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An Innovative Technique for Complete Digital Workflow in Full Arch Implant Rehabilitations

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Abstract

Purpose

The digitalization of the dental field has been recently introduced and has resulted in a significant simplification of clinical procedures. Accuracy of intraoral scanner was improved over the years, but the realignment of the files may be inaccurate, in some clinical conditions, due to the absence of reference points. The aim of this paper is to present an innovative protocol called "files overlapping technique" which allows a simplified complete digital flow in immediate full arch implant rehabilitations.

Materials and Methods

Twelve patients were treated with complete digital workflow following the proposed technique.

Ninenty - seven implants were inserted, and fifteen full arch implant restorations were performed. The protocol requires at least three residual and sufficiently stable dental elements. The protocol begins with a complete scan of the arch to be operated, its antagonist arch and the registration of occlusal relationship. A pilot fixed provisional was made to provide information about aesthetic and function. The key step for the realignment with the post-surgical scan was represented by a single scan of the pilot provisional and reduced teeth. A plaster

model was used to verify the precision of the proposed protocol.

Results

The correct matching was confirmed by radiographs and by coupling the provisional to the model obtained by resin rigid impression. The aesthetic and functional needs of all patients were satisfied. The patient parameters (such as vertical dimension and other aesthetic of functional data) have been registered with a functionalized provisional and utilized for definitive prosthesis construction without any data loss.

Conclusion

The protocol presented allows to realize a full post extractive implant rehabilitation with immediate loading using a complete digital workflow. The use of the pilot provisional allows to obtain aesthetic and functional information before the day of surgery. Clinical studies with longer follow-up are needed to better evaluate the potential of the files overlapping technique.

Introduction

The introduction of immediate loading in implant dentistry represented a paradigm shift in as it was previously believed that an unloaded period was essential for a successful osseointegration[i]. Dental implants immediate loading techniques have undergone numerous evolutions, over the years, both from a surgical and prosthetic point of view[ii].

International literature[iii,iv] has irrefutably shown that this technique offers similar results, in terms of implant survival and success rates, compared to early loading implants. A recent literature review study[v], analyzing 763 references, demonstrated that immediate loading could achieve comparable implant survival rates and marginal bone level changes compared to early loading.

Immediate loading protocols, however, allows the patient's waiting times to be reduced, lowering the discomfort associated with removable temporary prostheses. It was also reported that immediate loaded post-extractive implants were associated, in some cases, with better aesthetic results than conventional loaded implants[vi].

There is strong evidence to suggest that immediate loading protocols demonstrate high implant survival rates and could be cautiously recommended for many clinical situations[vii]. To this end, implant immediate loading protocols requires considerable skills and knowledge both from the surgeon and prosthodontist.

Implants should have sufficient primary stability to be immediately loaded and the surgeon must know the principles of implant stability[viii] and the factors that can influence it in a significant way. We can distinguish factors related to the implant such as implant geometry[ix,x], implant surface[xi], diameter and length[xii] and factors related to the bone site such as preparation type[xiii] (over or under preparation), site preparation technique (traditional drills, osteotomes[xiv], osseodensification technique[xv]) and local bone density[xvi].

The immediate prosthetic phase however, that follows the implant surgery, represents a key step of the whole immediate loading protocol and any mistakes made at this stage can lead to prosthetic or implant failure. It is fundamental to avoid any fracture of the provisional prosthesis because it may result in local overloading. Also, unevenly distributed occlusal

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contacts may contribute to implant failure and therefore occlusion ought to be evaluated at every occasion, especially during the early phase of healing.

In addition, patients restored with immediate full arch rehabilitation need the reconstruction of the occlusal plane and the restoration of the vertical dimension of occlusion. The correct registration of these occlusion parameters represents an essential phase of immediate prosthetic to obtain good aesthetic results for the patient.

The multi-unit implant impression, the restoration of the vertical dimension of occlusion and the correct repositioning of the implant analogues in the model are the three basic steps in immediate loading implant protocol that should be carried out with caution and considerable expenditure of time.

Last developments in digital dentistry process coupled with the increased precision of new intra-oral scanners[xvii,xviii], allows now a considerable simplification of prosthesis protocol for immediate full arch implant rehabilitations. Some Authors demonstrated that the digital impression might offer a viable alternative to traditional impressions to manufacture full-arch implant-supported prostheses with satisfactory passive fit[xix]. The main goal of the use of this technology, in the field of prosthetic dentistry, is represented by the generation of a complete virtual environment without any physical model.

Although there is no doubt about the advantages that digital technology offers in terms of speed of execution and precision in cases of full arch implant rehabilitation, there are still no standardized procedure for obtaining predictable results. To Author's knowledge, however, the most used digital protocols for immediate full arch restorations involved the creation of a physical master model or a double optical scan to obtain a sufficient precision in fixture-abutment coupling.

In particular, the realignment of the files may be inaccurate due to the absence of reference points. If it is a complete digital workflow, the lack of certain reference points inevitably forces the clinicians to a new registration of aesthetic and functional parameters (such as vertical dimension, teeth position, etc) both for the construction of provisional and the definitive prosthesis. In this way, the parameters detected for the construction of the provisional cannot be used in the construction of the definitive unless you go through analog phases or the construction of physical plaster models.

The aim of this paper is to show tan innovative protocol called "files overlapping technique" which allows a complete simplified digital workflow for full arch post-extractive implant rehabilitation cases.

Materials and Methods

Twelve patients were treated with one or more immediate loading full arch implant rehabilitations following the proposed technique of overlapping files. Each patient, needing the implant rehabilitation of an entire arch, received several titanium dental implants ranged from 4 to 9 (for one arch). Ninenty-seven implants were inserted (Table 1). This innovative protocol requires at least three residual and sufficiently stable dental elements.

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Table 1: Implant type and number in each patient

Patient No.	Implants type	Implants Number	Implants Details	Maxilla	Mandible
1 -	4 Standard (Neodent©) 2 Zygomatic (NorisZigo©)	6	3.5 x 13 mm 3.5 x 11.5 mm 3.5 x 13 mm 3.5 x 11.5 mm 4.2 x 45 mm 4.2 x42.5	X	
2 -	Standard (Straumann BLT©)	8	4.1 x 12 mm 4.1 x 14 mm 4.8 x 12 mm 4.8 x 10 mm 4.1 x 12 mm 4.1 x 14 mm 4.8 x 10 mm 4.8 x 12 mm	X	
3 -	Standard (Straumann BLT©)	8	4.1 x 12 mm 4.1 x 12 mm 4.1 x 12 mm 4.8 x 12 mm 4.1 x 14 mm 4.8 x 10 mm 4.1 x 14 mm 4.1 x 12 mm	X	
4 -	Standard (Straumann BLT©)	15 (9 in maxilla and 6 in the mandible)	Mandible: 4.1 x 12 mm 3.1 x 12 mm 4.1 x 8 mm 4.1 x 12 mm 4.1 x 10 mm 4.1 x 8 mm Maxilla: 4.1 x 12 mm 4.1 x 10 mm 4.1 x 10 mm 4.1 x 12 mm 3.3 x 12 mm 3.3 x 12 mm 4.1 x 12 mm 4.1 x 12 mm 4.1 x 12 mm	X	X
5 -	Standard (Geasssrl©)	6	4.5 x 10 mm 4.5 x 13 mm 4.5 x 10 mm 4.5 x 9 mm 4.5 x 11 mm 4.5 x 11 mm	X	
6 -	Standard (Geasssrl©)	6	3.8 x 11 mm 3.8 x 11 mm	X	

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			4.5 x 11 mm 4.5 x 11 mm 4.5 x 9 mm 4.5 x 9 mm		
7 -	Standard (Geasssrl©)	6	3.8 x 11 mm 3.8 x 11 mm 3.8 x 13 mm 3.8 x 13 mm 4.5 x 11 mm 3.4 x 11mm	X	
8 -	Standard (Neondent©)	10 (6 in the maxilla and 4 in the mandible)	Mandible: 5 x 11.5 mm 4.3 x 16 mm 4.3 x 16 mm 4.3 x 11.5 mm Maxilla: 4.3 x 16 mm 4.3 x 13 mm 4.3 x 10 mm 4.3 x 13 mm 4.3 x 16 mm 4.3 x 8 mm	X	X
9 -	Standard (Geasssrl©)	6	3.8 x 13 mm 3.8 x 13 mm 3.8 x 11 mm 3.8 x 11 mm 4.5 x 10 mm 4.5 x 10 mm		X
10 -	4 Standard (Geasssrl©) 2 Short (Geasssrl©)	6	3.8 x 11 mm 3.8 x 10 mm 3.8 x 10 mm 3.4 x 12 mm 4.5 x 5 mm 4.5 x 5 mm		X
11 -	Standard (Geasssrl©)	6	3.4 x 11 mm 3.4 x 11 mm 3.8 x 8 mm 3.8 x 8 mm 3.8 x 8 mm 3.4 x 13 mm		X
12 -	Standard (Straumann BLX©)	14 (8 in the maxilla and 6 in the mandible)	Mandible: 5.5 x 8 mm 4.5 x 12 mm 3.75 x 12 mm 3.75 x 12 mm 4.5 x 12 mm 4.5 x 10 mm Maxilla: 4.5 x 10 mm 4.5 x 12 mm	X	X

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			3.75 x 12 mm 5.5 x 10 mm 3.75 x 10 mm 4.5 x 14 mm 4.5 x 12 mm 4.5 x 10 mm		

A plaster model was created for each patient, to verify the accuracy of the proposed technique. Implant transfers were screwed onto the fixtures and subsequently splinted by rigid plexiglass plate and resin. The plexiglass plate was removed from the oral cavity of the patient and the analogues were screwed onto the transfers. A plaster model with implant analogues in it was created. This model will be used only to verify the precision of the digital impression.

In all cases, rotative abutments were positioned and cemented to the provisional prosthesis with dual core adhesive (DTK, Bredent, Italy)

In all cases, the immediate prosthesis was made of stratified PMMa. This material was preferred to others because of his physical properties. It shows flexural strength greater than 100 Mpa and an elastic modulus greater than 2200 MPa. It was assessed that it be left in the oral cavity, without undergoing substantial modifications, for two years.

Through a questionnaire, delivered at the beginning of treatment, the patient was asked the degree of appreciation of the entire digital protocol.

Files Overlapping Protocol

The file overlapping protocol implies, in extended or full arch rehabilitation cases, the creation of a fixed provisional on residual teeth of the patient called “pilot provisional”. The residual teeth will be extracted after the surgery and the digital scan. At least three residual stable teeth are needed to perform this technique.

The protocol begins with a complete scan of the arch to be operated, its antagonist arch and the occlusal relationship between mandible and maxilla in centric relation (Figures 1-2). The scan files are sent by e-mail to the dental lab. The dental technician can import images and files into the cad design software to plan the case (Figure 3). He will be able to position the models in a virtual articulator, using intra and extra oral photos and scans.

Based on the clinical indications found on the patient, it is possible to proceed with the virtual modeling of the provisional (Figure 4). It is important to establish the correct function and aesthetic, giving stable contacts in occlusion and evaluating the midline, smile line, occlusal plane, overbite, overjet and other elements that could influence the aesthetic outcome.

Once the CAD design has been carried out, the laboratory produced the PMMa milled provisional with a 5-axis milling machine (Figure 5).

At this point the clinician can proceed with the prosthetic reduction of the residual dental elements in the mouth of the patient. After the reduction a digital scan is necessary.

The purpose of the "pilot provisional" is manifold. In fact, the same, suitably relined and fixed in the oral cavity, provides us much informationabout the aesthetic and the functional aspect. After the time necessary for its functionalization and only after having assessed the correct aesthetic aspect, a new scan is performed. The scan must include the arch to be

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operated with the pilot provisionalfixed on residual teeth,the newocclusion, and the vertical dimension of occlusion.

The next step consists in drilling the pilot provisional in the palatine and / or occlusal portion of the residual teeth to create some scan window that can simultaneously detect the pilot provisional and the reduced teeth in a single image (Figure 6). This scan together with that of the reduced teeth isa key step for the realignment with the post-surgical scan.

Before starting with dental extraction and implant surgery it is necessary to choose the elements to keep for the post-surgical scan phase.These elements are fundamental for the realignment of all the files of all the scans made and, therefore, must be chosen strategically. It is strongly suggested to choose a tripod, three equidistant elements, sufficiently stable that allow us to align on the three axes of the Cartesian plane.

Dental titanium implants are inserted after this step. The last scan to be performed is the post-surgical one, where the scan bodies screwed to the implants and the selected residual elements are detected together (Figure 7).

At the end of the post-surgical scan, in order to produce the plaster model of verification, the transfers splinted to each other and to the plexiglass plate are screwed to the implants using self-curing resin.

The purpose of this template is to produce an analog base with analogs inserted in the plaster to verify the accuracy of the entire digital flow.

The obtained files are sent to the laboratory which through the dedicated software recalls the scan body files of the post-surgical scan with those of the libraries to verify the best fit (Figure 8).

The next step is to superimpose the scan files of the provisional perforated pilot pre-priming, with the scan files with the selected scan bodies and abutments using the scan windows as the method of re-coupling, obtaining the patient's arch in a single fileoperating with the temporary pilot provisional in the exact position (Figure 9).

This last file contains all the fundamental and already tested information on the patient such as occlusion, vertical dimension and aesthetics.

In this way the CAD operator will have to keep the shape of the project unchanged and adapt the prosthesis only in the cervical portion adapting it to the situation of the post-surgical patient. Once the virtual modeling is completed, a palatal cavity will be obtained where a reinforcement bar will be virtually modeled (Figure 10).

Then, the temporary in PMMa is milled and the CrColasermelting bar is produced (Figure 11). The prosthesis is then refurbished, and the metal bar incorporated with acrylic resin which provides rigidity and resistance to the prosthesis in immediate loading. Finally, after polishing, the provisional is bonded to the linkers, checking the correct housing on the analog template.

The last phase involves the passive screwing of the provisional to the oral cavity implants and control radiographs.

Intra-oral radiographs of scan body screwed to the implants were compared with those of the provisional screwed in order to check the accuracy of the scans (Figure 12).

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Discussion

The "file overlapping protocol" satisfied several objectives by both the patient's and doctor's point of view. Patients referred that they appreciate the digital protocol with a rating scale from medium to high.

An aspect of considerable difficulty in traditional immediate loading protocol consists in taking a correct post-surgical impression. In fact, the use of traditional impression materials has some disadvantages that could result in poor accuracy such as low comfort for the patient, long setting times and hydrophobicity of the material.

The optical impression, on the other hand, allows to record the area subjected to surgery without any contact. Moreover, the digital can be performed several times without any loss of precision.

The main problem with the fully digital workflow is represented by the accurate realignment of the files between the provisional and the definitive prosthetic restorations. In many cases, in fact, the clinical parameters of the patient (such as vertical dimension and aesthetic or functional data) recorded to perform the provisional prosthesis must be re-registered for the construction of the final prosthesis because it is not possible to perfectly align the files as there are no stable reference points.

This technique allows, in immediate post extractive implant cases, the identification of references points for an accurate realignment of files during the digital workflow. The patient parameters (such as vertical dimension and other aesthetic of functional data) could be registered with a functionalized provisional and utilized for definitive prosthesis construction without any data loss.

Andriessen et al[1] observed that in their intraoral scans, obtained in a clinical study on edentulous mandibles, distance and angulation errors were too large to fabricate well-fitting frameworks on implants in edentulous mandibles. The authors individuated the main reason for the unreliable scans in the lack of anatomic landmarks for scanning.

The protocol proposed allows to overcome the limit of the absence of reliable landmark of scanning.

The technique, discussed by the present study, eliminates the needing of master models and allows the correct identification of patient's vertical dimension avoiding any possible operator-dependent mistakes.The correct vertical dimension, detecting by associating a careful analysis of the masticatory function, could be replicated in the final restoration using a digital workflow without data loss. In fact, aesthetic and functional data are obtained through the pilot provisional in advance of the actual day of surgery and the scan of the provisional with the stable reference points ensured an accurate realignment of files.

The digital protocol proposed by the present paper is quite simple. A learning curve is required but, with constant exercise, a considerable degree of precision can be obtained (less than 50 microns).

Clinical studies with longer follow-up are need to better evaluate and validate the excellent results obtained with the file overlapping technique.

Declaration

Ethics Approval and Consent to Partecipate

The present clinical retrospective investigation was consistent with ethical principles of the Declaration of

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Helsinki including the World Medical Association. An informed and written consent was obtained from each subject according to the above-mentioned principles.

Consent for Pubblication

An informed and written consent was obtained from each subject accord in ordering to publish the radiological data and photos.

Availability of Data and Material

All data and material are available from the first Author Francesco Zingari.

Competing Interests

All Authors declare that there are no conflicts of interest between them and products listed in the manuscript.

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Authors' Contributions

Francesco Zingari (surgery, digital impression, prosthesis); Francesco Gallo (surgery and prosthesis); Marco Genovese (prosthesis manufacturer, digital analysis, photos);Marco Berardini (manuscript preparation)

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Figure legend

Figure 1 – Initial scan of the patient.

Figure 2 – Scanning in maximum intercuspation position (centric occlusion).

Figure 3 - CAD import of the patient's face and positioning of the upper jaw on the horizontal plane.

Figure 5 – CAD milling pf Pmma and pilot provisional finishing

Figure 6 – Creation of holes of sufficient width to an optimal scan of the underlaying abutments.

Figure 7 – From left to the right: pre-surgical scan with pilot provisional, pos-tsurgical scan with scanbodies, digital matching of the pilot provisional on post-surgical model.

Figure 8 – Best fit for checking a good scan of the scanbodies.

Figure 9 – Facial scan with the pilot provisional positioned on the implants.

Figure 10 – Design of the immediate provisional, starting from the pilot provisional.

Figure 11 – CAD framework design and the realized fixed provisional prosthesis.

Figure 12 – Control X-rays.

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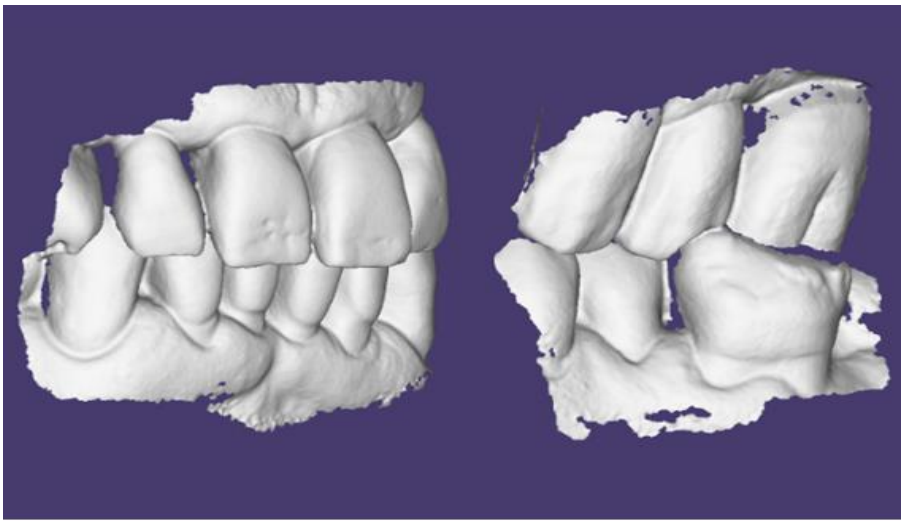

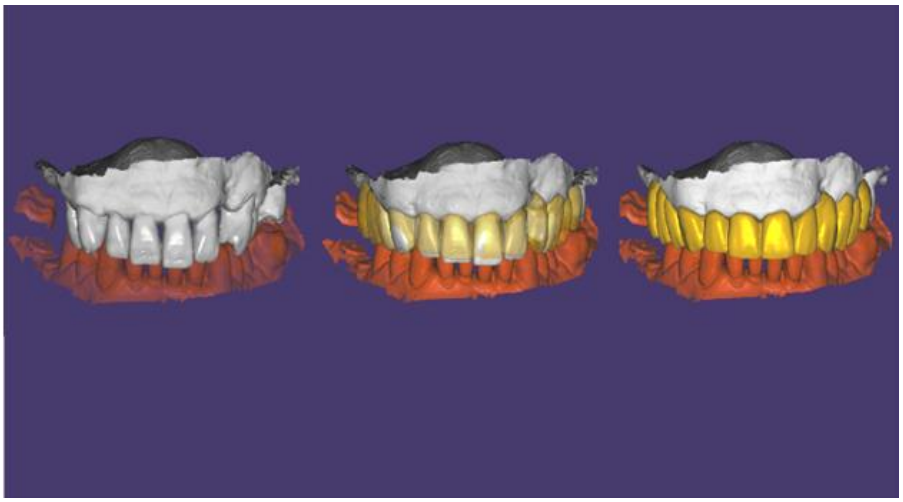

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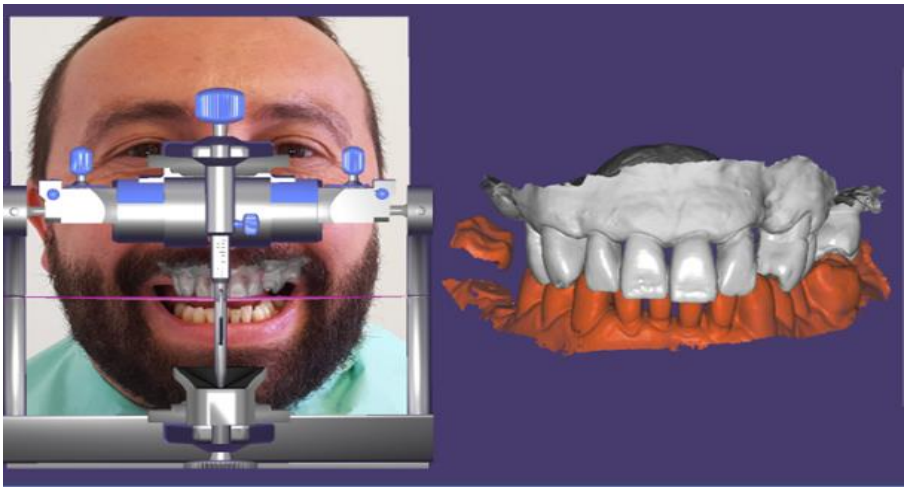

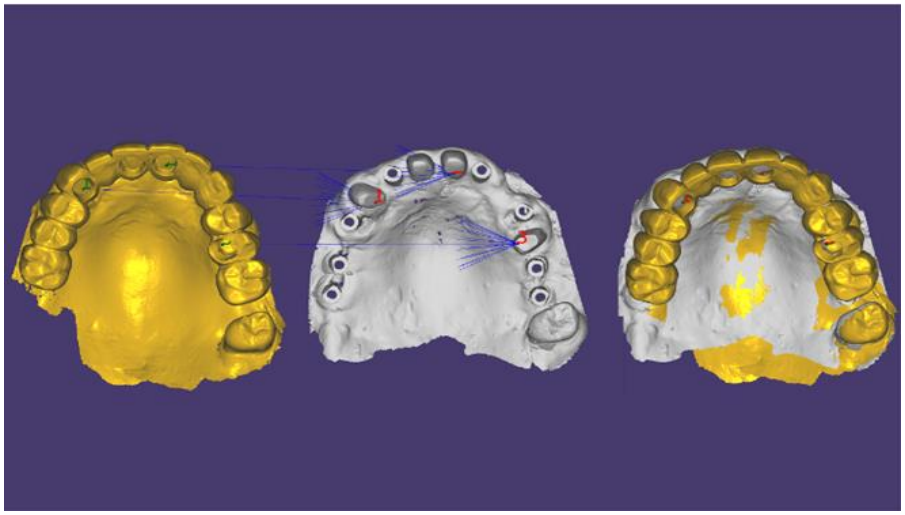

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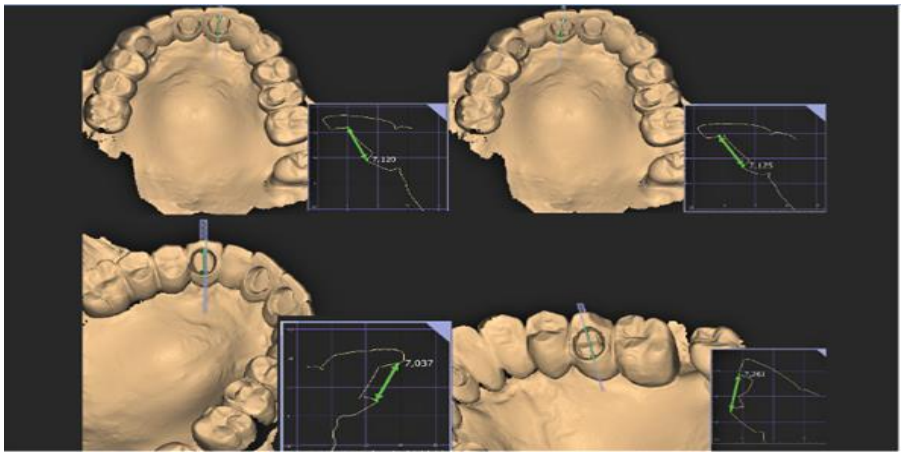

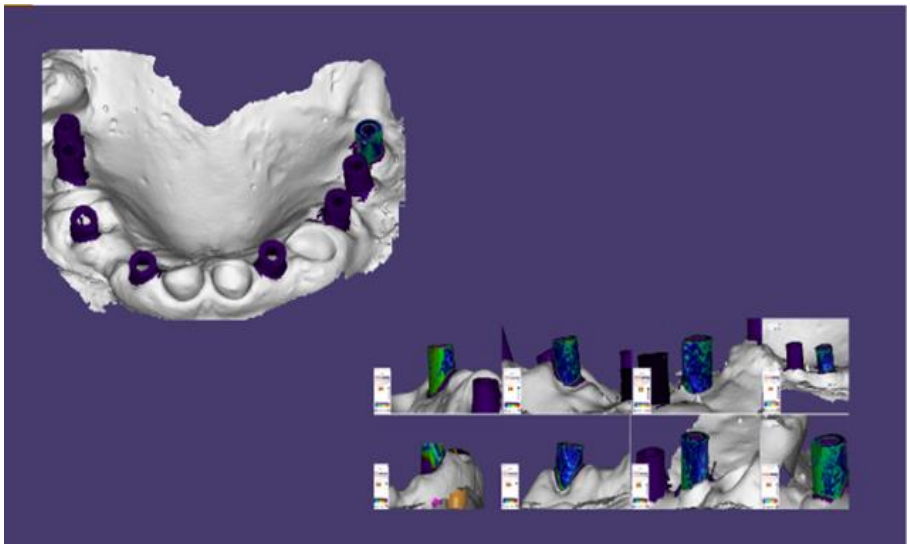

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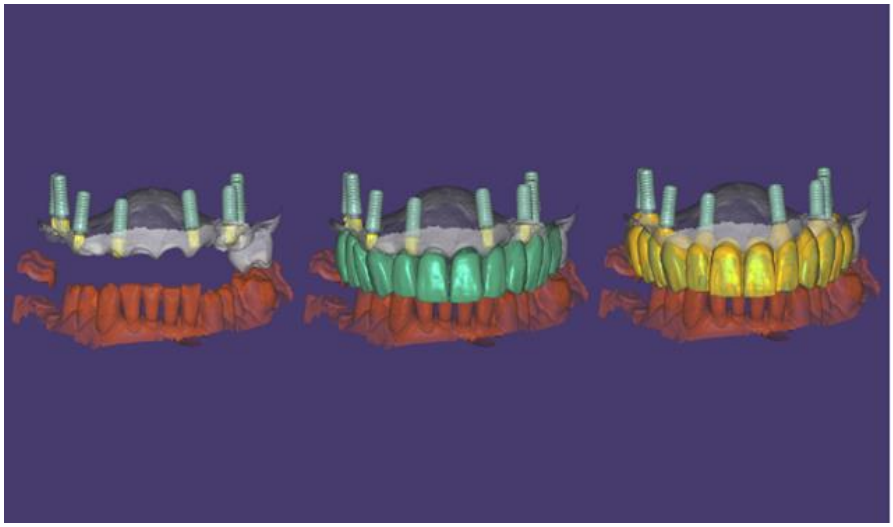

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