberg, Germany) on the second CT scan to compare the implants position to the initial planning. Values representing the implant locations of the original drill plan were compared to that of the placed implants using the SPSS software.

Results: Six measurements (3 vertical, 3 horizontal) were made on each implant to assess the deviation from the initial implant planning. A repeated measurement analysis of variance was performed comparing the location of measurement (center, abutment, apex) and type of deviation (vertical vs horizontal). The vertical deviation (mean: –0.168) was significantly smaller than the horizontal deviation (mean: 1.148).

Conclusion: The laboratory computer-based guiding system may be a viable treatment concept for placing implants.

Keywords: Laboratory computer-based guiding system, accuracy of implant placement, computerized drill plan.

INTRODUCTION

The use of dental implants is considered a predictable procedure with high survival rates. The protocol for a successful implant is one that demonstrates osseointegration, as well as optimal position of the implant for the fabrication of an esthetic and functional restoration. Advanced planning for future definitive rehabilitation has an impact on esthetics and biomechanics and can actually determine whether the planned prosthesis can be fabricated. Early knowledge and planning of the patient’s anatomy and implants location, diameter, length, and angulations can help avoid iatrogenic damage and has a potential to minimize treatment time and patient discomfort.

Computer-based guiding systems for dental implant placement intend to provide safe, fast, minimally invasive surgery by integrating data of future rehabilitation and the patient’s anatomy. Generally, these systems can be divided to navigators and surgical guides. The surgical guides systems can be further divided to stereolithographic and laboratory-based. In the laboratory-based systems, the surgical guide is made by the laboratory from acrylic. Initially, it is used for imaging and then serves as a surgical guide by the aid of a positioning device.

The accuracy of the navigators and stereolithographic guide systems has been investigated and was found superior to conventional surgery. However, deviations were found, mostly in the lateral aspect of the implant apex for the stereolithographic guides systems and vertical aspect for navigators. Little information exists regarding the accuracy of the laboratory-based systems. The purpose of this study was to evaluate the accuracy of a laboratory-based guide system.
MATERIALS AND METHODS

The study used a fresh sheep’s mandible in which space of approximately 30 mm exists between the anterior and posterior teeth, presenting virtually a natural edentulous ridge. Tissues covering the mandibular bone were carefully removed, and impression of the teeth and the edentulous ridge between the anterior and posterior teeth was taken with irreversible hydrocolloid (Kromopan, Lascod Laboratories, Firenze, Italy). Working model was fabricated using Dental stone (Quickstone, WhipMix, Louisville, KY, USA). A “Roentgen” guide was made from acrylic resin (Keystone Industries, Cherry Hill, NJ, USA) mixed with barium sulfate (E-Z-EM, Westbury, NY, USA) in a ratio of 1:5 (Fig. 1). A radiopaque Lego brick (Lego Company, Billund, Denmark) was attached to the top of the guide. This Lego brick serves for 3-dimensional calibration between the software and CT, and for relocation of the guide to a positioning device (Hexapod, Schick Dental Gmbh, Schemmerhofen, Germany) which enables insertion of guiding tubes into the guide (Fig. 2).

A cone beam CT (I-Cat, Imaging Sciences, Hatfield, PA, USA) of the sheep’s mandible was taken with the guide affixed to the jaw and processed with 3D planning software (Med3D, Heidelberg, Germany). After determining the available bone and future location of the implants, a drill plan was processed and sent to the laboratory. In the drill plan, the exact location of each implant is represented by 12 values which calibrate the positioning device in placing 8 metal tubes 5 mm long and with diameters of 2 and 2.8 mm (for each site) into the Roentgenic guide (Fig. 3).

Eight implants, 3.3 × 8 mm (Biocom, MIS Technologies, Shlomi, Israel), were placed in the direction and depth determined by the tubes. After placing the implants according to the drill plan a second CT scan of the sheep mandible was taken.

The drill plan figures of the planned implants were positioned using assigned software (Med3D, Heidelberg, Germany) on the second CT scan to compare the implants position to the initial planning (Fig. 4). Values representing the implant locations of the original drill plan were compared to that of the placed implants using the statistical package for social sciences (SPSS) software (Chicago, Illinois, USA).

RESULTS

Six measurements (3 vertical, 3 horizontal) were made on each implant to assess the deviation from the initial implant planning. The vertical and horizontal deviations were measured (mm) at the implant shoulder (center), 9 mm above the shoulder (abutment) and implant apex. A repeated measurement analysis of variance was performed comparing the location of measurement (abutment, shoulder, apex)
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and type of deviation (vertical vs horizontal) Table 1. The statistical analysis yielded a significant effect of the type (vertical vs horizontal) of deviation \([F(1,7) = 47.3, \ p < 0.001]\), showing that the vertical deviation (mean = – 0.168, SD = 0.17) was significantly smaller than the horizontal (mean = 1.148, SD = 0.21).

At the implant shoulder (center) the mean vertical deviation was – 0.17 mm, the mean horizontal deviation was 0.99 mm (p = 0.001). At the abutment level the mean vertical deviation was – 0.12 mm, the mean horizontal deviation was 1.04 mm (p = 0.001).

Table 1: Presents the means and SD of the deviations from planned location among the 8 implants placed

<table>
<thead>
<tr>
<th>Deviation from planned</th>
<th>Range</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center level - Vertical</td>
<td>0.04-0.83</td>
<td>– 0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Center level - Horizontal</td>
<td>0.43-1.66</td>
<td>0.99</td>
<td>0.15</td>
</tr>
<tr>
<td>Abutment level - Vertical</td>
<td>0.04-0.86</td>
<td>– 0.12</td>
<td>0.19</td>
</tr>
<tr>
<td>Abutment level - Horizontal</td>
<td>0.66-1.57</td>
<td>1.04</td>
<td>0.13</td>
</tr>
<tr>
<td>Apex level - Vertical</td>
<td>0.04-0.84</td>
<td>– 0.22</td>
<td>0.16</td>
</tr>
<tr>
<td>Apex level - Horizontal</td>
<td>0.13-1.93</td>
<td>1.41</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Fig. 3: Implants placement according to the metal tubes

Fig. 4: The initial drill plan was positioned on the second CT scan
At the apex level the mean vertical deviation was –0.22 mm, the mean horizontal deviation was 1.41 mm (p = 0.0002) (Graph 1).

Graph 1: Deviation from planned by location and type of deviation. The vertical bars represent range values. The p values represent the differences between vertical and horizontal deviations as assessed by Tukey HSD tests. (Type 1 = vertical, Type 2 = horizontal)

DISCUSSION

Computer-aided surgery in dentistry is used for maxillofacial surgery and implant placement. User-friendliness and cost contribute to the preferred use of computer-based surgical guides rather than navigators.

The accuracy of the system tested in the present study should be compared to the laboratory-based guide studies available in the literature, to elucidate its potential clinical use. Fortin et al. used three dry bone and one plaster jaw models to determine the accuracy of inserting a 1.8 mm drill into a 2 mm surgical guide tube. Transfer error was less than 0.2 mm for translation and less than 1.1° for rotation. These results show that this system has a high precision. However, this study assessed only the initial stage of the actual clinical work. Although, it demonstrates the accuracy of the software, the drilling machine and the interface between them, it lacks further inaccuracies resulting from further drilling up to implant insertion. The advantage of the present study is the use of a fresh bone model. Moreover, it demonstrated that most deviations from the initial planning occurred during implant placement. Another laboratory-based guide study, compared pre- and intraoperative data about implant length and diameter in 30 partially and fully edentulous patients treated with a laboratory-based guide systems. Strong agreement was found between pre- and intraoperative data for both implant dimensions. However, this study did not examine the actual differences between the implant position in the preoperative planning and following placement. In the present study, the vertical match between the planned and placed implants positions were compared at three locations (implant shoulder, abutment level and apex level). The vertical differences between the planned and placed implants positions at the implant shoulder were within 0.04-0.83 ± 0.17 mm at abutment level within 0.04-0.86 ± 0.19 mm, and at the implant apex within 0.04-0.84 ± 0.16 mm, mean = –0.168 ± 0.17. The horizontal differences between the planned and placed implants positions at the implant shoulder were within 0.43-1.66 ± 0.15 mm, at the abutment level within 0.66-1.57 ± 0.13 mm, and at the implant apex within 0.13-1.93 ± 0.37 mm, mean = 1.148 ± 0.21. For all implants, there was a greater horizontal discrepancy between the planned and the actual positions at the implant apex than at the implant head.

Results from the present study cannot be compared to the other laboratory guide-based systems studies, in which the pre- and postoperative data were not numerically compared. However, results can be compared to studies using stereolithographic-based systems. Di Giacomo et al. compared differences between the location of the planned and placed implants in four patients. The guides were bone or tooth-bone supported. After implant placement, a second CT was taken, and software was used to fuse the implant images in the planning stage with the placed implant images. Differences in distance between planned and placed positions (at the implant shoulder were 1.45 mm and 2.99 mm at the apex) were higher than in the present study. Van Steenberghe et al. used bone-supported templates in two cadavers. After drilling and implant placement through the templates, a new CT scan was taken, and the planned and achieved implant locations and axes were compared. At the level of implant neck, the match was on average within 0.8 mm, and at the apex on average within 0.9 mm. Differences in distance between planned and achieved locations were most prominent in the horizontal direction of the implants (maximum 1.1 mm), similar to the present study. In another study, comparing the accuracy of surgical drilling guides by placing six zygoma implants in three formalin-fixed human cadavers, preoperative CT images were matched with postoperative ones to assess the deviation between planned and installed implants. The largest deviation was 2.7 mm, found at the exit point of one of the implants. Those results are worse than the present study.
Sarment et al \(^9\) conducted a study on five edentulous epoxy mandible models. On the right side a conventional surgical guide (control side) was used, and on the left, a stereolithographic guide (test side). Each jaw was CT scanned, and a registration method was applied to match it to the initial planning. Measurements included distances between planned implants and actual osteotomies. The average distance between the planned implant and the actual osteotomy was 1.5 mm at the entrance and 2.1 mm at the apex when the control guide was used. The same measurements were significantly reduced to 0.9 mm and 1 mm when the test guide was used. Again, the results are worse than the present study.

The present study was conducted on the fresh jaw, contrary to other studies in which dry jaws, or plastic or stone models, were used.\(^8,9,13-16,20\) Fresh bone is a more accurate model since it can be affected by factors such as implant system, size of bur steps, rotational speed, and guiding system, can influence the final implant position.\(^29,30\) Stability and precise location of the surgical guide are crucial to the accuracy of the implant position.\(^22\) Since the same guide is used for both imaging and surgery in the laboratory-based tested system, rigid fixation of the guide during roentgen examination and surgery with temporary implants could improve the accuracy and can recommended especially in extremely atrophic cases with limited bone volume.\(^31\)

In conclusion, the data regarding the accuracy of the laboratory-based guide system investigated in the present study is better or at least comparable to the data regarding available computer-based guiding systems for dental implant placement. Further research is needed in order to validate its clinical accuracy and limitations.

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**REFERENCES**


