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AN INVITRO STUDY COMPARING TWO SOFTWARE PROGRAMS USED FOR IMPLANT PLANNING AND SURGICAL GUIDE FABRICATION

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ABSTRACT

INTRODUCTION: The accuracy of surgical guides is crucial for the success of implant-supported prostheses. Minor errors in data acquisition, software planning, or fabrication can lead to significant deviations, compromising implant placement. This study evaluates how two software programs—BlueSky Bio and 3Matic—affect the accuracy of surgical guide fabrication by comparing final implant positions to planned positions.

OBJECTIVES: To determine which software enhances precision in implant placement by examining the impact of BlueSky Bio and 3Matic on surgical guide accuracy.

MATERIALS AND METHODS: In this in-vitro study, a patient with a bounded saddle edentulous area and a missing central tooth was selected, resulting in 20 surgical guides. The arch was recorded using condensation silicone, and an epoxy resin cast was created. STL files from the scanned model and DICOM files from a CBCT scan were imported into BlueSky Plan 4 and Mimics software. Surgical guides were designed to include adjacent teeth and proper seating windows, fabricated by the same operator using the same printer. Implant placement accuracy was assessed by measuring deviations between planned and actual positions.

RESULTS: In horizontal measurements at the hexagon, the BlueSky group had a mean deviation of 0.48mm (SD = 0.10mm), while the Mimics group averaged 0.73mm (SD = 0.14mm), significant at p = 0.001. For apex measurements, BlueSky averaged 0.67mm (SD = 0.19mm) compared to Mimics' 0.93mm (SD = 0.20mm), significant at p = 0.04.

CONCLUSION: Both programs produced clinically acceptable results but BlueSky's lower deviations suggest it may be the preferred clinical tool.

KEYWORDS: Dental implants, Surgical guides, Scanbodies, Software programs.

RUNNING TITLE: Comparison between two different software used for guide fabrication.

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INTRODUCTION

Dental implants have become a vital component in oral rehabilitation, boasting a success rate of 90% to 95% over the past decade (1, 2). The successful placement of implant-supported prostheses relies on the precise positioning of dental implants within the bone (3). Traditionally, this preoperative planning was conducted using 2D radiographic imaging techniques, such as panoramic and periapical radiographs (4). However, advancements in dental radiography, particularly Cone Beam Computed Tomography (CBCT), have introduced 3D imaging capabilities (5, 6). CBCT enables a detailed assessment of bone structures and the identification of anatomical features using surgical stents with radiopaque markers, enhancing the planning process for implant placement. Notably, CBCT also significantly reduces radiation exposure while focusing on constrained fields of view (7, 8).

The emergence of computer-assisted surgery has further refined the planning of implant-supported prostheses, making it more precise and predictable (9-11). This approach emphasizes a prosthetically driven concept, which involves meticulous planning of the future prosthesis to ensure optimal aesthetic and functional outcomes (12, 13). By integrating surface scans-obtained via intraoral scans or desktop impressions-with CBCT data, a comprehensive 3D virtual representation of the patient's oral structures can be created (12, 14). Specialized software allows clinicians to plan the ideal implant position within the alveolar bone, subsequently using a surgical guide to translate this planned position into the surgical environment. Consequently, the accuracy of these surgical guides is critical for the success of the implant procedure (15).

Stereo-lithographically produced surgical guides facilitate easier implant placement compared to conventional methods and contribute to shorter surgical times (16-18). Despite these advancements, concerns persist regarding the accuracy and precision of static surgical drill guides in replicating the intended implant position. Research indicates that each phase of the digital workflow-whether performed independently or in conjunction with other steps-can introduce errors, potentially leading to deviations from the planned implant placement (3). Such inaccuracies may result in complications that compromise both the surgical procedure and the final prosthetic outcome (19).

Several factors influence the accuracy of static computer-assisted implant surgery (sCAIS), including the quality of data acquired from CBCT scans, the impression materials used, the accuracy of intraoral or extraoral scans, the type of surgical guide supporting tissue, and the operator's experience (20-22).

While various software programs are now popular for planning prosthetically driven implants and fabricating surgical templates for sCAIS, there is limited research on their accuracy and their impact on final implant positioning. This in vitro study aims to investigate whether the accuracy of postoperative implant positioning is affected by different surgical templates produced using various software programs. The null hypothesis posits that the final implant position will not be influenced by the different templates fabricated with different software programs.

MATERIALS AND METHODS

The study was performed after gaining the approval of the Research Ethics Committee, Faculty of Dentistry, Alexandria University (IRB No. 001056-IORG 0008839) prior to any research-related activities.

This in-vitro comparative study involved a sample of 20 surgical guides (n=20). The minimal sample size was calculated based on a previous study aimed to assess the errors introduced during the manufacture of stereolithographic surgical guides generated from CBCT and digital scans by using a virtual implant planning software. Based on the findings of Shah et al. (2022) (23), a power of 80% (β=0.20) was used to detect a standardized effect size in accuracy (the primary outcome) of 0.638, with a significance level of 5% (α error accepted = 0.05). Consequently, the minimum required sample size was calculated to be 10 surgical guides per group, resulting in a total sample size of 20 surgical guides (24).

A patient with a bounded saddle edentulous area featuring a missing central tooth was selected for the study. The patient's arch was recorded using condensation silicone impression material, and a cast was duplicated with epoxy resin. The epoxy resin model was then scanned using an intraoral scanner (Cerec Omnicam, Sirona, Germany, software version 4.5.2) to generate standard tessellation language (STL) files, which were imported into two software programs for surgical guide fabrication. CBCT scan for the model was taken using an I-CAT Next Generation machine (Imaging Sciences International, Hatfield, PA) with the following parameters:120 Kvp, 5 mA, and 26.9 seconds at 0.25 mm voxel size.

For the surgical guide design, two software programs were utilized: Blue Sky Plan 4 (Blue Sky Bio, USA), Mimics (Materialise, Belgium). A virtual wax up central tooth was placed in the bounded saddle area in the optimal position functional and aesthetic. Custom designed implant was planned then at a standard size of 3x10mm. Fig.1&2

Surgical guides were then designed in each software program including at least four supporting teeth to ensure proper stability of the surgical guide on the epoxy model.(25)
All surgical guides were designed and printed by the same operator using the same printer Anycubic Photon Mono X 4K SLA 3D printer (Anycubic, Shenzhen, China) and the eSun Model Resin (eSun, Shenzhen, China) following the manufacturer's guidelines. Print orientation and printing layer thickness were standardized.

For image evaluation, the STL files of scanned surgical guides seated on models imported into analysis software. Virtual implants were added in relation to the scan bodies, allowing for superimposition of the planned and actual implant positions. The degree of deviation was assessed by measuring linear and angular discrepancies between the actual placements and the virtual plans. A line was drawn through the center of the apex and the center of the platform for both planned and virtual implants. Horizontal linear deviation at implant platform and apex Fig.3 were measured. Furthermore, vertical depth Fig.4 and angular deviation Fig.5 between planned and actual implants were measured.

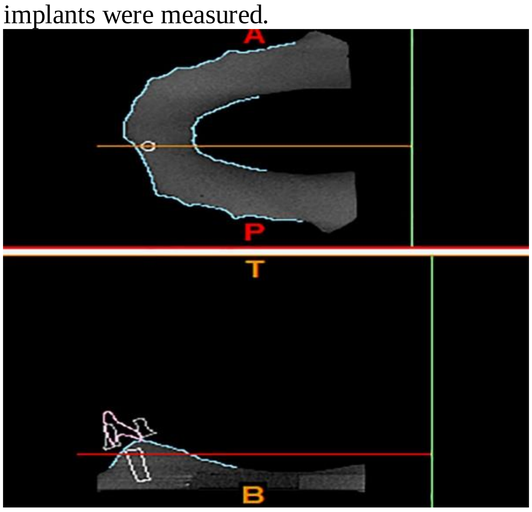

Figure 1: Axial and sagittal views showing implant planning in Mimics software.

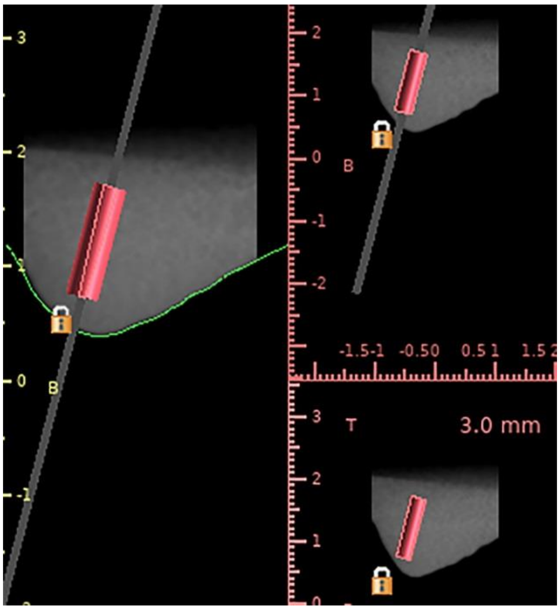

Figure 2: Cross section view showing virtual implant position in BlueSky Plan software.

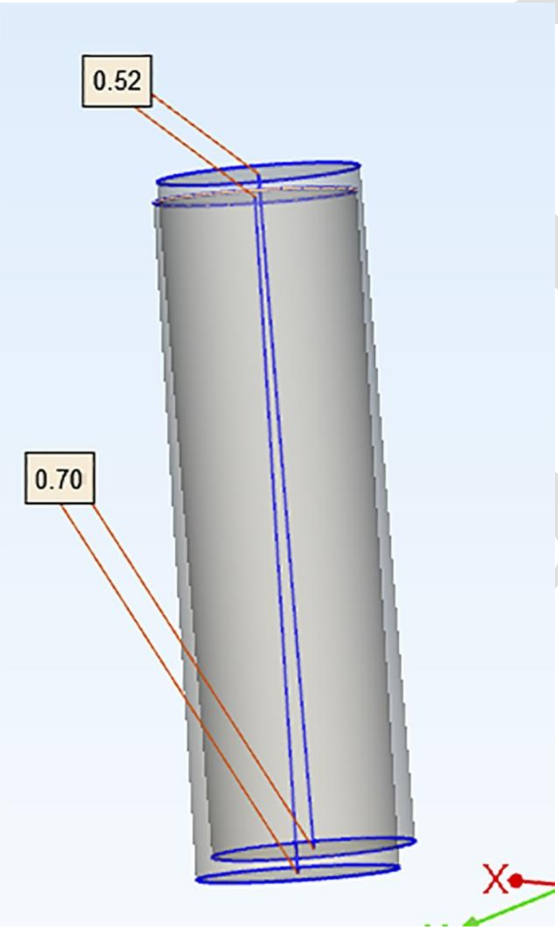

Figure 3: Horizontal deviation between virtual planned and placed implants measured at implant platform and apex.

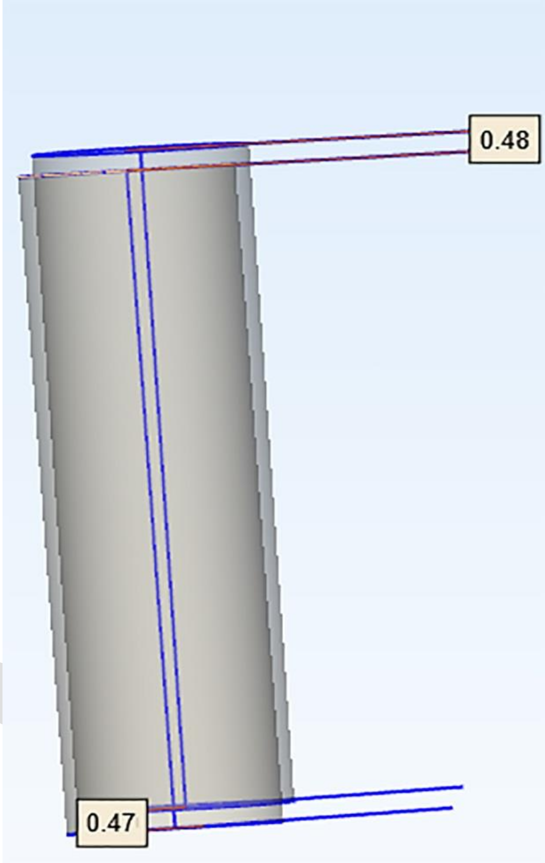

Figure 4: Vertical depth deviation measurement at implant platform and apex.

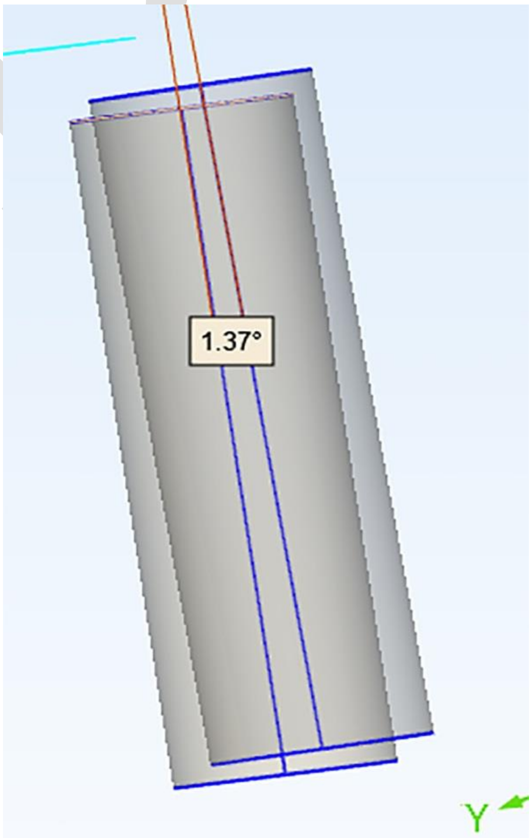

Figure 5: Angular deviation between planned and placed implants.

RESULTS

As for horizontal Measurements at the Hexagon: The Bluesky group exhibited a mean value of 0.48 mm with a standard deviation of 0.10mm, while the Mimics group had a mean of 0.73mm and a standard deviation of 0.14mm. This comparison yielded a statistically significant p-value of 0.001. For the horizontal measurement at the apex, the Bluesky group had a mean of 0.67 mm (SD = 0.19mm), compared to the Mimics group, which had a mean of 0.93mm (SD = 0.20mm). The p-value for this comparison was 0.04, suggesting a statistically significant difference. The angular measurements showed no significant difference between the two groups, with the Bluesky group averaging 1.33mm (SD = 0.51mm) and the Mimics group averaging 1.69mm (SD = 0.89mm). The p-value for this comparison was 0.76, indicating that any observed differences were not statistically significant. In terms of vertical depth at the apex, the Bluesky group had a mean of 0.56mm (SD = 0.23mm), while the Mimics group had a mean of 0.89mm (SD = 0.23mm). This comparison resulted in a p-value of 0.01, demonstrating a statistically significant difference between the two groups. Finally, for vertical depth at the hexagon, the Bluesky group recorded a mean of 0.43mm (SD = 0.10mm), whereas the Mimics group had a mean of 0.73mm (SD = 0.14mm). The p-value was less than 0.001, indicating a very strong statistically significant difference.

Table (1): Comparison of deviation between planned implant position and placed implant between the two software.

	Bluesky	**Mimics**	**P value**
Horizontal at hexagon	0.48 (0.10)	0.73 (0.14)	*0.001**
Horizontal at apex	0.67 (0.19)	0.93 (0.20	*0.04**
Angular	1.33 (0.51)	1.69 (0.89)	0.76
Vertical depth at apex	0.56 (0.23)	0.89 (0.23)	*0.01**
Vertical depth at hex	0.43 (0.10)	0.73 (0.14)	*<0.001**

DISCUSSION

The present study examines and compares two implant planning software programs: BlueSky and Mimics. BlueSky is accessible as a free download, allowing users to utilize its planning features without initial costs, with fees applying only for guide exports. In contrast, Mimics requires a substantial upfront investment to access its comprehensive functionalities. By analyzing these two options, the study aims to highlight the differences in cost-effectiveness and usability, providing insights for dental professionals in selecting the most suitable software for their practice needs.

The results of the present study highlight significant differences in implant positioning accuracy between the Bluesky and Mimics software programs, particularly in horizontal and vertical measurements. These findings are critical for clinicians aiming to optimize implant placement and enhance patient outcomes. The mean horizontal deviation at the hexagon for Bluesky was 0.48 mm (SD = 0.10), significantly lower than Mimics, which had a mean of 0.73 mm (SD = 0.14) (p = 0.001). Similarly, at the apex, Bluesky's mean deviation was 0.67 mm (SD = 0.19) compared to Mimics' 0.93 mm (SD = 0.20) (p = 0.04). Accurate horizontal positioning is essential for ensuring that the implant aligns properly with the planned prosthetic restoration (26). Previous studies showed that deviations in horizontal positioning can lead to complications such as improper occlusion and aesthetic failures (27). Horizontal linear deviation may affect the diameter of alveolar bone supporting the dental implant. The presence of inadequate buccal bone thickness around dental implant subjects the surrounding bone to dehiscence defects and subsequently recession of gingival tissue. This may lead to aesthetic and functional failures (28). Therefore, it is advisable to leave at least a 1.2 mm distance as a safe margin coronally to overcome errors resulting from horizontal coronal deviation (29). As for horizontal deviation at the apex a margin of 1.7 mm is recommended (30).

In terms of vertical depth, Bluesky group showed superior performance with a mean depth at the apex of 0.56 mm (SD = 0.23), significantly less than Mimics' group 0.89 mm (SD = 0.23) (p = 0.01). At the hexagon, Bluesky's mean was 0.43 mm (SD = 0.10), compared to 0.73 mm (SD = 0.14) for Mimics (p < 0.001).Accurate vertical positioning is crucial for achieving adequate bone support and ensuring the long-term stability of the implant (31).

A research done by de Siqueira et al has indicated that vertical discrepancies can compromise the success of the implant and the longevity of the prosthetic restoration (32). If an implant is too shallow, it may not be securely anchored, leading to mobility and potential failure (33). Furthermore, Improper depth can lead to visibility of the implant or unnatural gum recession, affecting the overall aesthetic results (34, 35). it is recommended to drill 1 mm deeper than planned to avoid such error (36). The significant differences observed in the present study suggests that Blue-sky may offer a more reliable solution for achieving optimal vertical positioning.

Interestingly The mean angular deviation for Bluesky was 1.33° (SD = 0.51), while Mimics recorded a mean of 1.69° (SD = 0.89), with no significant difference found (p = 0.76). This finding suggests that both software programs may provide comparable performance in terms of angular alignment of implants. However, maintaining proper angular orientation is still vital for the functional and aesthetic success of implant-supported restorations (37).

A systematic review conducted in 2023 indicated that a satisfactory level of accuracy in guided surgery can be attained with an angular deviation of under 8° (38). Therefore, the results of angular deviation from the present study are considered quite satisfactory. Future studies could explore the factors contributing to this lack of significant difference and whether specific clinical scenarios might favor one software over the other.

Despite the significant differences observed between the two groups, the mean range of deviations reported in this study is comparable to findings from other studies (3, 30, 37). However, our study is limited by the absence of actual clinical situation and actual placement of implants in a patient mouth which may present different results from the present study. Therefore, further studies including more clinical situations including cases with multiple teeth loss and free end saddle cases are needed.

CONCLUSION

In summary, the present study underscores the critical role of software selection in achieving accurate implant positioning. Bluesky software significantly lower horizontal and vertical deviations compared to Mimics software; therefore, it is the more preferred tool in clinical settings. As the field of implant dentistry continues to evolve, further research is needed to explore the accuracy of various software programs and their impact on clinical outcomes, ultimately guiding practitioners toward more effective and reliable implant placement strategies.

CONFLICT OF INTEREST

The authors announce that they have no conflicts of interest.

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