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An innovative computer guided ridge splitting flapless technique with simultaneous implant placement: A case report

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ABSTRACT

Purpose: In the conventional ridge splitting technique, a complete flap is raised to allow adequate visibility of the bone defect which can result in disturbance of vascular supply and increase bone resorption rates. In this case report, a new innovative computer guided closed alveolar ridge splitting flapless technique has been advocated to avoid this disruption.
Materials and Methods: After thorough clinical and radiographic evaluation, the patient presented in this case report showed inadequate bone width in the missing first premolar region.The procedure involved a series of creating and designing special 3D virtual guide slits that can accommodate and precisely fit the tools used for the alveolar ridge splitting technique.
Results: After a three months follow-up, the Implant was found to have successfully osseointegrated both clinically and radio-graphically. The Implant deviation from the pre-planned virtual implant position was as well found to be within an acceptable range.
Conclusion: For the alveolar ridge with insufficient thickness, this flapless, computer guided ridge splitting technique can be a predictable, less invasive and an atraumatic technique with immediate implant placement.

1. Introduction

The need for more than just osseo-integrated implants led to the evolution of the “Prosthetic-driven implant placement” concept which recommends the placement of implants in the position that serves both functional and esthetic requirements [1,2]. The goal of computer-aided implant planning and placement system is the achievement of maximal safety, allows implant placement in less time, less postoperative bleeding and discomfort, accelerated recovery for the patient, fewer changes in crestal bone level and reduced tissue trauma [3,4]. However, is this technique safe, accurate, efficient and effective to be used in routine clinical settings? [5].

The alveolar ridge expansion technique by means of hand osteotomes with progressively increasing sizes was introduced by **Tatum** [6] and then later revised by **Summers** [7] . A similar approach was then advocated and described by **Simion et al.** [8] as the alveolar ridge splitting technique: This technique involved producing a longitudinal alveolar ridge splitting provoking a greenstick fracture using small chisels and are recommended only in soft bone quality (types 3 or 4). However, a minimum ridge width of 3–4 mm is a prerequisite [9,10]. The limitations of these two techniques are the presence of highly compact bone and the lack of a cancellous bone layer between the cortical plates. With the introduction of microsaw devices by **Suh et al.** [9] and piezoelectric devices by **Vercellotti** [10] for cutting hard alveolar bone under adequate control, the alveolar ridge splitting/expansion technique (ARST) can be used regardless of the bone quality. Four anatomical requirements are suggested: (1) a minimal horizontal bone width of 2 mm, (2) a minimal vertical bone height of 10 mm, (3) no concavity in alveolar bone profile and (4) the horizontal

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osteotomies have to end at least 1 mm before the neighboring teeth [11,12].

In a narrative review discussed by **Chiapasco et al.** [13], data from 3 ARST studies performed in humans were reported and considered a highly successful technique. In another recent systematic review on the subject of various bone augmentation procedures by **Milinkovic & Cordaro** [14], only six publications on ARST were included, but no animal studies were considered. ARST seems to be a well-functioning one-stage alternative to extended two-stage horizontal grafting procedures [15].

2. Materials and methods

A 32 year old female patient was selected from the outpatient clinic of the Department of Prosthodontics and Implantology, Cairo University. The Patient; with a maxillary Class I Kennedy's classification and normal maxillo-mandibular relationship (Class I Angle classification); was a non-smokers, with adequate zone of keratinized attached mucosa over the crest of the upper ridge and systemically free from any medical conditions. After thorough clinical and radiographic evaluation, the patient showed sufficient bone height but inadequate bucco-lingual bone width in the missing first premolar region on her left side of the arch.

2.1. Pre-surgical preparation

The pre-surgical preparation required the construction of conventional maxillary partial denture. Preliminary impressions, facebow records and diagnostic mounting and wax-set up were performed to achieve a prosthetic driven implant placement. Duplication of the partial denture using heat cured clear acrylic resin was performed. After adequate finishing and polishing of the radiographic template, 2mm channels were drilled through the stent at the centers of the teeth with the proposed implant placement. Radiographic markers were then produced by adapting four amalgam tablets on the stent's polished palatal surface using self cured acrylic resin.

2.2. CBCT acquisition

The patient's maxilla was radiographed using Cone Beam Computed Tomographic (CBCT) scanning machine (Sanora 3D Soredex, Helsinki, Finland). During imaging the patient was instructed to wear the scan stents and to stabilize it in place by biting on an occlusal index, separating the mandibular teeth from the stent. DICOM files obtained from the CT scan were loaded into the Mimics software (Mimics, Materialise HQ, Technologielaan 15, 3001 Leuven, Belgium) whereby coronal and sagittal reformatting and panoramic views were obtained (Fig. 1). The desired implant sites were identified through the radiolucent channels previously prepared in the radiographic stent at the prosthetic teeth centers. The bone volume at the potential implant site was meticulously evaluated. The CBCT revealed bone width of about 3.54 mm and bone height of about 16mm in the first premolar region which indicated the necessity of alveolar ridge splitting in the first premolar region.

In the conventional ridge splitting technique, a complete flap was raised to allow adequate visibility of the bone defect which can result in disturbance of vascular supply and increase bone resorption rates. In this case report, a new innovative computer guided closed alveolar ridge splitting flapless technique has been advocated to avoid this disruption. A conventional alveolar ridge splitting technique has been performed except that it was done using a novel computer guided flapless technique. Using the Mimics program, the first step involved a simple registration procedure whereby superimposition of the base of the radiographic stent to its proper position using the dual scan technique was performed. The radiographed stent was then grown into a 3D object using the "Calculate 3D object" tool.

2.3. Designing the guide tools

The second step involved a series of creating and designing special 3D virtual guide slits and boxes that can accommodate and precisely fit the tools used for the ridge splitting technique (Fig. 2). The armamentariums that were to be used during the ridge splitting technique were the Blade No. 15 (Xinda.china), Blade handle followed by the Split Chisel (MrCurette, 13 SK Techno-Parck Tech-Center 124. Korea mct@mrcurette.co.kr). The 3D virtual designing and creation of these boxes and Slit guides was performed using the Rhinoceros program (Rhinoceros® North Seattle, WA 98103 USA). These tools were designed as follows:

1. External Box: is a hollowed rectangular shaped box with an outer dimension of 7 × 5x8mm and 1mm in thickness. There was also a 0.5 mm internal ledge created 1mm away from the top aspect of the box. This Box will accommodate the box shaped guides (Fig. 2E).
2. Blade Guide: is a rectangular shaped box that fits precisely into the External Box. Its upper aspect has an external ledge that will precisely fit the ledge on the inner aspect of the box. It contains an internal slit that is 0.5mm in width and that will exactly fit the blade tip (Fig. 2A).
3. Blade Handle Guide: is a rectangular shaped box that fits precisely into the External Box. Its upper aspect has an external ledge that will precisely fit the ledge on the inner aspect of the box. It contains an internal slit that is 2.6mm in width and that will exactly fit the lancet blade handle (Fig. 2C).
4. Split Chisel Guide: is a rectangular shaped box that fits precisely into the External Box. Its upper aspect has an external ledge that will precisely fit the ledge on the inner aspect of the box. It contains an internal slit that is 1.7 mm in width and that will exactly fit the Split bone chisel (Fig. 2B).
5. Internal splitting plane: the rationale behind this plane was to facilitate the visibility of the direction of entry within bone thus used as a virtual planning tool (Fig. 2G).
6. Drill Implant Sleeve Guide: is a rectangular shaped box that fits precisely into the External Box. Its upper aspect has an external ledge that will precisely fit the ledge on the inner aspect of the box. This guide contains no slits as the supra-bony portion of the virtual implant model will be minused from this box thus creating the implant guide sleeve (Fig. 2D).

2.4. The virtual stent fabrication

These rectangular shaped boxes and guides were drawn and designed using the Rhinoceros program. The external box, guides and internal splitting plane complex were temporarily and virtually attached together, then exported as STL objects and then imported into the mimics program (Fig. 2F). The desired splitting and implant site was identified through the radiolucent channels previously prepared in the scan appliance at the prosthetic teeth centers. The box complex was then dragged and rotated at the proposed splitting and implant site until a satisfactory trajectory of entry within the exact center of the ridge was reached. Once a satisfactory path of entry was agreed upon, The Box complex was then minused from the 3D stent object using the Boolean Minus tool. The Box complex was then separated using the "all parts" split tool to detach all its components again to make the external box, guides and the

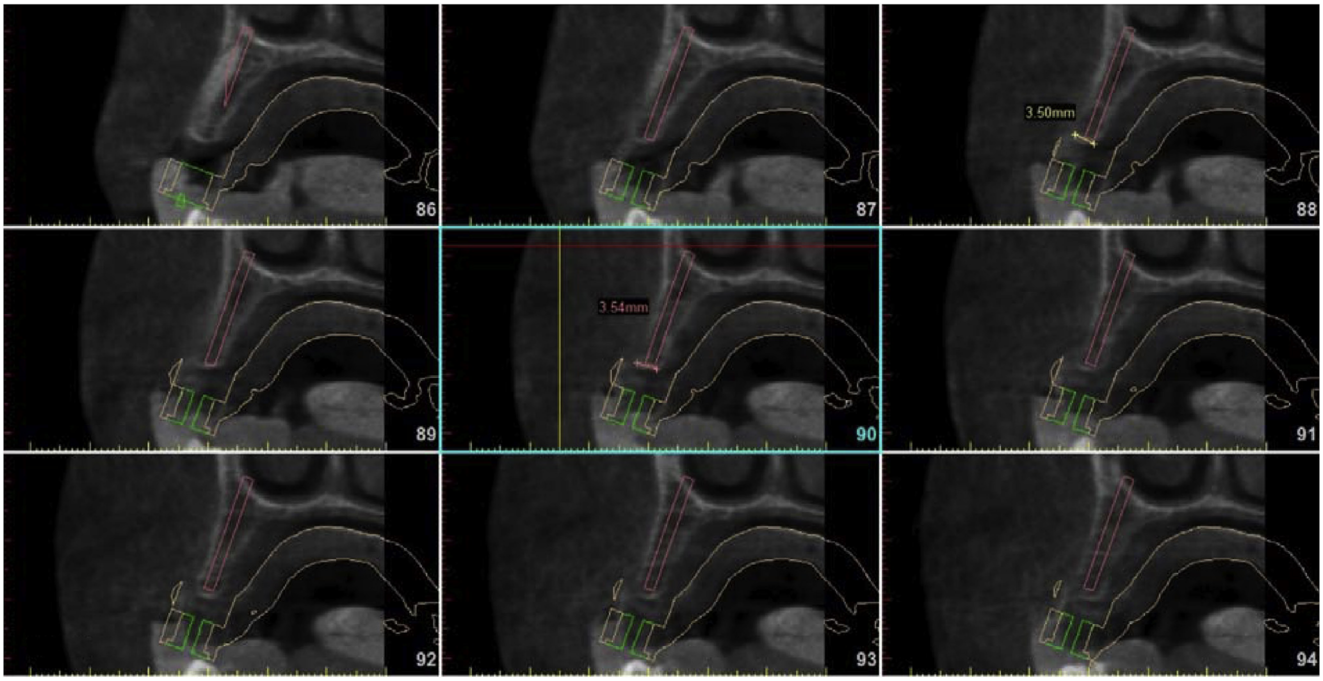

Fig. 1. The box complex being planned at the proposed splitting and implant site until a satisfactory trajectory of entry within the exact center of the ridge is reached.

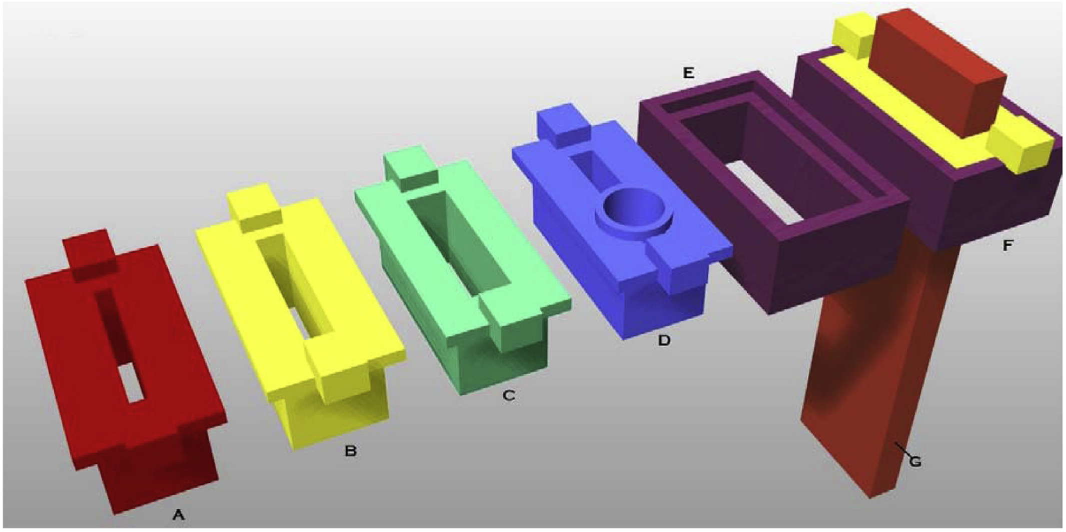

Fig. 2. The designed Bone Split and Implant Guide Tools: a: Blade Guide, b: Split Chisel Guide, c: Blade Handle Guide, d: Drill Implant Sleeve Guide, e: External Box and f: Box Complex.

internal splitting plane as distinct separate objects. The External Box was then united with the split 3D object using the Boolean “Unite” tool. The resultant virtual 3D stent was then exported as an STL (Stereolithographic) file (Fig. 3) to a 3D printing machine (Invision Si2, USA) to build the stent from a photo curable resin material (Fig. 4).

The last step involved producing the Drill Implant Sleeve Guide (Fig. 2D). A data base library of the virtual implant models used for implant planning is available and consists of intra and supra bony portions with a clearance space in between. The intra bony portion of the implant model is an accurate reproduction of the length; diameter and taper of the intra bony portion of the implant system to be used. The supra bony portion consists of a hollow cylinder with 6.05mm outer diameter, 5.05mm inner diameter and 7mm in height. The virtual implant model was then dragged and rotated at the proposed splitting and implant site until a satisfactory position within the exact center of the ridge is reached. The intra and supra bony portions of the implant models were separated using the “split” tool for each of the planned implants. The supra-bony portion of the virtual implant model was then united with the Guide box using the Boolean operation “Unite” tool (Fig. 2D). The resultant 3D virtual stent (Fig. 3), Blade guide (Fig. 2A), Blade handle guide (Fig. 2C), Chisel guide (Fig. 2B) and Drill Implant sleeve guide (Fig. 2D) were all exported as STL (Stereolithographic) files to a 3D printing machine (Invision Si2, USA) to build the stent from a photo curable resin material (Fig. 4).

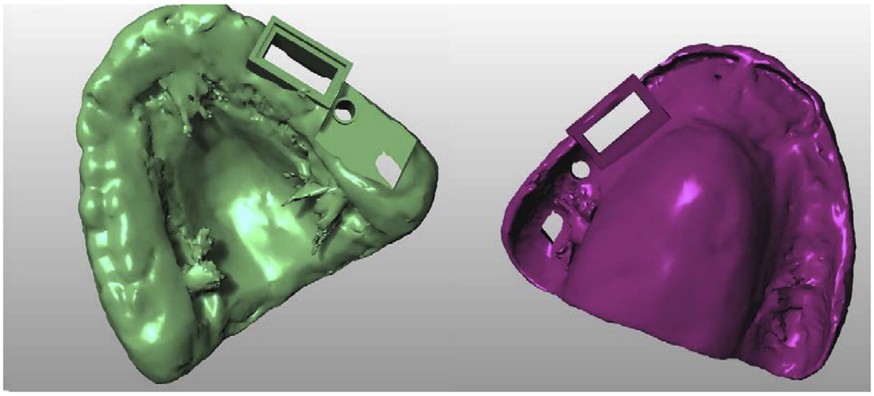

Fig. 3. The final virtual stent.

Fig. 4. The 3D printed virtual stent and guides.

Fig. 5. The Handle and blade was passed through the slit until a pre-determined depth was reached.

2.5. *The surgical procedure*

Before starting the surgical procedure, the peri-oral region of the patient was wiped by Betadine antiseptic solution, the surgical instruments were autoclaved and the computer guided stent was disinfected with a suitable disinfectant (Cidex Activated Dialdehyde Solution. J. and J. Medical). At the time of surgery, infiltration anesthesia was injected at each implant site. The stent was checked for adequate stability and fit and then fixed in place using a small amount of flowable composite injected onto the fitting surface of the anterior part of the stent opposing the natural teeth then cured while the patient was biting on the silicon interocclusal index (Fig. 4).

The Sequence of tools designed especially for this technique was used through the external box. First, the blade guide was secured in place and then the Blade No.15 (Xinda.china) was passed through the slit to start dissecting an alveolar crestal flap. Periosteum preservation was intended to reduce bone resorption and prevent free fracture of the split ridge. The Blade No.15 was then further introduced into the crestal bone to create a sagittal osteotomy using hand pressure until the blade handle hindered its further entry. The Blade guide was then replaced by the Blade handle guide allowing the handle and blade to pass through the slit until a pre-determined depth of 9mm was reached (Fig. 5). The blade handle guide was then replaced by the Chisel guide (Fig. 6) and the Bone Split Chisel (MrCurette, 13 SK Techno-Parck Tech-Center 124. Korea mct@mrcurette.co.kr) was progressively driven deeper in the crestal osteotomy using a mallet provoking a flapless split or fracture of the buccal plate of bone (Fig. 7).

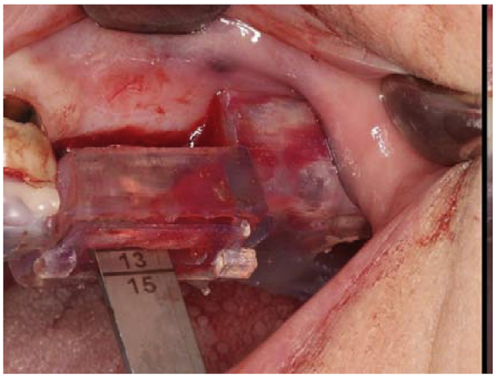

Fig. 6. The Bone Chisel was progressively driven deeper in the crestal osteotomy using a mallet provoking a flapless split or greenstick fracture of the buccal plate of bone.

2.6. *Implant placement*

The Chisel guide was then replaced by the Implant guide sleeve and Osteotomies were then prepared using the classical drilling sequence and were irrigated with sterile saline after each drill (Fig. 8). For every drill a specially designed “drill key” was used. (Fig. 9). In this case, the final drill was not used to ensure that the 3.7mm Implant diameter was slightly wider than the osteotomy

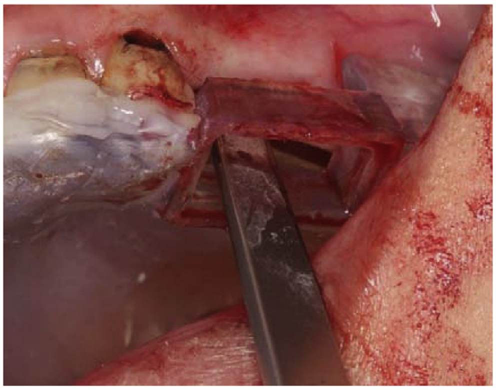

Fig. 7. The flapless split or greenstick fracture of the buccal plate of bone being produced.

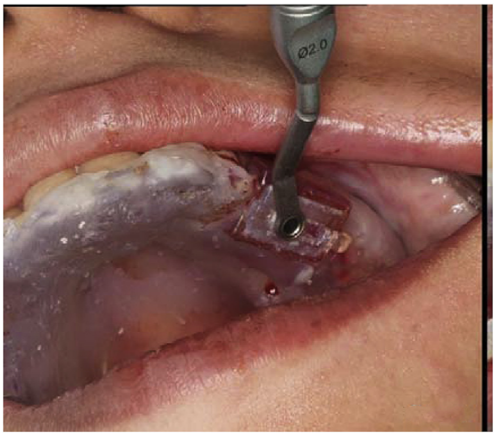

Fig. 8. The Chisel guide was then replaced by the Implant guide sleeve and the pilot drill drill key was used.

Fig. 9. Intermediate drill being used to further prepare the Osteotomy.

site created to increase primary stability. Tapered internal implant 13mm in height and 3.7mm in diameter (Osteoseal Internal Hex 51, Dupont Drive, Irvine, 92696, CA, USA) were gently tapped into position through the stent till manual tightening met resistance and further tightening was completed with a ratchet. The stent was retrieved then the primary stability of the implant was checked using the Osstell device (Osstell AB, Gamlestadsvägen 3B, SE415 02, Sweden) to ensure adequate primary stability and then the implant was allowed to heal for 3 months until satisfactory osseointegration was obtained. The patient was recalled 24hrs after prosthesis delivery and on a weekly basis for a periodic checkup. The patient was also instructed to immediately report the outbreak of any complication.

3. Results

After 3 months, the patient was recalled and the Implant was checked for adequate osseointegration clinically, using the "Osstell" ISQ device readings and radiographically using Cone Beam Computed Tomography. The Implant deviation from the preplanned virtual implant position was as well calculated by superimposing the Preoperative Ct scan over the Postoperative Ct scan performed 3 months after surgery using the Mimics program. Clinically, the Implant in this study was considered successfully osseointegrated as the following requirements were fulfilled: No pain was observed with palpation, percussion, no clinical implant mobility, no exudate as well as no peri-implantitis. The vertical Bone height measurements between the apex of the implant and the crestal bone was found to be 12.98mm buccally, 10.98mm palatally, 12.32mm mesially and 12.15mm distally (Fig. 10) while the Osstell ISQ values were found to have an ISQ value of 69. The total amount of bucco-lingual bone width was 3.54mm preoperatively while reached 5.6mm postoperatively.

To evaluate the accuracy of computer guided implant placement, superimposition of data from DICOM images of preoperative and postoperative CBCT scans was performed by the help of the radiopaque reference markers. To assess accuracy of computer based implant placement, both linear and angular deviation between the virtually planned and the actually placed implants was measured in the cross-sectional bucco-lingual planes (Figs. 10 and 11). Linear deviation measurement was represented by three separate readings (global, lateral and vertical deviations). The global linear deviation is the linear measurement between two points irrespective of the direction. On the other hand, angular deviation is the angle between the long axis of the planned implant and that of the actually placed implant as viewed in a corono-apical section. From the bucco-lingual cross-sectional view, the angular deviation was found to be 4.02°, 0.49mm coronal global linear deviation, 0.46mm apical global linear deviation, 0.48mm coronal lateral deviation, 0.44mm apical lateral deviation, 0.15mm both coronal and apical vertical deviation. While from the axial view, the linear deviation from the global center of planned and global center of placed was found to be 0.37mm in a palatal direction (Fig. 11).

4. Discussion

The bone splitting technique using this novel computer guided ridge method in this case report proved to be valid method for the immediate placement of implants in cases where the buccal-lingual dimension of alveolar bone is insufficient but the bone height is adequate. This was in accordance with a study performed by **Bassetti et al.** [15] where they considered alveolar ridge splitting as a well-functioning one-stage alternative to extended two-stage horizontal grafting procedures [15]. This surgical technique was as well described by **Simion et al.** [8] as a longitudinal alveolar ridge splitting in two parts, provoking a greenstick fracture using small chisels allowing simultaneous positioning of implants and thus significantly shortening the treatment time.

In this case report, a new innovative flapless computer guided ridge splitting technique has been advocated allowing preservation of the periosteum thus avoiding the disruption of the blood supply to the provoked flapless split or greenstick fracture of the buccal

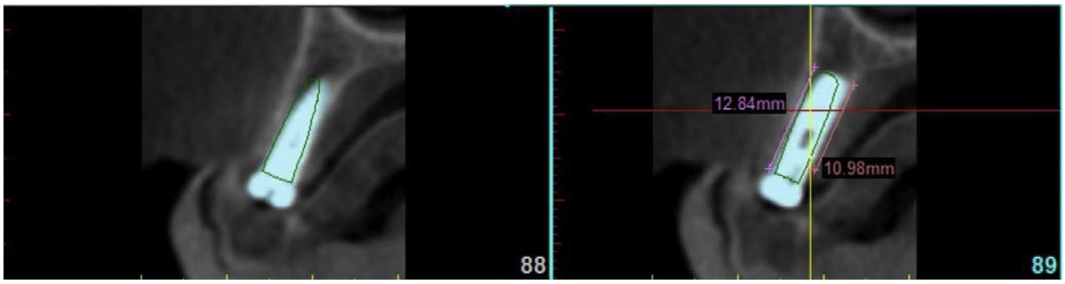

Fig. 10. Superimposition using the STL Registration tool showing the degree of deviation between the Virtually Planned Implant (green) and The actually Placed Implant (blue). Bone height values are also shown in the bucco-lingual view.

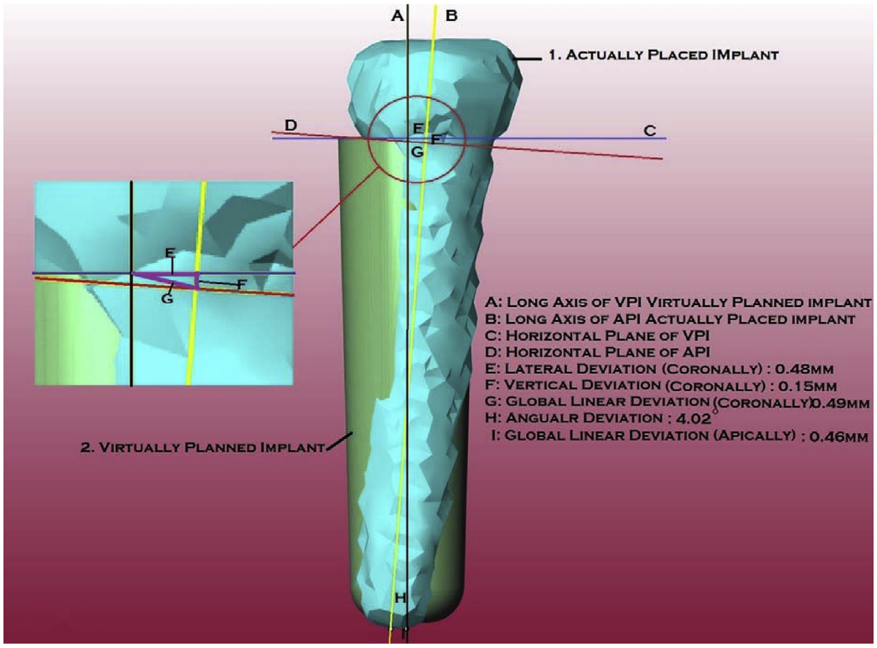

Fig. 11. Linear and Angular Deviation measurements between the Virtually Planned Implant (green) and the Actually Placed Implant (blue) in the bucco-lingual plane.

plate of bone. The periosteum preservation also helped stabilize the ridge split fracture and reduced the resorption of bony plates and marginal bone. This was in accordance with a study performed by **Zheng** [16] who used a modified split-crest flap technique. Owing to this minor flap, the buccal bony plate connected with the vascular periosteum was able to achieve reconstruction of the free fracture [16], the results of this study showed minimal deviations between the planning before and after implant installation and this in agreement with previous studies [4,5].

5. Conclusion

Due to the computer guided, flapless, alveolar ridge splitting technique, the periosteum preservation helped maintain an adequate blood supply to the split buccal plate of bone, stabilized the ridge split fracture and reduced the resorption rate of the bony plates. For the alveolar ridge with insufficient thickness but adequate height, this computer guided flapless alveolar ridge splitting technique can be a predictable, less invasive, an atraumatic technique and a viable treatment option when immediate implant placement is a prerequisite and minimized treatment time is required.

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Conflicts of interest

None.

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