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Evaluation of implant placement accuracy utilizing DLP 3D-Printing Technologies: A Case study

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Abstract

The aim of the case study was to evaluate the in vivo accuracy of flapless, computer-aided implant placement by comparing the three-dimensional (3D) position of planned and placed implants through an analysis of linear and angular deviations. Implant position was virtually planned using 3D planning software based on the functional and aesthetic requirements of the final restorations. Computer-aided design/computer-assisted manufacture technology was used to transfer the virtual plan to the surgical environment. The 3D position of the planned and placed implants, in terms of the linear deviations of the implant plate form and apex and the angular deviations of the implant axis, was compared by overlapping the pre- and postoperative computed tomography scans using dedicated software.

Keywords: Computer-aided design, Dental implants, X-ray computed tomography

Case study

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1. Introduction

The accurate placement of dental implants is crucial to avoid harm to critical anatomical structures, achieve an ideal prosthesis, and guarantee a favorable and sustainable result. Consequently, several surgical guides systems have been devised to accurately place a dental implant at the intended site. The utilization of a comprehensive surgical guide represents the most precise and reliable approach. The most common technique used was combination of cone-beam computed tomography (CBCT), digital scans of existing oral tissues or a study plaster model and a template of the definitive prosthetics to produce a computer-aided design and computer-aided manufacturing (CAD-CAM) guide. This guide controls the drill angulation, depth, and location of the implant. CAD-CAM guide is commonly fabricated by milling or additive manufacturing, specifically using three-dimensional (3D) printing techniques [1]. A milled guide is dimensionally stable and usually less brittle and despite being the most accurate, CAD-CAM guides are the least used surgical guide, in part because of the cost of the systems in addition of the material waste that results from the milling process are all drawbacks. Recently developed, affordable, high-quality 3D printers offer an alternative that can produce a guide with limited material waste and minimal polymerization shrinkage [2]. Affordable desktop 3D printers with high precision can allow a dental office to produce anatomic casts and implant drilling guides. Although many 3D printing techniques are available, this report will focus on DLP because of its proven accuracy and its history of use in dentistry. This is a method where a photosensitive resin bath is positioned between a build platform and light-polymerizing source of a specific wavelength [3]. The build platform is lowered into the resin bath, and the light is directed by the computer to polymerize the resin to create the desired 3D object. The resin and printer combination should be precisely paired to prevent inaccuracies in the process. Furthermore, the materials used for drill guides should at a minimum be compatible with United States Pharmacopeia (USP) class VI standards for biocompatibility before in vivo use is considered. This report presents the use of a desktop, DLP printer (Form 2; Formlabs Inc) coupled with synergistic biocompatible resin (Dental SG; Formlabs Inc), which is certified to comply with the international standards for class I biocompatibility, International Organization for Standardization (ISO) standard 10993-1 and USP class VI. When the manufacturers' instructions are followed, it is suitable for intraoral use of 24 hours or less [3].

2. Clinical report

A 40-year-old Caucasian man presented with this chief complaint: "I cannot chew on the left side. I lost one of my lower molars." Approximately 1 year previously, After Clinical examination checking the mucosa and inter arch distance, a CBCT scans were taken using I CAT machine then radiographic evaluation for a qualitative and quantitative analysis of the bone.

The results showed a satisfied vertical and horizontal dimension of the bone that provides possibility of installing the implant with appropriate diameter and length (Figure 1 & Figure 2). Preoperative CBCT scans and STL file of scanned study cast was imported in Real guide software version (5.1 by 3diemme company, Italy) and implant placement in the most optimal positions. Virtual positioning was guided with appearance of future prosthetic work, and software made correct implants' positions, then the surgical guide was designed and planned using parameters that coincided with the NEO NAVI guided kit's (Figure 3). Nearly half-arch guide was designed to achieve optimal stability by using the teeth mesial and distal to the edentulous area. The stereolithography (STL) file was exported from the planning software and imported into the 3D printing software (Preform Software; Form labs Inc) to set up and complete the print. The guide was oriented to minimize cross sectional peeling forces during printing and to allow for the drainage of excess resin, and support points were added in areas that did not interfere with an accurate fit of the guide (Figure 4). The resin volume used was 11.30 mL, and the settings for the print were 50-mm layers in the z-axis with a print time of 3 hours. Next, the guide was removed from the build platform, rinsed twice with 91% isopropanol for 20 minutes and allowed to air dry. Complete polymerization was accomplished with a polymerization chamber (LC3D print box; Vertex-Dental B.V.) by exposure for 10 minutes to 108 watts each of Blue UV-A (315-400 nm) and UV-Blue (400-550 nm) light in a heated environment at 60C. Supports were removed, and a stainless-steel guide tube (neo-biotech) that coincided with the Navi Guided Surgery kit was inserted. The guide was then autoclaved sterilized. The patient was premedicated with 2 g of amoxicillin 1 hour preoperatively, and a 0.12% chlorhexidine gluconate rinse was used immediately before the surgery. The surgical guide was evaluated intraorally, and the guided surgery was performed using a flapless approach. The osteotomy site was prepared by using serial drills of 2.3, 2.8, 3.4, and 3.8 and 4.1 mm in width to 10 mm in depth (Figure 5). Primary stability was approximately 50Ncm, hemostasis was achieved. Postoperative care included chlorhexidine mouth rinse (twice a day for 2 weeks, amoxicillin (500 mg 4 times a day for 2 weeks), oral pseudoephedrine decongestant (30 mg twice a day for 5 days). A postoperative periapical radiograph and a CBCT scan were made after the surgery. Superimposition of Pre-Operative and Post-Operative Aligned Data for Implant placement accuracy measurement. The pre and post aligned data set and the STL file of the virtual implant were both imported in Real Guide software. Both Linear and Angular discrepancies between the planned and actual positions of each implant were analyzed. The implant placement accuracy was measured according to the following parameters (Figure 6 & Figure 7):

- Horizontal deviation at the implant platform in mm (HP).
- Horizontal deviation at the implant apical in mm (HA).
- Vertical deviation in depth at the implant platform in mm (VP).
- Vertical deviation in depth at the implant apical in mm (VA).
- Angular deviation in degree.

The 3D Deviation was calculated by the software using Pythagorean Theorem:

$$\text{Equation 3D dev.} = \sqrt{(x^2+y^2+z^2)}$$

The x, y, and z-axis, where x=bucco-lingual, y= mesio-distal, and z=Vertical depth deviation.

3. Results and Discussion

The surgery with an implant surgical guide realized a higher accuracy in terms of all parameters describing in the deviation of the actual and planned implant position, as shown in the radiographic measurements. As In this case study, we found an overall degree of deviation was significantly lower in guided surgery with fully guided implant approach as from radiographic measurements the horizontal and the vertical deviation in mesial-distal and Bucco-ling dimension at implant apex and platform was less 2mm from planned and the angular deviation was less than 8 degrees. From all aspects of compatibility of restoration such as functional, esthetical, and biological, implants must be placed correctly in an ideal position. Correct implant position not only has favored prosthetic and esthetic outcomes it has also shown long-term stability of peri-implant hard and soft tissues. Guided surgery can be used with or without elevating a full-thickness flap. In this patient, a flapless approach was chosen because of the availability of adequate keratinized tissue and bone volume that would require no contouring or other grafting procedures. Lack of flap and elevation and subsequent interruption of blood flow can decrease postoperative discomfort, reduce surgical time, reduce healing time, and reduce bone loss. However, the flapless technique does have some drawbacks, including the inability to visualize anatomic landmarks and possible damage to anatomic structures, the inability to contour osseous topography or graft if the bone volume is insufficient, and the mal-positioned angle or depth of the implant body [4]. With proper and accurate planning, guided surgery can limit complications. The workflow presented here uses an affordable desktop 3D printer, which, in turn, reduces costs compared with that of previous commercial printers and software, eliminates laboratory and shipping expenses and possibly increases the use of guided surgery. However, this method is only as accurate as the virtual plan and technique applied during the surgery [5]. A knowledge of additive manufacturing and some calibration of the implant planning and the 3D printing software will be needed initially, as there are many areas where errors may be introduced. Although this workflow is practical and can produce an accurate outcome, this case is only a preliminary trial. The potential for this technology in dentistry is great and will only increase as the technology evolves. One example of ongoing research is such applications as 3D printing tissue engineered bone scaffoldings conceivably allowing for customized grafting materials [6].

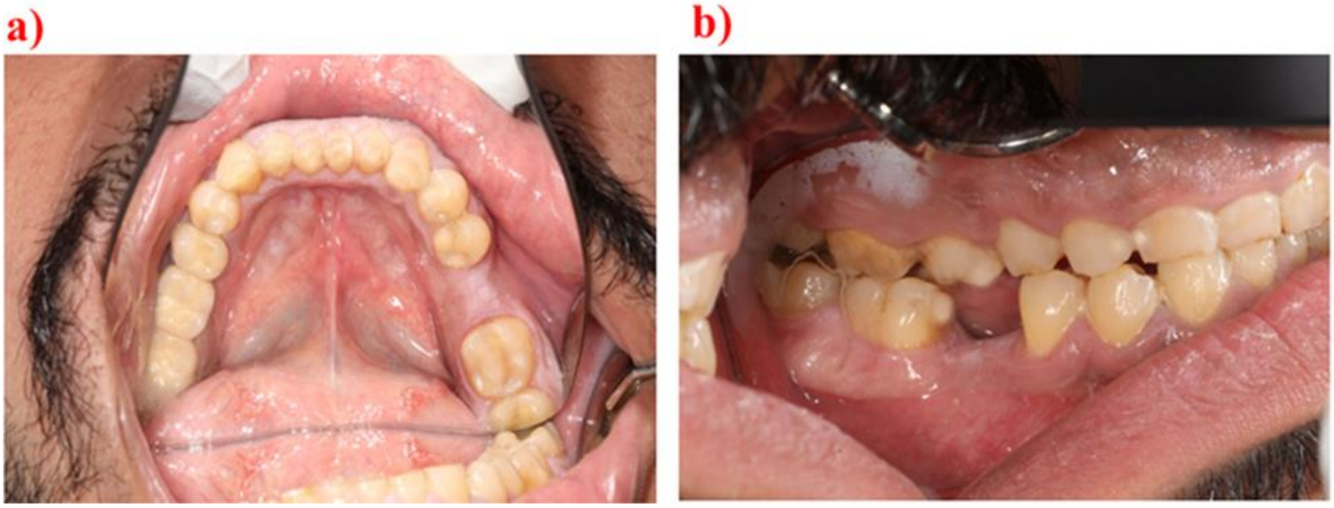

Figure 1: Clinical examination; a) Occlusal view**;** b) lateral view.

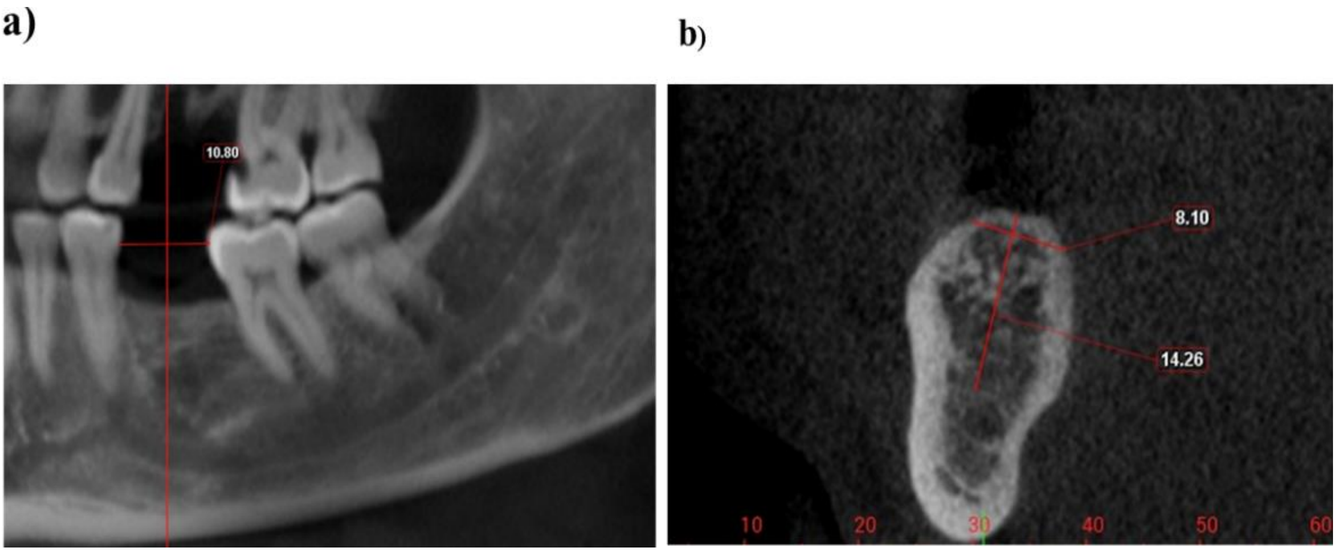

Figure 2: Radiographic examination**; a)** Mesio-distal evaluation**; b)** Measurement of bone width, height.

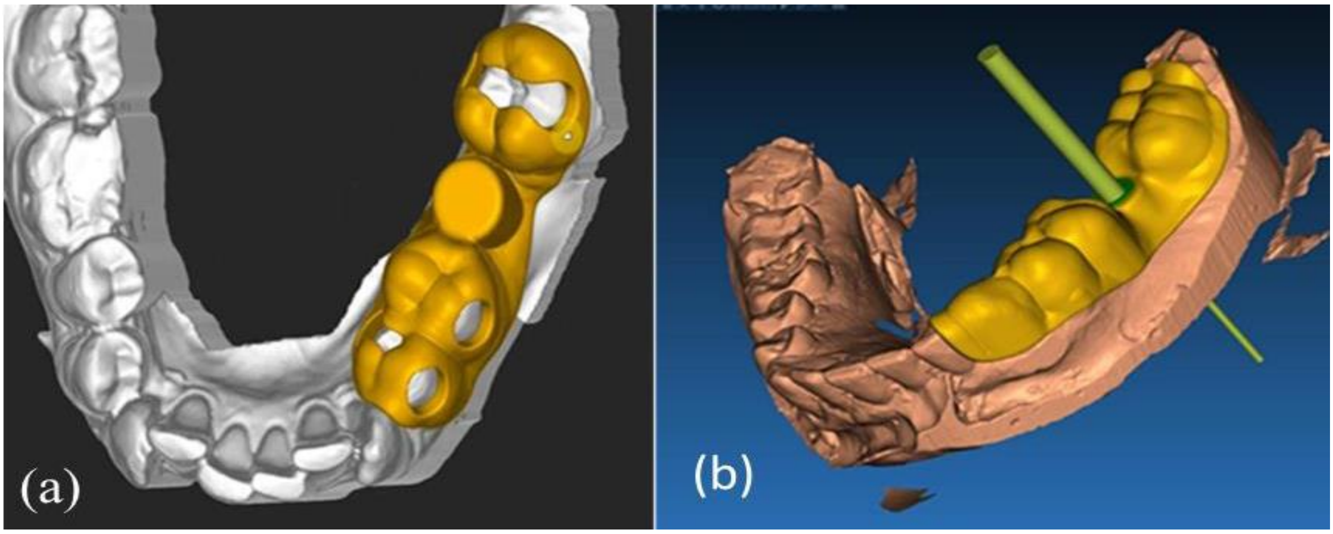

Figure 3: a) and b) Implant planning and surgical guide design.

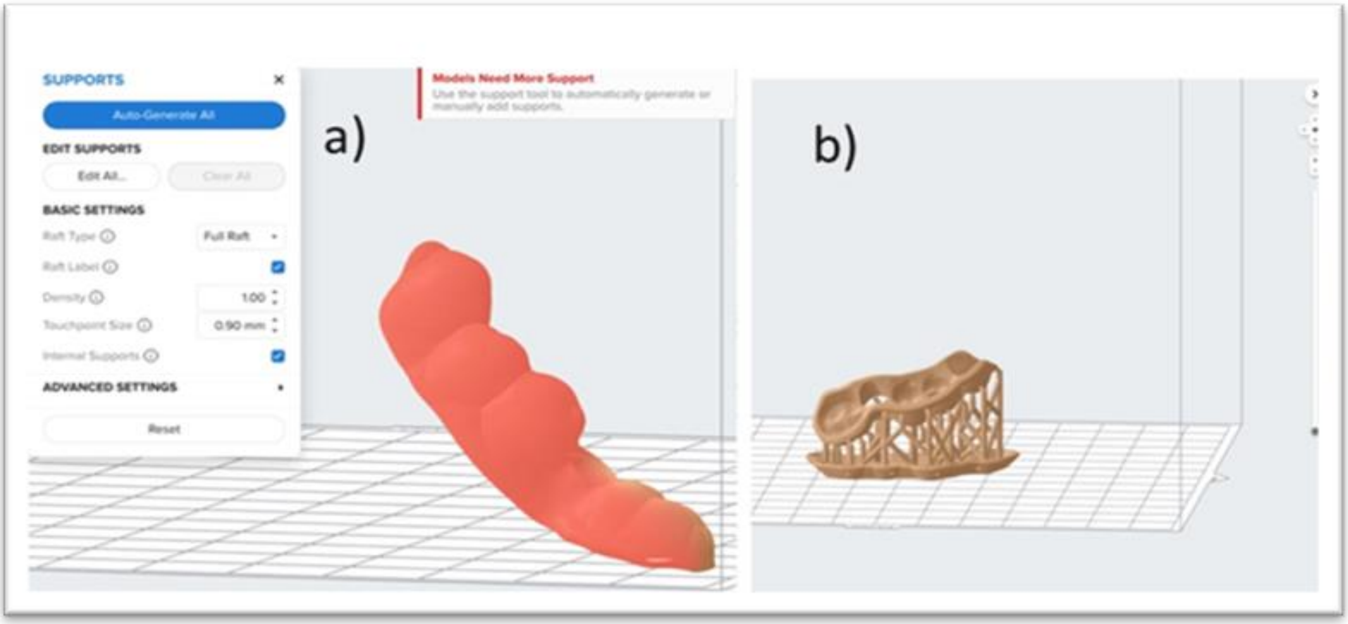

Figure 4: 3D printer software a) model without support b) sufficient support and correct model orientation.

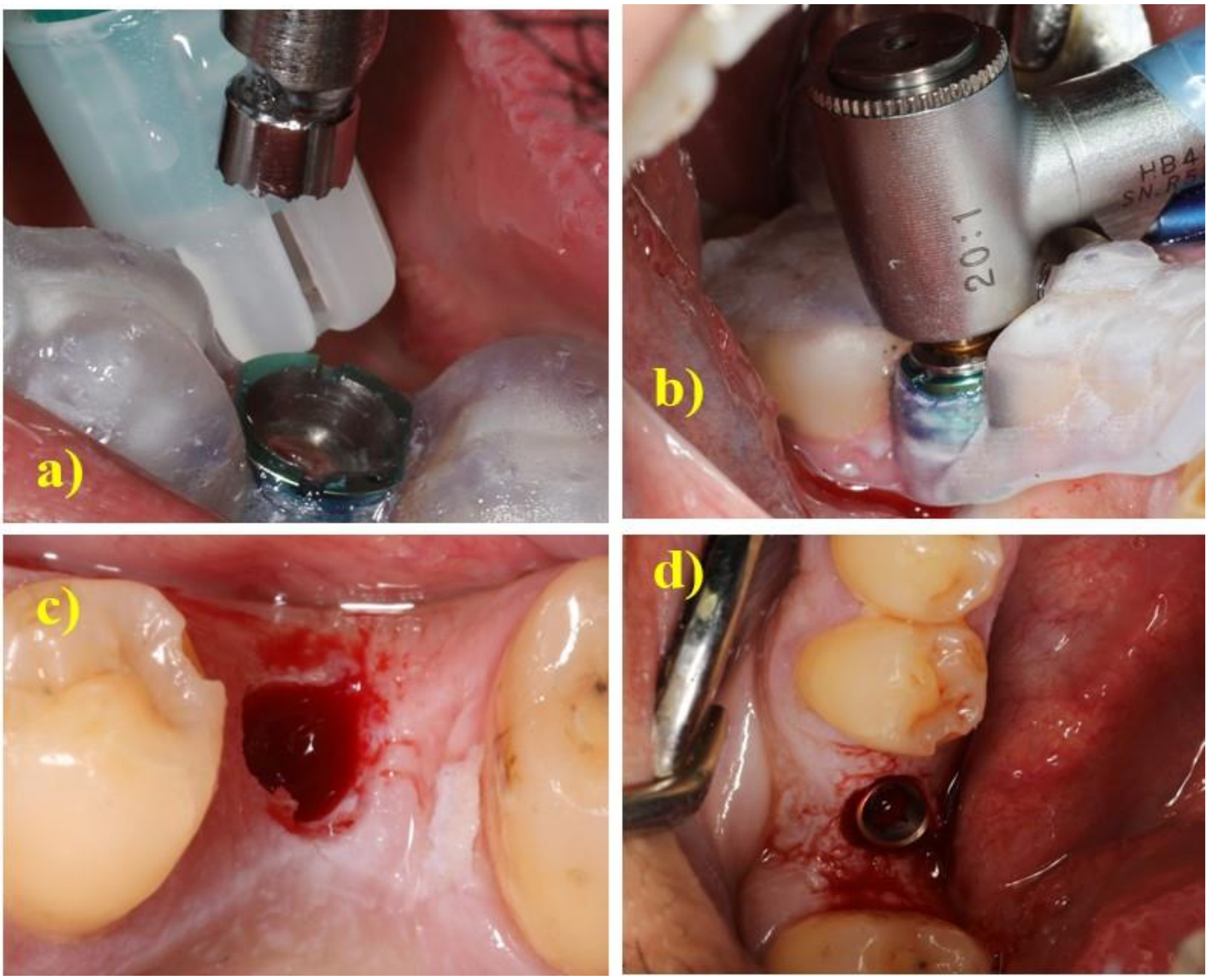

Figure 5: a) tissue puncher for flapless technique; b) bone trimmer; c) flapless post-opretive site; d) Implant inserted.

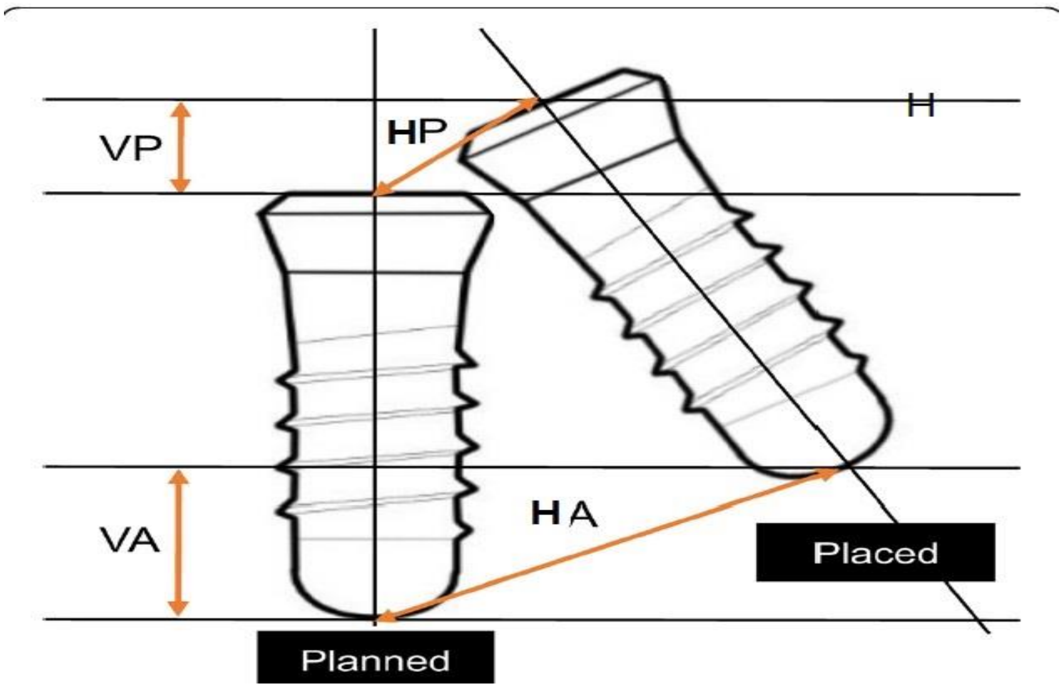

Figure 6: The implant placement accuracy method [7].

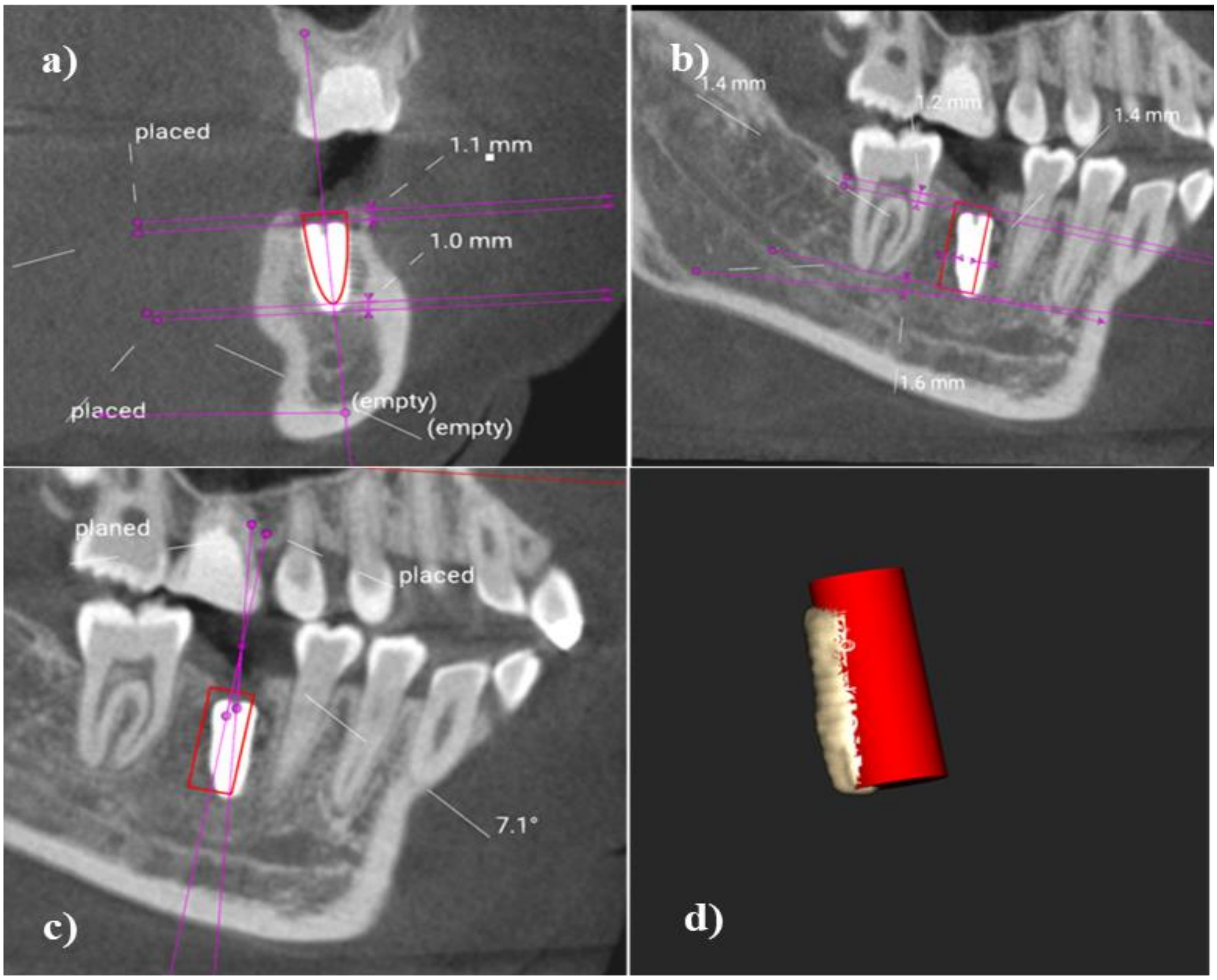

Figure 7: Parameters for implant deviation measurement. a) buccolingual and b) mesiodistally for VP vertical deviation at implant platform (mm); VA, vertical deviation at implant apex (mm); HP, Horizontal deviation at implant platform; HA, Horizontal deviation at implant apex (mm).c) angular deviation d) global deviation.

4. Conclusions

The use of desktop DLP 3D printers are a practical option to produce accurate implant drilling guides.

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