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Accuracy Evaluation of 14 Maxillary Full Arch Implant Treatments Performed with Da Vinci Bridge: A Case Series

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Abstract: The use of pterygoid implants can be an attractive alternative to sinus bone grafting in the treatment of posterior atrophic maxilla. This technique has not been widely used because of the difficulty of the surgical access, the presence of vital structures, and the prosthetic challenges. The use of dynamic computer aided implantology (DCAI) allows the clinician to utilize navigation dental implant surgery, which allows the surgeon to follow the osteotomy site and implant positioning in real time. A total of 14 patients (28 pterygoid implants and 56 intersinusal implants) were enrolled in the study for a full arch implant prosthetic rehabilitation (4 frontal implants and 2 pterygoids implants), using a dynamic navigation system. The reported accuracy of pterygoid implants inserted using DCAI was 0.72 mm at coronal point, 1.25 mm at apical 3D, 0.66 mm at apical depth, and 2.86° as angular deviation. The use of pterygoid implants in lieu of bone grafting represents a valid treatment opportunity to carry out a safe, accurate, and minimally invasive surgery, while reducing treatment time and avoiding cantilevers for a full implant prosthetic rehabilitation of the upper arch.

Keywords: dynamic navigation implantology; pterygoid implants; atrophic maxilla; totally edentulous patients; computer aided implantology

1. Introduction

Implant–prosthetic rehabilitations have greatly improved the quality of life for partially and fully edentulous patients [1–3].

Cumulative survival rates of osseointegrated implants in totally edentulous patients over a 10-year observational period have been shown to exceed 90%. However, placing an implant in the posterior atrophic maxilla is a challenge because of bone availability and poor bone quality, and there are also challenges associated with the difficulty of the surgical access [4–6].

The insertion of an implant in a poor bone quality has been demonstrated to have a higher rate of failure. [7] In addition, implant length affects success rate when the implant is inserted in Type III and Type IV bone quality. On the other hand, the length of an implant seems to have less importance on stress distribution, except for instances where Type IV bone quality exists where the implant length plays a key role [8–11].

Several techniques have been proposed for the treatment of the totally edentulous atrophic upper jaw: use of tilted implants, sinus floor elevation, short and ultra-short implants, and pterygoid or zygomatic implants [12–23].

The use of pterygoid implants was proposed for the first time by Tulasne et al. in 1989 as an implant to be inserted through three different bones (maxillary tuberosity, horizontal process of the palatine bone, and pterygoid process of the sphenoid bone) engaging the pterygoid plate. In this area, 80% of the native bone remains stable over time, even after atrophy and residual ridge resorption patterns ensue following extractions [24,25].

Inserting a pterygoid implant with DCAI allows several advantages [24–30]:

- Minimally invasive (no bone grafting) approach;
- Avoid posterior prosthetic cantilevers;
- Predictability;
- Shorter period of treatment;
- Stable during the time;
- Immediate loading is possible;
- Decreasing of costs (patient and dentist).

In this direction, the use of pterygoid implants could be a suitable alternative to a sinus bone graft in the treatment of posterior atrophic maxilla [24,28–30].

Notwithstanding the use of pterygoid implant is a reasonable option, this technique has not been widely used because of the difficulty of surgical access in this area (insertion of a long implant with a semi-blinded surgery made free-hand), the presence of vital structures (greater palatine artery and pterygomaxillary fossa), and the prosthetic difficulty in the short- (tilted implants in a limited vertical space of this region) and long-term (owing to high occlusal masticatory stresses in this area that could end in prosthesis or screw fractures) [24–30].

For the above mentioned reasons, the accurate placement of pterygoid implants (13–20 mm of implant length) using free-hand techniques becomes incredibly difficult compared with the other proposed techniques for the rehabilitations of atrophic edentulous maxilla [26–30].

The use of computer-aided implantology (CAI) has been reported to be accurate by measure of minimum deviations between planned and inserted implants [31–33].

In particular, the use of dynamic computer-aided implantology (DCAI) allows the clinician not only to be computer guided during surgery (following in real time the advancing of the drill into the bone), but also to verify (by touching a landmark) if the workflow is progressing in an accurate way; the latter option becoming very important in such high-risk anatomic areas.

A new workflow involving dynamic navigation, called Trace and Place (TaP), has been enabled by ClaroNav™, a Canadian company manufacturing Navident®, in which patient's jaw registration to her cone beam computerized tomography (CBCT) images is accomplished by tracing the existing teeth or mini screws, both of which can be used as fiducial markers [31–34], thus performing dynamic guided surgery without any in-mouth template. This provides a fully digital implant–prosthetic workflow and is less obtrusive [35,36].

Furthermore, the use of angled multi-unit abutment (M.U.A) can reduce prosthodontic difficulties by allowing tilted implant axis correction.

Another solution for the final prosthesis is the OT Equator™ (Rhein83 Srl, Bologna, Italy) implant connection. It comes from the Normo Ball attachment concept and can be used in both fixed and removable prostheses.

When used in place of an M.U.A. for fixed screw-retained dentures, it allows the OT Bridge™ turrets to compensate up to 80° of divergence between two implants as a result of its "Extragrade™" feature. "Extragrade" is a minimal flap that, if correctly positioned, allows the metal structure to overcome an implant created undercut and gets connected with OT Equator in a passive manner.

The Seeger (Rhein83 Srl, Bologna, Italy) inserted inside the OT Bridge turrets engages the undercuts of the OT Equator head, holding the structure passively anchored. To complete, the screw is inserted onto OT Equator's head.

The OT Bridge prosthetic screw has a core of 1.3 mm compared with the 1 mm standard M.U.A. screw core. This allows an advantage in terms of toughness and resistance to mechanical stresses and strains (resistance to stresses is directly proportional to section).

The aim of this study is to evaluate the placement accuracy of both pterygoid and frontal implants for a full maxillary implant supported rehabilitation.

The second aim of this study is to suggest a new terminology for this implant layout named as a Da Vinci bridge.

2. Material and Methods

2.1. Study Design

This study is a clinical single blinded retrospective case series.

2.2. Study Population/Demographics

Fourteen patients treated between 1 February 2018 and 30 September 2019 for a full arch implant supported rehabilitation were included in this study. All the treatments followed the concept of the "Da Vinci Bridge" and were performed at Department of Periodontics and Implant Dentistry at the Policlinico Umberto I, Sapienza University of Rome, Italy.

The "Da Vinci bridge" is a concept suggested in this paper to identify the placement of two to four implants in the frontal area between the two anterior maxillary sinus walls and two implants in the pterygoid process area [24–30].

Written informed consent was obtained from each patient after a detailed description of the study protocol. The research protocol was in accordance with "1975 Declaration of Helsinki" on medical protocols and ethics and its later amendments. A post-operative CBCT scan was included to assess the accuracy of implant placement related to virtual plan. This study protocol was approved by the Department of Oral and Maxillofacial Sciences—Sapienza, University of Rome (protocol identifying number: 582/17).

2.3. Inclusion and Exclusion Criteria

The CBCTs used for the retrospective study were selected from a pool of clinical cases complying with the following criteria at the time of surgery:

2.3.1. Inclusion Criteria

- Any totally or partially edentulous patient that needs a full arch implant prosthetic rehabilitation.
- Bone crest width and height in the area between right and left premolars enough to place two to four implants with at least 1 mm of bone around the implant.
- Bone width and height in the pterygoid area enough to place one implant at least 13 mm long per side.

2.3.2. Exclusion Criteria

- Patients with general contraindications to implant surgery.
- Patients with systemic diseases that could influence the outcome of the therapy (i.e., diabetes with HbA1c $\geq$ 6.5%, osteoporosis, or use of bisphosphonate medications).
- Patients with a history of radiation to the head and neck region.
- Patients who are pregnant or nursing.
- Patients with no available bone to plan a pterygoid implant.

- Patients with residual bone in the molar area higher and wider than 6 mm.
- Patients with insufficient residual bone crest in the frontal area to place two to four implants.

2.4. Trace and Place (TaP™) Protocol

The workflow has been described in previous publications [32,34], but is described here briefly. TaP protocol consists of three steps: (1) Plan: creation of a virtual surgical plan on the basis of the volumetric Digital Imaging Communication in Medicine (DICOM) data acquired from a cone beam computerized tomography (CBCT) scan. (2) Trace: registration of the patient's jaw to CBCT. This is done by tracing radiopaque landmarks that get selected/marked on patient's CBCT. (3) Place: navigated implant placement according to the plan.

2.4.1. Plan

A CBCT (Scanora 3Dx) and an intraoral surface scan (IOS) were taken on each patient. An ideal virtual wax-up of teeth was completed by Lab Technician. Both DICOM files from CBCT and stereolithography (STL) files from the IOS were matched in Navident software and semi-automatically superimposed to residual teeth (or in toothless cases, using reference points in the wax-up) using the provided mesh-to-image registration tool. In addition, the STL files of the final teeth set-up were matched above previous IOS files of the baseline oral conditions and displayed in Navident software to perform prosthetically driven implant planning (Figure 1).

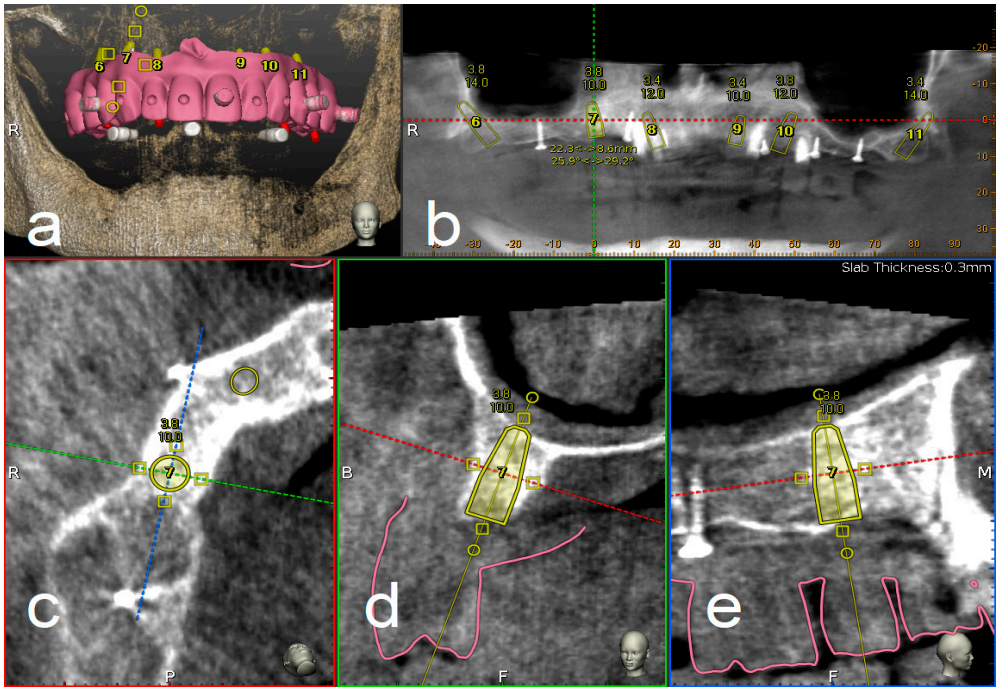

Figure 1. Implant planning using stereolithography (STL) files as reference for a prosthetic driven implantation (**a**). Panoramic (**b**), axial (**c**), bucco-lingual (**d**), and parasagittal (**e**) view.

2.4.2. Trace

To track the patient's jaw by the system cameras, an optical tracking tag needs to be fixed to the patient's jaw where the surgery has to be performed. This requires a JawTracker™ to be connected to 1–2 teeth in the patient residual dentition by light-curing composite resin or by anchoring with mini screws into bone. Alternatively, but only in the maxilla, a HeadTracker™ can be used for tracking by placing it directly on the patient's head (Figure 2). Tracing can then be performed starting at landmark locations. During tracing, the surgeon slides the tracer's ball tip in full contact with each landmark

surface (if Salvin™ mini screws are used, software automatically recognized them once they come into contact with the tracer) (Figure 3).

Figure 2. Head tracker used in the upper jaw for dynamic navigation Trace and Place (TaP).

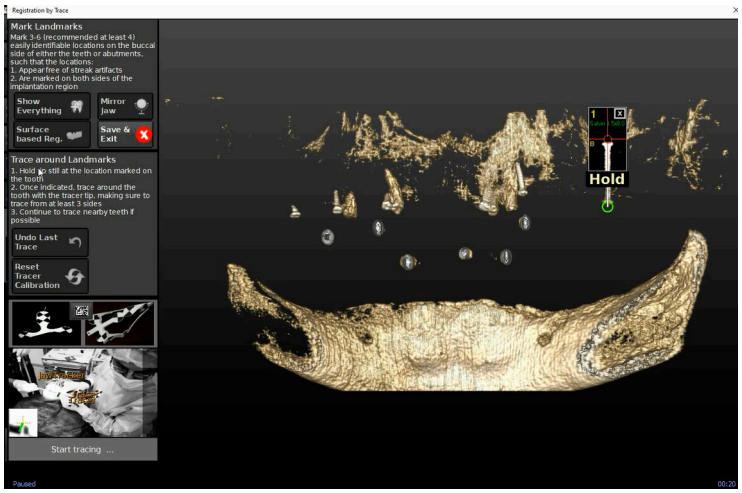

Figure 3. The figure shows the mini screws automatic recognition by the software and the related tracing progress.

After all selected landmarks/teeth are traced, the software automatically performs registration. Sampled trace points get superimposed with CBCT 3D rendering. The complete trace and registration process takes an average of 1–2 min. The accuracy of trace registration is then assessed by touching with tracer's ball tip any patient's anatomical marker and confirming congruency between the touched marker and what is shown on the laptop screen (Figure 4). If the accuracy check is not satisfactory, the tracing process can be immediately repeated.

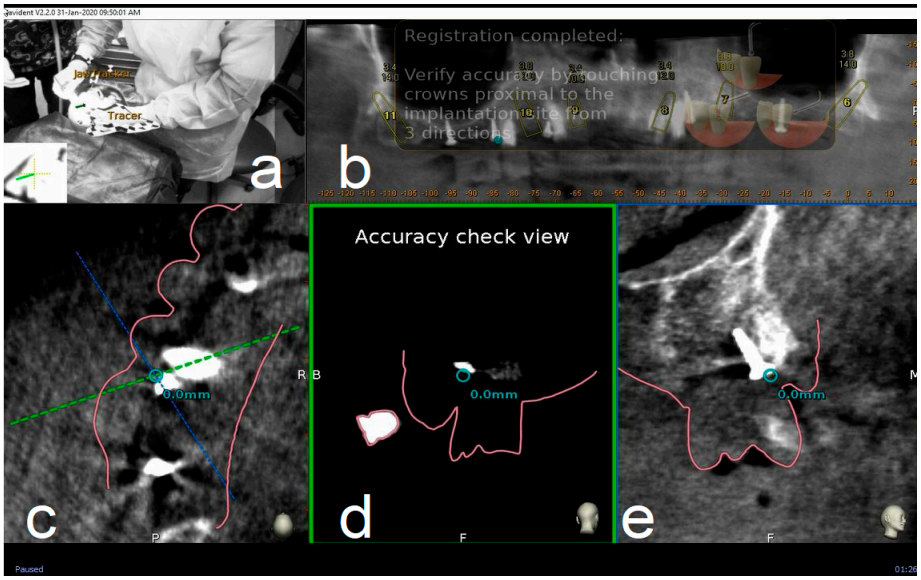

Figure 4. The surgeon (**a**) can then verify the registration accuracy (**b**) by touching with the tracer's ball tip one of the patient's landmark (mini screw used in this case) (**c**). The matching quality can be verified from each view (**d**,**e**).

2.4.3. Place

Handpiece drill axis and drill tip length are then calibrated using a metallic caliber; a second accuracy check is carried out in the same manner as for tracing. Once accuracy is confirmed, navigated implant placement can be carried out following target view. This allows clinician to verify, in real time, entry point, depth, and angulation of planned osteotomy as related to the plan. Other views that the clinician can see on the screen enable her/him to follow the position of the handpiece drill during osteotomy in coronal and sagittal views (Figure 5).

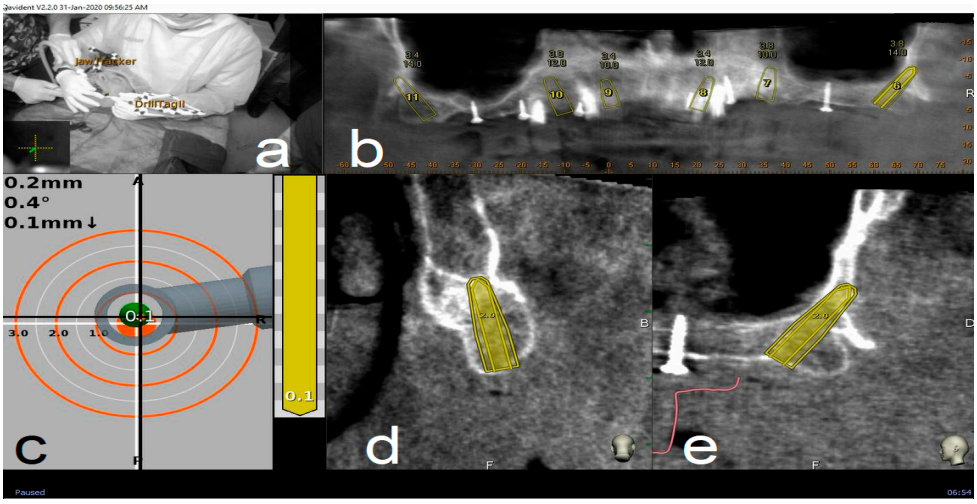

Figure 5. Clockwise from up left. The figure indicates the several views on the screen during surgery: tracker video stream (**a**), panoramic view (**b**), target view and depth indicator (**c**), bucco-lingual section view (**d**), and mesio-distal section view (**e**).

2.5. Surgical Treatment

Before the surgical treatment, all patients underwent an oral hygiene protocol that consisted of supra- and subgingival debridement and final polishing. One hour prior to surgery, patients received prophylactic antibiotic therapy with 2 g of Amoxicillina (GlaxoSmithKline, London, UK).

Immediately before the procedure, they were instructed to rinse with a 0.2% chlorhexidine digluconate solution (Corsodyl, GlaxoSmithKline Consumer Healthcare, Genval, Belgium) for 2 min. All surgical procedures were performed by same experienced surgeon (L.V.S.). Local anesthesia was obtained with 2% mepivacaine 1:100,000 adrenalin (Carbocaine, AstraZeneca, Milan, Italy).

Four frontal implants and two pterygoid implants (TPA, AZ implant, San Lazzaro di Savena, Bologna, Italy), for a total of six implants (Da Vinci Bridge®), were planned and inserted in each upper arch.

For partially edentulous patients, the first inserted implants were those planned in healed ridges. Then, immediate implants were placed and, finally, all residual teeth were extracted.

After implant insertion and/or teeth extraction, multi-unit abutments (or alternatively OT Equator™ abutments) were screwed and an impression was taken to prepare a provisional screwed prosthesis.

The healing screws were screwed at 20 Ncm torque value.

On the basis of the implant angulation degree, an MUA or OT Equator abutment was selected in order to obtain a passive fit of the temporary prosthesis.

After 6 h, the provisional prosthesis was screwed, using the OT-bridge (Figure 6) or conventional M.U. abutments (Figure 7).

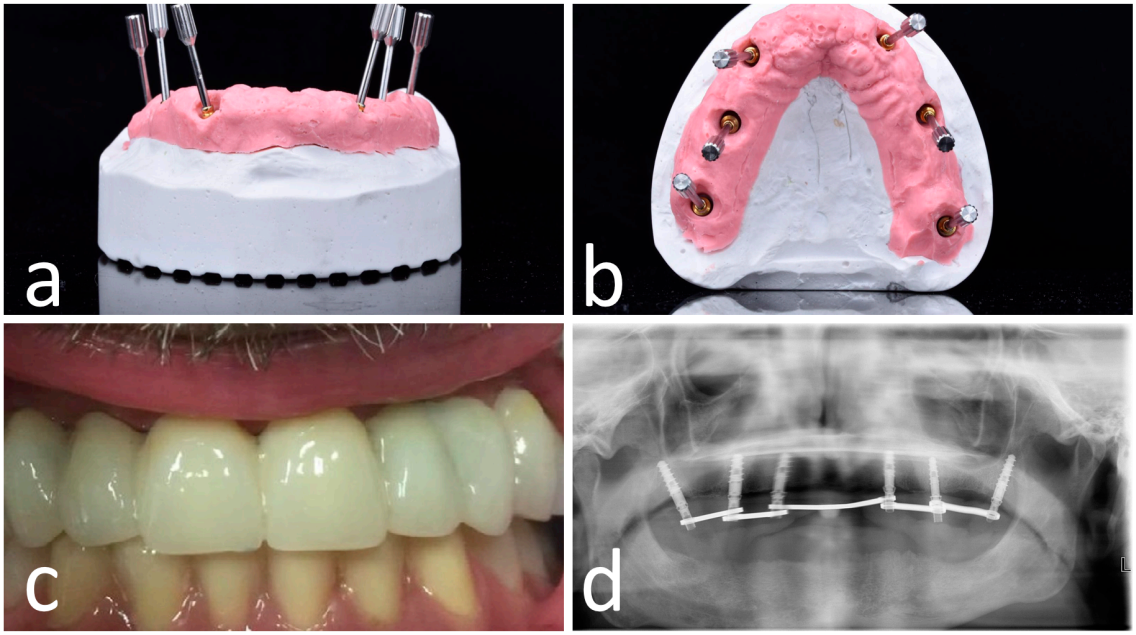

Figure 6. OT-bridge abutments use the "Extragrade™" feature, a system allowing to compensate up to 80° of the divergence between two implants (**a**,**b**). Pictures c and d show the clinical (**c**) and X-ray (**d**) view of the provisional prosthesis using OT-bridge abutments.

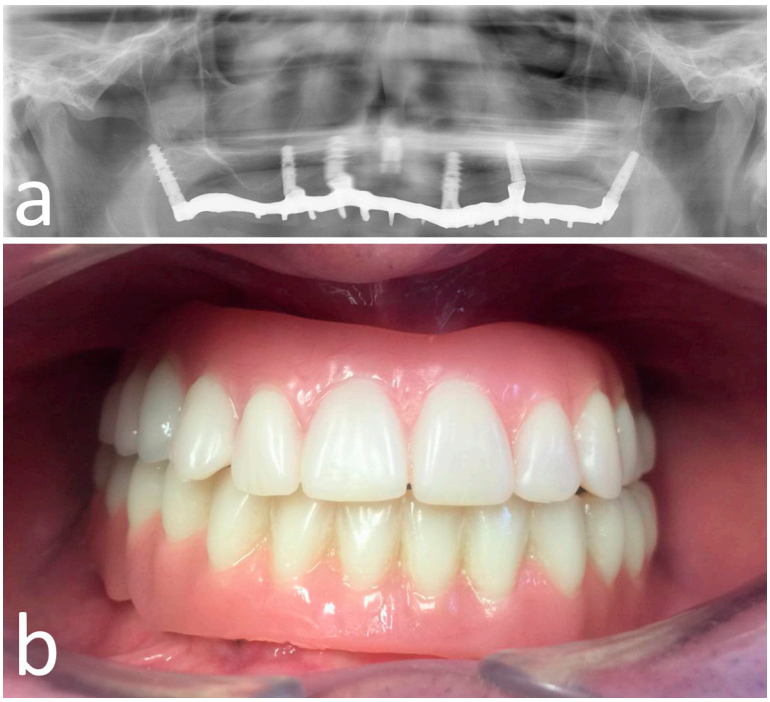

Figure 7. Opt X-ray (**a**) and clinical (**b**) view of the provisional prosthesis realized using conventional straight and angled multi-unit abutment (M.U.A.).

2.6. Post-Surgical Protocol

All patients were prescribed Augmentin (GlaxoSmithKline, London, UK) 1 g twice daily for 7 days. After surgery, analgesia was achieved with 200 mg of ketoprofen (Ibifen, Aprilia, Latina, Italy) for a maximum of three times daily according to the needs of individual patients. Each patient was instructed to rinse with 0.12% chlorhexidine digluconate (Corsodyl, GlaxoSmithKline Consumer Healthcare) three times daily for 2 weeks; to follow a soft diet for 1 week; and to gently cleanse with a soft toothbrush, avoiding the use of floss in the surgical area for the first month post-operatively.

2.7. Outcome Measures

2.7.1. Post-Surgery Complications

The possible following post-surgery complications were recorded: (1) early implant failure, (2) post-operative infection, and (3) post-operative hemorrhage.

2.7.2. Accuracy Evaluation Assessment

The assessment of accuracy was determined by overlapping the pre-operative CBCT with planned implants and the post-operative CBCT with achieved implants. This analysis was performed by two independently calibrated investigators (A.F., S.D.C.) who were blinded to other aspects of the study.

Any disagreement was solved by consensus, and a third investigator was consulted when it was not initially possible to achieve complete agreement (defined as the difference between the measurements made by the two experts of >0.1 mm).

The preoperative surgical plan and the postoperative CBCT were superimposed using an accuracy evaluation software (EvaluNav™) part of Navident™ navigation system (Claronav Inc., Toronto, YTO, Canada). Calibration was done directly between the two volumetric images (Figure 8). Software provides various visualization tools that confirm two CBCTs are precisely matched. Once the user is satisfied with volumetric registration, the software automatically matches the planned implant shape onto the post-operative image and computes deviations between the planned and placed implant locations (Figure 9).