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**DENTAL IMPLANT PLACEMENT DEVIATION
UTILIZING PRINTED SURGICAL GUIDES:
SIMULATED USER ERROR**

Kirk C. Goebel, DDS

ABSTRACT

Background: Improper implant placement is the root cause of deleterious clinically based factors resulting in previously placed dental implants with peri-implant mucocitis, peri-implantitis, and even failure¹. Through the introduction of implant guides, fabricated by means of patient models, implant placement accuracy improved and the number of adverse outcomes decreased². The next evolution of implant guides replaced the data from the diagnostic patient models with data from the cone beam computed tomography (CBCT). Computer-based implant positioning software uses the CBCT data to virtually place a dental implant, guided by the desired restorative outcome, which is then rendered within the surgical guide. Implant placement error can still occur by improper virtual implant positioning, which is translated to the improper guide fabrication. The majority of implant placement error is still caused by the provider with improper use of a surgical guide. Objective: To evaluate the extent of possible implant placement deviation, while using a in a surgical guide, during simulated user error. This information may allow providers to incorporate a mean deviation into their implant planning, possibly reducing the number of adverse clinical outcomes.

Methods: The initial 2mm osteotomy was prepared in 50 printed models, each with a single use printed guide, and a single use 2mm twist drill. User error was simulated by incorporating a plausible directional force, perpendicular to the implant site, while drilling the initial 2mm osteotomy.

Results: The minimum and maximum directional force(oz) was 16.5 and 43.1 respectively (mean 33.7 SD 5.8). The minimum and maximum recorded angulation(degrees) was 3.17 and 14.48 respectively (mean 8.8 SD 3.1). The minimum and maximum recorded coronal deviation(millimeters) was 0.46 and 3.48 respectively (mean 1.43 SD 0.67). The minimum and maximum recorded apical deviation(millimeters) was 0.91 and 3.25 respectively (mean 1.88 SD 0.67).

Significance: Increased provider error, demonstrated with perpendicular lateral pressure during the initial 2mm osteotomy preparation, resulted in increased implant placement error. The mean plausible directional force of 33.7oz led to a mean coronal deviation of 1.43mm, which is clinically significant. This information may lead to an increase in implant placement accuracy, translating to decreased adverse clinical outcomes. Additional studies investigating restorative challenges following deviations during implant positioning appear warranted.

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Introduction

Printed stereolithographic surgical templates can contribute to improved accuracy of positioning during implant placement. Complications during surgical implant placement to include practitioner error while using a surgical guide may lead to deviations from the planned implant position. Determining the amount of deviation possible while using a surgical template with simulated user error may help prevent restorative challenges.

Significance

Fully-guided implant placement has been shown to be more accurate in implant placement compared to the initially proposed location compared to non-guided or free-hand implant placement, especially in the vertical dimension.¹ Partially-guided implant placement provides less need for specialty equipment while still providing assistance through the initial 2mm Twist Drill osteotomy. There are hundreds of endosteal implants being placed throughout the US Army annually. Accurate treatment planning and specific implant locations play a crucial role in manhours spent planning, placing, and restoring these implants. Large financial investments are utilized when every stage of an implant restoration is completed when viewing on a global scale. The surgical implant position places a critical step and at times, may create a significant challenge during the restoration process.² If the accuracy of a surgical 2mm Twist Drill guide increases ease of placement while decreasing chair time, there is value placed on the resources utilized for the surgical guide fabrication. If there is implant placement challenges or practitioner error while utilizing a surgical guide, the errors made/time and money spent for the fabrication of the guide is lost.

Purpose

When using a partially-guided surgical guide, similar to the guide being discussed, the 2mm Twist Drill is consistently the initial osteotomy site preparation step in which all sequential Quad Shaping Drills can follow. The tolerance within sleeve inserts of different surgical guides has been previously evaluated.^{3,4} While adjustments to angulation can be made using the Quad Shaping Drills, the path of least resistance will continue to follow the initial osteotomy. If deviation of the 2mm Twist Drill occurs while using a surgical guide, subsequent final implant position can be deviated from the preliminary, ideal implant planning position. Depending on the severity of the deviation, there may be additional challenges in restoring the definitive restoration.⁵ This study will determine a realistic degree of possible deviation when using a printed surgical implant guide with the initial 2mm Twist Drill osteotomy and to what degree user error can affect the osteotomy preparation compared to the originally planned.

Hypothesis

Intentional force applied in a horizontal direction to the implant handpiece with a 2mm twist drill will facilitate a deviation from the control osteotomy, while utilizing a printed stereolithographic surgical template.

Materials and methods

A typodont with tooth #30 removed was scanned with the Primescan Intraoral Scanner (Dentsply Sirona). The Standard Tessellation Language (STL) file was obtained. Cone Beam Computed Tomography (CBCT) was taken of the typodont, and the Digital Image and Communications in Medicine (DICOM) image was rendered (Planmeca). The STL and CBCT were combined using Blue Sky Plan 4 software (Blue Sky Bio v4.9.4). An ideal implant position sized 5mmx10mm (Zimmer Biomet Dental) was digitally planned using standard parameters of equicrestal platform placement while centered mesio-distally and buccal-lingually to allow screw access through the occlusal center of a single crown restoration. This serves as the control position. A surgical guide was then designed with a 2.0mm guide tube. The STL and BSB files were used to print 51 quadrant casts and 51 surgical guides (Army Dental Laboratory). Each surgical guide was stabilized to a cast. A visual aid was utilized to approximate the perpendicular buccal direction from the cast. A professional digital trigger gauge (Wheeler 710904) was utilized to record an approximate lateral force of 32oz in the buccal direction of each osteotomy site with the 2mm Twist Drill. The maximum lateral pressure was recorded for each cast preparation. Each preparation was filled with Gutta-percha (Obtura Spartan) as a radiographic indicator and a CBCT image was captured. BSB software was utilized to superimpose each of the 50 DICOM images individually on the ideal control DICOM by matching anatomical structures and visually verified. The digital image was rotated to find the angulation with the maximum deviation from the control. Measurements from each of the 50 cast preparations were taken and combined in Table 1.

Detailed Methodology

A typodont (Nissin Dental) with tooth #30 removed was scanned with the Primescan Intraoral Scanner (Dentsply Sirona). The Standard Tessellation Language (STL) file was obtained and exported (Image 1). Cone Beam Computed Tomography (CBCT) was taken of the typodont, and the Digital Image and Communications in Medicine (DICOM) image was rendered (Planmeca) and exported. The STL and CBCT were combined using Blue Sky Plan 4 software (Blue Sky Bio v4.9.4). A full-contour crown was digitally positioned for angulation and visualization. An endosseous implant position sized 5mmx10mm (Zimmer Biomet Dental) was digitally placed using standard parameters of equicrestal platform placement while centered mesio-distally and buccal-lingually to allow screw access through the occlusal center of the crown restoration

(Image 2). This served as the control position. A surgical guide was then designed to extend from the mandibular midline (#25) to the second molar (#31) with a 2.0mm guide tube (Image 3) and exported as BSB file. The STL and BSB files were sent to the Army Dental Laboratory (Ft. Gordon). 3-dimensional printing was utilized to print 51 quadrant casts from the STL file and 51 surgical guides from the BSB file. Guide tubes (Blue Sky Bio ID=2.0mm, Height=4mm) were placed in each surgical guide and secured with Super Glue (Loctite). Each printed cast was individually numbered. The casts were placed flat on a benchtop. Mimicking live-patient care each surgical guide was seated and stabilized to a cast with digital pressure on the anterior teeth (#25-27). An occlusal line was approximated from #29-31 with a perpendicular line drawn on the desktop as a visual aid to represent the buccal direction. A professional digital trigger gauge (Wheeler 710904) was utilized to record an approximate lateral force. The gauge was placed and stabilized to the benchtop at the appropriate height to grasp the Contra Angle Implant Handpiece (Aseptico). The 2mm Twist Drill (Biomet 3i) was used in the handpiece and operated at 1200rpm per the manufacturer recommendation. The digital trigger gauge was used to grasp the head of the handpiece as a lateral force was applied once the Twist Drill was approximately one millimeter in the guide tube. The force was applied as the osteotomy was prepared to an approximate labeled depth of 16mm to allow for a 10mm osteotomy depth. The labeled cast identification number and maximum lateral pressure was recorded for each preparation. Compressed air was used after each preparation and subsequently filled with gutta-percha (Obtura Spartan) as a radiographic indicator. An individual CBCT image was captured for each cast. BSB software was utilized to superimpose each of the 50 DICOM images individually on the ideal control DICOM by matching anatomical structures and visually verifying. The combined digital images were rotated to find the angulation with the maximum deviation from the control. Measurements from each of the 50 cast preparations were taken and combined in Table 1.

Data Analysis

The data obtained is presented as deviation of angulation in degrees. Apical and coronal osteotomy deviation in mm. The mean and standard deviation was calculated.

Results

The minimum and maximum directional force recorded in ounces(oz) was 16.5 and 43.1 respectively (mean 33.7 SD 5.8). The minimum and maximum recorded angulation measured in degrees was 3.17 and 14.48 respectively (mean 8.8 SD 3.1). The minimum and maximum recorded coronal measurement measured in millimeters was 0.46 and 3.48 respectively (mean 1.43 SD 0.67). The minimum and maximum recorded apical measurement measured in millimeters was 0.91 and 3.25 respectively (mean 1.88 SD 0.67)

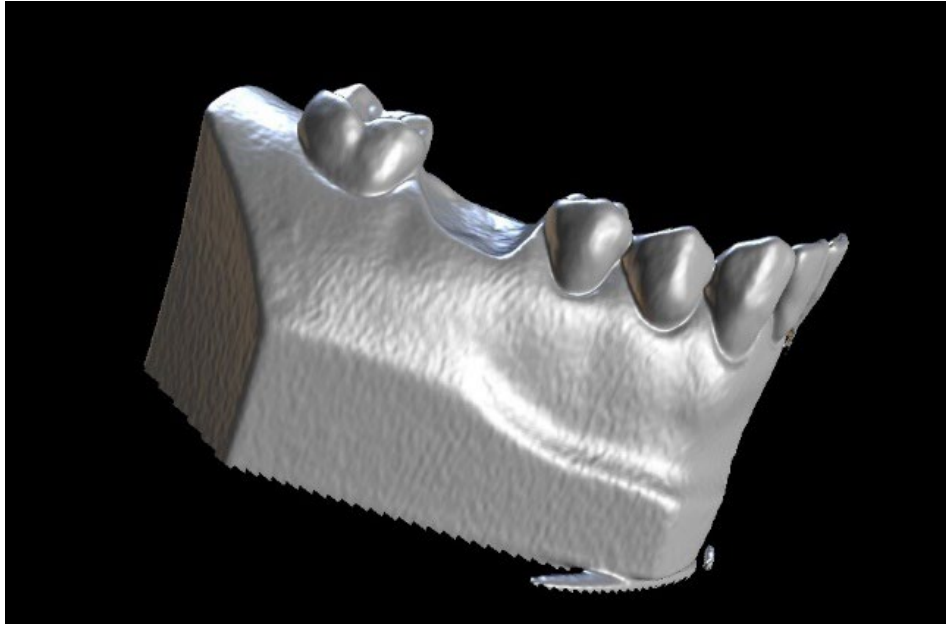


Image 1: Digital image capture of typodont.

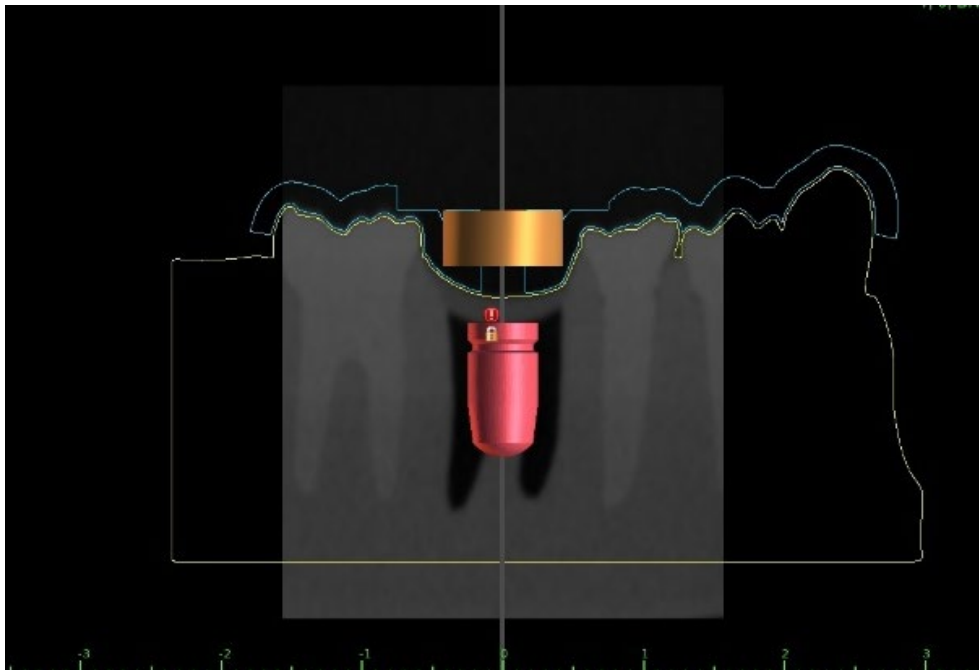


Image 2: Digitally planned implant position.

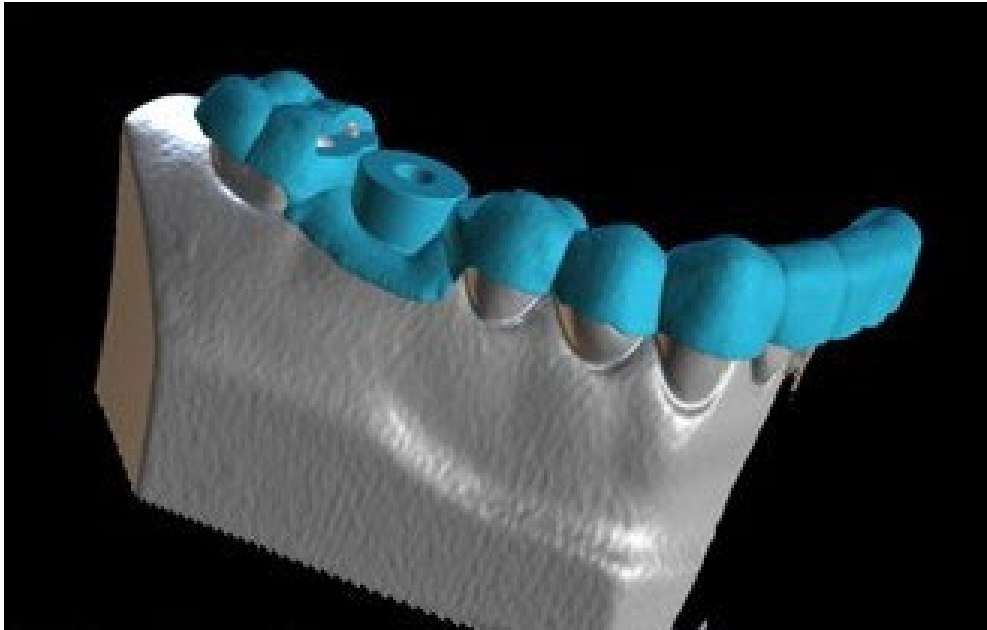


Image 3: Stereolithographic surgical template design.

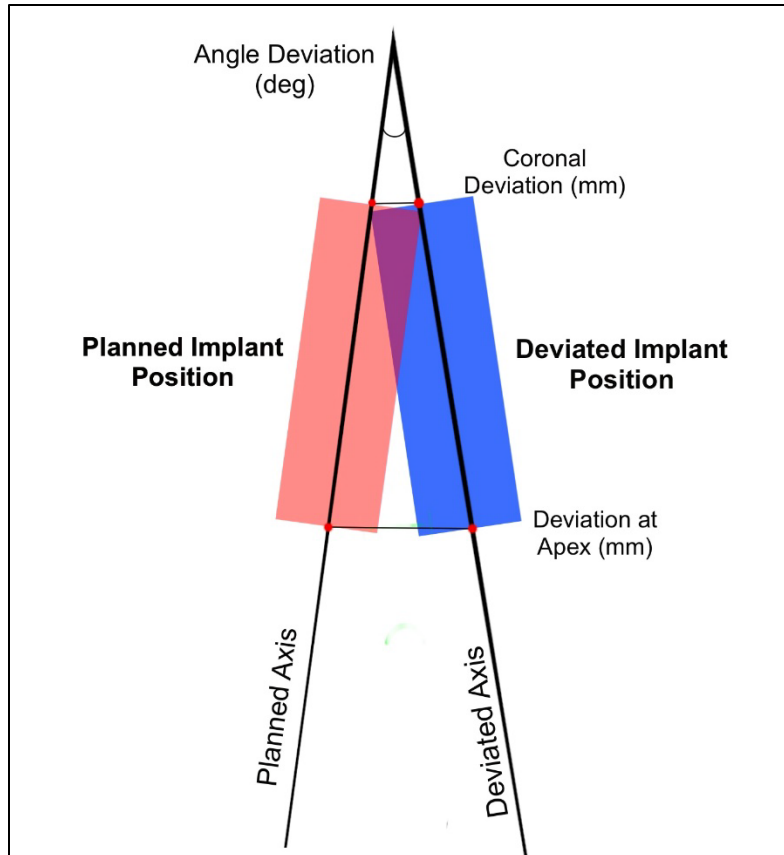


Image 4: Depiction of measurements recorded: angulation, coronal distance, and apical distance.



Image 5: Professional Digital Trigger Gauge.

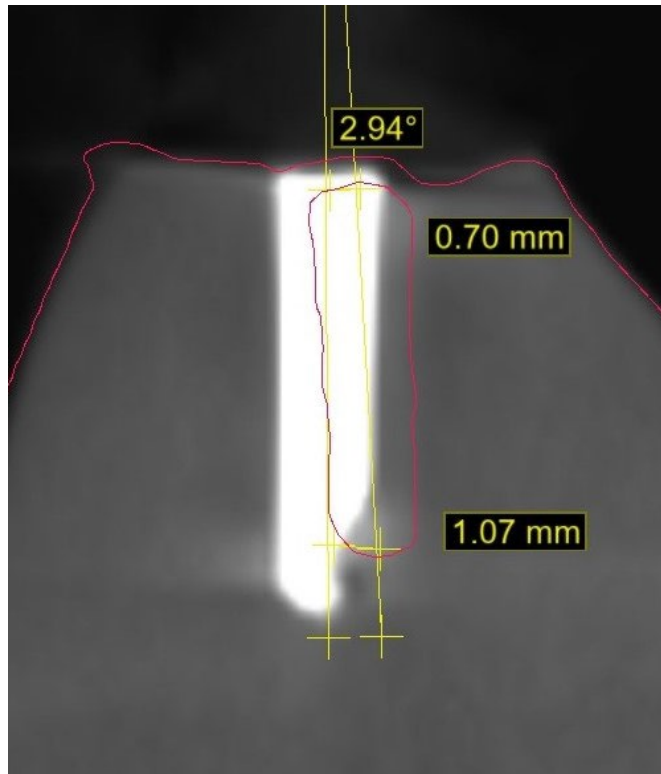


Image 6: Depiction of measurements recorded: Angulation, coronal distance, and apical distance.

Measurements	Max	Min	Mean
Directional Force (oz)	43.1	16.5	33.66
Angulation (deg)	14.48	3.17	8.78
Coronal (mm)	3.48	0.46	1.43
Apical (mm)	3.25	0.91	1.88

Table 1: Recorded variances between planned and deviated preparation positions (n=50).

Discussion

When using a partially-guided surgical guide, like the guide being discussed, the 2mm Twist Drill is consistently the initial osteotomy site preparation step in which all sequential Quad Shaping Drills can follow. Inherent freedom for movement in a surgical guide tube sleeve may allow minimal displacement of an osteotomy preparation. With increased user error, being expressed as lateral pressure during the initial osteotomy preparation, there is an increased chance of deviated implant positioning. Knowing this may help prevent restorative challenges and decrease patient chair-time and resources. A patient's maximum incisal opening ability or space confinement may lead to a surgical error and create inadvertent lateral pressure during the initial implant preparation. Although adjustments to angulation may be made using subsequent Quad Shaping Drills, the path of least resistance will likely follow the initial osteotomy. Depending on the severity of the deviation, there may be additional challenges in restoring the definitive restoration. Additional parameters may also affect the accuracy of a stereolithographic surgical guide to include surgical experience, distance between the guide tube and the alveolar ridge, differences in diameter between the implant system, the design of the surgical guide, the bone density and length of the implants.^{6,7} Proper treatment planning and surgical guide design can help ensure the desired implant positioning is achieved. Along with verifying the surgical guide be fully seated and the initial osteotomy drill move freely in the guide tube. Minimizing lateral forces on the surgical guide with multiple verifications of angulation and positioning during implant placement is highly recommended.

Conclusion

Based on the findings in this study the following conclusion was drawn:
Lateral forces caused by user error may create deviation of the 2mm Twist Drill osteotomy. If the divergence is not corrected for during subsequent osteotomy preparations, the final implant position may be differed from the intended implant position. Additional studies investigating restorative challenges following deviations during implant positioning appear warranted

Disclaimer

The views expressed herein are those of the author and do not necessarily reflect the official policy of the Department of the Army, Department of Defense, or the US Government

Disclosure

The authors disclose that they have no financial gain or affiliations with any company or product used in this research.

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