SURGICAL GUIDE PREPARATION FROM COMPUTED TOMOGRAPHY DATA FOR PLACEMENT OF DENTAL IMPLANTS

Dissertation submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

In partial fulfillment for the Degree of

MASTER OF DENTAL SURGERY

BRANCH III

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CERTIFICATE

This is to certify that this dissertation titled **"SURGICAL GUIDE PREPARATION FROM COMPUTED TOMOGRAPHY DATA FOR PLACEMENT OF DENTAL IMPLANTS"** is a bonafide record of work done by **Dr. PRASHANT KUMAR** under our guidance and to our satisfaction during his postgraduate study period **2009-2012.**

This Dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the award of the Degree of **MASTER OF DENTAL SURGERY – ORAL AND MAXILLOFACIAL SURGERY, BRANCH III.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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CONTENTS

INTRODUCTION

Precise placement of dental implants have revolutionized our ability to provide the better dental prosthesis with ideal function compatible with excellent esthetics and phonetics, without compromising hygiene maintenance.[23]

Also accurately placed dental implant becomes the key for success of dental implant osteointegration & its longevity.

Conventional technique done with Orthopantomogram, mock surgeries does not give much information and is not accurate.

Computer - aided implant planning on the 3-dimensional (3D) CT data has been introduced to overcome the diagnostic limitations of conventional two - dimensional radiographic means including expansion and distortion factors, setting error and position artefacts and the lack of complete three - dimensional information.

Various implant libraries are available to simulate and select the appropriate implant size and options are also available to produce the sterolithographic models to fabricate surgical guides.

The locations, angulations, depth of dental implant, height and density of bone can be determined accurately using computerized tomography (CT) imaging.

CT data in DICOM (Digital imaging & communications in medicine) format is imported into Implant simulation software (IMPLANT 3D) for reconstruction and is used to identify regions were bone is adequate & virtual Implants are positioned on the computer screen so that enough amount of good quality bone lies all around its body and coronal emergence to be directed prosthodontically. This data is then exported in STL (standard triangulation language) format to generate a physical model using Rapid Prototyping technology, which is then used to fabricate the *surgical guide*.

In this prospective study, a *surgical guide with progressive 316L stainless steel sleeves of diameter 2mm, 3mm, 4mm, 5mm & 6mm are* designed to facilitate accurate transfer of virtual implant position from the computer screen to the patient's edentulous jaw.

This *surgical guide* can be used in completely as well as partially edentulous situations. It can be supported by soft tissue, by bone, or by remaining teeth. The guide used in this study was bone borne.

Preoperative prosthetic planning is crucial for a long term success. This *surgical guide* fabricated on stereolithographic model which is generated through the use of implant software helps to precisely transfer a prosthetically directed treatment plan to the patient. It reduces the intra operative surgical time and increases the accuracy and efficacy of the surgery.

AIM & OBJECTIVE

AIM:

"The aim of this study is to simulate virtual implant placement with computed tomography data using implant simulation software (IMPLANT 3D) and to construct a surgical guide with progressively diameter sleeves to accurately place implants."

OBJECTIVE:

To compare and evaluate the;

1. Pre-operative virtually planned position of implants using Panormic (Pan) & Sectional (Sect.) angles with,
2. Post - operative actual position of implants using Pan & Sect. angle.

MATERIALS & METHOD

The materials used in the present study:

1. High end multimedia computer with minimum 4GB of RAM

2. Software – Implant 3D, Media Lab Limited.

3. Rapid prototype model.

4. Surgical guide.

5. 316L Stainless steel sleeves of 2mm, 3mm, 4mm, 5mm & 6mm

METHODOLOGY

The following methodology was adopted for the study:

Selection of patients

↓

Clinical examination

↓

Radiological diagnosis

Computerised spiral tomography scans (0.5 mm cuts, in DICOM format in a compact disc)

↓

Import of data in the implant simulation software

↓

Evaluation of available bone height, width, density and adjacent vital structures

↓

Positioning of virtual implants

↓

Export of data in STL format

↓

Fabrication of rapid prototype model

↓

Preparation of surgical guide

↓

Implant placement through guide

↓

Post-operative evaluation of implant position and angulation to their pre-operative values.

This clinical study was conducted in the department of Oral & Maxillofacial Surgery, Ragas Dental College & Hospital, Chennai, India. The recruitment of patient and subsequent treatment was conducted under an informed consent document.

Approval of the study protocol was obtained from the Institutional Review Board (The Ethical Committee) of the Ragas Dental College & Hospital, Chennai, India.

Selection of patients

Selection of all the patients for this study was done under the following standard protocol:

Inclusion criteria:

- Patients willing and able to complete the study after obtaining informed consent in accordance with ethical clinical policies.
- Edentulous and / or partial edentulous maxillary and / or mandibular ridge.
- Acceptable oral hygiene.

Exclusion criteria:

- Alcohol or drugs, or have a daily smoking habit.
- Uncontrolled periodontal disease.
- Radiation therapy to the head and neck region.
- Patients with any disease or condition or on any medication that might compromise healing or osseointegration.
- Patients with para functional habits/severe bruxism.

During the initial consultation, patient's chief complaint and the expectations were elicited and noted regarding treatment requests for all the patients screened and included in the study.

CASES & RESULTS

Case 1

A 25 year old male patient came with chief complaint of missing lower posteriors(Fig.1b) and wanted replacement with permanent teeth.

On examination, inter occlusal clearance was found to be 4 mm because of supraeruption of maxillary left posteriors(Fig.1a). In such situation surgical correction is always preferred as it offers advantage of correcting alignment of the segment also.

Patient was made aware of the existing situation.

CT scan was taken and data imported for reconstruction(Fig.2). The right mandibular posterior teeth were mirrored and aligned on the left side and implants were simulated along the long axis of posterior teeth(Fig.3a). The left posterior maxillary segment was osteotomised and intruded so that it aligns properly with lower left segment of mandible(Fig.3b). An stereolithographic file(Fig.3a,b) was produced in the same position. A rapid prototype model(Fig.4) was created. Splint to position upper maxillary segment was prepared(Fig.5).

In the lower jaw a surgical guide was created using implant extensions(Fig.6) as described earlier. Case was posted under general anaesthesia and left posterior maxillary osteotomy done to reposition the segment(Fig.7) and 3 implants in the planned positions were placed in mandibular arch using the surgical guide(Fig.8,9,10).

Prosthetic rehabilitation was done 6 months post operatively(Fig.15b,16).

Case 2

A 59 year old female patient with several missing teeth and poor periodontal status(Fig.17) was presented from the department of Prosthodontics to the department of Oral and Maxillofacial Surgery, Ragas Dental College, Chennai for discussion.

Patient wanted replacement of missing teeth. On clinical and radiological examination several edentulous spaces in upper and lower arch, periodontially compromised anteriors, inadequate width in 46 region and sinus level was found too low bilaterally(Fig.17b-g)

Case was discussed and planned for bilateral sinus lift and bone ridge augmentation in 46 region, removal of compromised teeth and later rehabilitation using endosseous implants.

Case was posted under general anesthesia, autogenous bone graft was harvested from right iliac crest. Bilateral sinus lift(Fig.18,19) and ridge augmentation in 46 region was done using the bone graft(Fig.20)

Six months later CT scan was taken to evaluate present situation and virtual planning for implant placement was done(Fig.22). Data was imported in stereolithographic file, a maxillary rapid prototype model with implant extensions was obtained(Fig23), surgical guide was prepared as discussed earlier(Fig.24) and 8 implants were placed in maxillary arch. Implants in mandible were placed using conventional technique.(Fig.25)

Patient recalled for regular follow up.

Seven months later prosthetic rehabilitation was done with implant supported fixed bridge in both upper and lower jaw(Fig.34b,36).

Case 3

A 40 year old, male patient was presented with edentulous region in both upper and lower jaw and periodontially compromised posteriors(Fig.37). Patient was planned for implant supported fixed bridges, initially with mandible and then the maxilla. A maxillary denture was prepared and 5 implants were planned in the mandible. Pre operative planning and simulation of virtual implants(Fig.38), rapid prototype model with implant extensions(Fig.40a) were done and surgical guide(Fig.40b) was prepared as described earlier. Implants were placed in pre operative planned position using surgical guide under local anesthesia(Fig41). Prosthetic rehabilitation was done 6 months post operatively(Fig.48c,50)

Case 4

A 67 year old, male patient of edentulous maxilla, maxilla was severely resorbed, causing inadequate retention of maxillary denture(Fig.51). The situation demanded implant placement without using bone graft to support the upper denture for retention. So it was planned to place two implants in nasal buttress and one in midline to give an implant supported hybrid denture. A CT scan was taken, pre operative virtual planning and implant simulation(Fig.52) was done to place one implant in the midline above the incisive foramen and canal and 2 in nasal buttresses. A rapid prototype model were obtained(Fig.53a,b). Surgical guide was prepared(Fig.54) as described earlier and used to place implants in the planned position(Fig.55c,56). Patient has to be rehabilitated.

STATISTICAL ANALYSIS

Case 1

Name : Mr. Siva Subramaniam

Age : 26 years

Sex : Male

Arch : Mandibular arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	-11	0	-11	-3	0	3
2	-11	0	-11	0	0	0
3	-11	0	-13	2	2	2

Total number of implants : 3

Case 2

Name : Mrs. Muthumal Peter

Age : 61 years

Sex : Female

Arch : Maxillary arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	-18	178	18	178	0	0
2	17	183	17	180	0	3
3	12	192	12	185	0	7
4	11	196	11	190	0	6
5	-6	192	-5	182	1	10
6	-11	187	-11	180	0	7
7	-10	182	-10	179	0	3
8	-18	171	-18	179	0	0

Total number of implants : 8

Case 3

Name : Mr. Kanthappan

Age : 42 years

Sex : Male

Arch : Mandibular arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	31	8	31	0	0	8
2	23	0	20	344	3	16
3	22	353	21	357	1	4
4	-29	9	-10	328	19	32
5	-34	358	-24	345	10	15

Total number of implants : 5

Case 4

Name : Mr. Viswanathan

Age : 67 years

Sex : Male

Arch : Maxillary arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	-8	190	-8	185	0	5
2	6	187	6	187	0	0
3	0	190	0	188	0	2

Total number of implants : 3

A total of 19 implants were placed in the planned positions that were used for rehabilitation. No complication as nerve injury has occurred.

2 out of 19 implants showed minor deviations in angulation from the planned angulation, being compensable by standard angle abutments.

1 out of 19 implants showed major deviation in angulation from the planned angulation which required correction by, custom milled abutment during rehabilitation.

Data was entered and analysed using SPSS 10.5 (Statistical package for social science). Paired-t test was used to compare the variables (PAN angle & SEC angle) between pre operative and post operative conditions.

The p value less than 0.05 is considered statistically significant.

VARIABLE	GROUP	SAMPLE (N)	MEAN	STANDARD DEVIATION	P - VALUE
PAN ANGLE	PRE OP	19	-0.6842	18.2027	0.227
	POST OP	19	0.7368	15.5594	
SEC ANGLE	PRE OP	19	146.7368	112.9562	0.233
	POST OP	19	144.0526	115.4318	

P value greater than 0.05 indicates there is no statistically significant difference between pre operative planned virtual position and post operative actual position of implants.

INTRODUCTION

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REVIEW OF LITERATURE

Skalak R (1983)[47] proposed that close apposition of bone to the titanium implant is the essential feature that allows a transmission of stress from the implant to the bone without any appreciable relative motion or abrasion. The use of a threaded screw provides a form of interlocking with the bone on a macroscopic scale that allows full development of the strength of the bone in shear or compression. A smooth, cylindrical implant may require an adhesive bond for satisfactory performance, but a screw shape is able to work as long as the apposition of bone and implant is close, whether or not a true adhesive bond is developed.

T. Albrektsson, G. Zarb, P. Worthington, A.R. Eriksson (1986)[55] proposed criteria for the evaluation of dental implant. These criteria are applied in an assessment of the long-term efficacy of currently used dental implants including the sub-periosteal implant, the vitreous carbon implant, the blade-vent implant, the single-crystal sapphire implant, the Tubingen implant, the TCP-implant, the TPS-screw, the ITI hollow-cylinder implant, the IMZ dental implant, the Core-Vent titanium alloy implant, the transosteal mandibular staple bone plate, and the Branemark osseointegrated titanium implant. An attempt was made to standardize the basis for comments on each type of implant.

Christoph H. J. Basten, andJohn C. Kois (1996)[10] described a procedure to fabricate a radiopaque template that uses radiopaque material, barium sulfate (Hypaque-sodium, Winthorp Pharmaceuticals, New York, N.

Y.), for fabrication of a radiographic template during the diagnostic phase. The radiographic template, which is a copy of the provisional restoration, is used as a blueprint of the planned restoration. The full-contour radiopaque template enables the clinician to visualize the outline of the planned restoration in relation to the bone structures. Treatment planning can be facilitated at this phase to allow any necessary procedures, such as ridge augmentation, to be completed before implant placement.

Souheil Hussaini, and Dalinda Canela-Pichardo (1997)[48] described a procedure that introduces palatal impression template design that can be used during stage multiple implant placement to obtain a relationship for fabrication of a provisional resin restoration for an edentulous patient.

Tarnow D P, Emtiaz S, Classi A. (1997)[54] evaluated immediate loading of threaded implants with a fixed provisional restoration at stage 1 surgery in 10 consecutive patients. The patients selected had to be completely edentulous and have adequate bone for a minimum of 10-mm-long implants. A minimum of 10 implants were placed in each patient's arch. A minimum of five implants were submerged initially for medicolegal reasons and allowed to heal without loading. The remaining implants were loaded the day of stage 1 surgery. Once the provisional restoration was relined, it was cemented or screw retained. The results of this study indicated that immediate loading of multiple implants rigidly splinted around a completely edentulous arch can be a viable treatment modality.

Schnitman PA, Wohrle PS, Rubenstein JE, DaSilva JD, Wang NH (1997)[44] developed a method to provide patients with a fixed provisional prosthesis placed at the time of implant placement. Sixty-three standard 3.75-mm Nobel Biocare implants of varying lengths were placed into mandibular sites in 10 patients and followed for up to 10 years. Twenty-eight implants were immediately loaded at implant placement, providing support for fixed provisional prostheses, while 35 adjacent implants were allowed to heal submerged and stress-free. Following a 3-month healing period, the submerged implants were exposed and definitive reconstruction was accomplished. All 10 prostheses supported by 28 implants placed into immediate function at the time of implant placement were successful during the 3-month healing period. Of these 28 implants placed into immediate function, 4 ultimately failed. Of the 35 submerged implants, all are osseointegrated and in function to date. Life-table analysis demonstrates an overall 10-year survival rate of 93.4% for all implants. The 10-year life-table analysis of survival is 84.7% for immediately loaded implants and 100% for submerged implants. Statistical analysis of the submerged versus immediately loaded implants demonstrates failure rates for immediately loaded implants to be significantly higher (P = .022 by the log rank test). These data demonstrate that although mandibular implants can be successfully placed into immediate function in the short term to support fixed provisional prostheses, long-term prognosis is guarded for those implants placed into immediate function distal to the incisor region.

Harald Eufinger, Albert R. M. Wittkampf, Michael Wehmoller, Frans W. Zonneveld (1998)[25] evaluated navigation systems, which allow the precise intra operative orientation of surgical instruments, can be used for greater accuracy in determining resection margins of tumours. These techniques support ablative procedures very well, but defect reconstruction still remains a problem. In contrast, computer-aided design (CAD) and computer-aided manufacturing (CAM) systems allow the construction and fabrication of individual templates for bone resection based on coherent numerical 3-D models.

The template determines the exact pathway of an oscillating saw so that the planned extent of the resection and, if necessary, also the orientation of the cutting plane are verified. An individual titanium implant is prefabricated with a geometry fitting to that of the template. This implant closes the bone defect so that the contour is reconstructed precisely and individually.

This new method was used for the first time for a single-step resection of a meningioma and defect-reconstruction. The tumour which had infiltrated the frontal bone resulting in a protrusion. Fronto-orbital resection and insertion of the titanium implant worked precisely as planned, so that this method offers promising new applications in the field of computer-aided surgery.

K Randow, I Ericsson, K Nilner, A Petersson, PO Glantz (1999)[29] performed to compare the outcome of oral rehabilitation in the edentulous mandible by fixed supra constructions connected to implants installed according to either i) a 1-stage surgical procedure and immediate loading

(Experimental Group-EG), or ii) the original 2-stage concept (Reference Group-RG). The EG comprised 16 subjects with edentulous mandibles. Beyond the non-smoking criteria the following specific inclusion criteria were adopted: i) all patients had to consider themselves to be in good general health, ii) the amount of bone had to enable the installation of 5-6, at least 10 mm long fixtures to be bicortically anchored (Mk II fixtures; Nobel Biocare AB, Göteborg, Sweden) between the mental foramina, and iii) the patients had to be available for the follow-up and maintenance programme. A total of 88 implants were placed in the EG (16 patients) compared to 30 in the RG (11 patients). In the EG, fixed appliances were connected to the implants within 20 days following implant installation while the fixed appliances in the RG were connected about 4 months following fixture installation. At the time for delivery of the supra constructions all 27 patients were radiographically examined, an examination that was repeated at the 18-month follow-up. The analysis of the radiographs from the EG disclosed that during the 18-month observation period the mean loss of bone support amounted to 0.4 mm. The corresponding value observed in the RG was 0.8 mm. During the 18-month observation period no fixture was lost in any of the 2 groups examined. The implants under study as well as those in the reference material were at all observation intervals found to be clinically stable. The present clinical study demonstrated that it is, at least based on an 18-month observation period, possible to successfully load titanium dental implants immediately following installation via a permanent fixed rigid cross-arch supra construction.

However, such a treatment approach has so far to be strictly limited to the inter-foramina area of the edentulous mandible.

Fabio Scutella, Luca Landi, GirolamoStellino, and Steven M. Morgano (1999)[19] described a patient treatment with a surgical-guide template that has been developed to facilitate surgical planning and enhance communication between periodontist and restorative dentist.

CE Besimo, JT Lambrecht and JS Guindy (2000)[8] evaluated the possible error in transferring the position and axial inclination of implants from paraxial reformatted CT scans to the study cast with the help of template-guided digital CT analysis.

These results indicated that the error resulting from transfer of CT-based implant planning to study casts and surgical templates is minimal. The resulting angle between the plane of the CT reformats and the plane perpendicular to the dental arch should not necessarily be taken into consideration. According to Jacobs et al, other factors involved in transferring positional and angular measurements to the surgical site will probably result in more significant errors than those reported in this study. These factors may included inaccurate indication of the position of paraxial reformats in axial CT scans, intra-oral orientation of the surgical template and finally the surgeon's skill in placing the implant at a pre-determined angle.

Stephen L. Wheeler, Robert E. Vogel, Renzo Casellini (2000)[51] reviewed techniques that provide for the preservation of both bone and soft tissue while enhancing the esthetic results around implants.

A technique has been presented that is based on scientifically proven modifications to conventional implant protocols. By placing stepped-tapered implants immediately into extraction sockets where normal hard and soft tissue contours were found, and then attaching custom healing abutments that replicate the emergence profiles of the teeth being replaced, it has been possible to preserve both the hard and soft tissues surrounding the extraction sites. Not only is this procedure more predictable than trying to regenerate these tissues in a delayed implant placement protocol, but it involves less surgery for the patient. The result is less potential morbidity, lower cost to the patient, and significantly reduced overall treatment time. This has been found to be an advantageous addition to available treatment protocols for patients who present with ideal hard and soft tissues surrounding non restorable teeth to be replaced with dental implants.

Murat C. Cehreli, Saime Sahin (2000)[36] described a technique to fabricate a template that served as a guide for radiographic evaluation and was then modified for use in the surgical phase of the treatment. An implant-supported prosthesis can potentially provide a functional and esthetic reconstruction, provided that the implants are precisely placed in the predetermined location and angulation. Since the accurate placement of osseointegrated implants in the anterior maxilla with questionable bone support is often a clinical challenge, the use of computed tomography and surgical guides is crucial.

The use of a dual-purpose template is a valid choice if the modification procedures are performed in accordance with the measurements carried out on the CT scan. Although the converting process may be time-consuming, such guides offer the advantage of placing implants in the desired 3-dimensional position. Removing the radiopaque markers in the conversion procedures may lead to loss of some data provided by its guidance in a 3-dimensional scale.

The information regarding location and angulation of implants that is viewed in a 2-dimensional plane can easily be transferred to a 3-dimensional environment by placing reference marks on the working cast with the radiopaque marker. Such marks facilitate correct re-orientation of the working cast and further procedures with negligible error. More clinical experience is indicated to see whether this inevitable error rate in transferring the information will affect implant prosthesis success.

Alberto Sicilia, Francisco J. Enrile, Pedro Buitrago, Javier Zubizarreta (2000)[4] presented to compare the precision of placement of implants inpatients edentulous in the maxilla, with slight alveolar ridge resorption, who have been rehabilitated with implant-supported dental prostheses, using surgical templates fixed with micro implants to the precision of a conventional movable template.

4 different types of restoration could be considered for the rehabilitation of a completely edentulous maxilla:

1. An over denture.
2. A hybrid removable prosthesis with precision milled bar.
3. A fixed prosthesis with space beneath for oral hygiene and a removable labial resin veneer.
4. A fixed prosthesis with the design of a fixed partial denture.

The precision in the placement of the implants has been analyzed by means of employing 2 variables, which represent the deviation of the surgeon from his ideal objective. From a practical view point, these results appear to relate the use of a fixed template with a clinically significant improvement in the placement of the implants: an increment of precision of 61%, and a risk of invasion of the tooth contour 11 times lower. This represents considerable reduction in the esthetic problems related to incorrect placement of the implants and facilitates the work of the restorative dentist, allowing him or her to achieve the best possible results from the esthetic, hygienic, and phonetic points of view.

Roger A. Solow (2001)[42] presented a template that provides radiographic evaluation of the implant site and precise or modified surgical placement.

A versatile radiographic-surgical template for multiple parallel implant placement has been described. Simple materials and methods allow the restorative dentist to evaluate the final prosthetic contours, implant locations, and treatment plan before surgical or patient consult. The precise guide for implant pilot drills can be modified easily after radiographic evaluation or during surgery.

Daniel van Steenberghe, Ignace Naert, Matts Andersson, Izidor Brajnovic, Johan Van Cleynenbreugel, Paul Suetens (2002)[15] examined to what extent precision data from 3-dimensional planning software for oral implants can be transferred to the operative field by means of a drilling template, containing high-precision drilling sleeves, fitted on the jawbone. It was investigated whether this procedure would allow advance preparation of a fixed definitive prosthesis that could be placed at the completion of surgery.

Encouraged by reports indicating that early and even immediate loading can result in osseo-integration, a new approach has been developed, based on a high-precision 3-dimensional (3-D) computed tomographic (CT) image implant planning system, which is applicable in both jaws. It is called LITORIM (Leuven information technology based oral rehabilitation by means of implants).

It consists of a custom-fit template adaptable to the jaw bone surface which, by the inclusion of removable sleeves with diameters precisely adapted to the series of drills and the implants themselves, offers precision in transferring the planned orientation for drilling to the surgical field. This facilitated placement of the prosthesis at the end of surgery. Both the template and the prosthesis are fabricated on the basis of a combination of 3-D software planning and clinical data.

This article reported the results obtained in the edentulous maxilla of 2 ex vivo specimens and of 8 consecutive patients.

Patrick J. Henry (2002)[38] provided an overview of some of the current treatment options for the edentulous maxilla. The edentulous jaw may be treated with a complete denture prosthesis, a complete denture overlay prosthesis supported and retained by implants, or an implant-supported prosthesis.

Rehabilitation of the edentulous maxilla continues to be comparatively more challenging than rehabilitation of the edentulous mandible. Although single-stage surgery with immediate loading concepts were well established in the mandible, they should be considered experimental in the maxilla until long term, evidence-based data and guidelines are established. Recent advances in diagnostic imaging modalities, bone grafting protocols, and prognostic technology able to monitor the functional responses of implants are encouraging. The implant option for the edentulous maxilla is increasingly becoming the treatment of choice for many patients.

Charbel Bou Serhal, Reinhilde Jacobs, Marc Quirynen, Daniel van Steenberghe (2002)[9] reviewed the available literature about various imaging techniques and their indication for the preoperative planning of oral implants. The advantages and drawbacks of each technique are described. A dosimetri cover view is given relative to different radiologic techniques used in various clinical situations.

Currently oral implant placement is routinely used as a treatment modality in the rehabilitation of the edentulous jaw bone. The increasing demand for implant treatment has also raised interest in the available imaging techniques to perform a proper preoperative planning prior to oral implant placement. For oral implant surgery, preoperative radiologic planning is of utmost importance to warrant a successful treatment outcome. Various imaging techniques may be used, but the clinician should always attempt at making a risk benefit assessment, depending on the extent of the edentulous jaw bone area. Considering the radiation doses involved and the information obtained, conventional tomographic surveys are considered to be the examination of choice in many cases. ACT scan, on the other hand, is recommended for rehabilitation of extended edentulous areas or in a fully edentulous upper jaw. It should, however, be kept in mind that in cases for which enough clinical information can be obtained, cross-sectional imaging might not be required.

Bernard Keough (2003)[5] discussed two elements of the occlusion, in the order of their evaluation-centric relation position of the mandible and vertical dimension of occlusion. A successful physiologic occlusion may be described as one that enables the patient to function with efficiency and comfort, and one that is well-tolerated by the periodontium, teeth, and TMJs. It acts to minimize activity of the muscles of mastication, creating neuromuscular harmony, and it does not create any pathologic symptoms in these muscles. There are several generally accepted criteria for this occlusion.

Through an understanding of the significance, inter-relationship, and workings of these various elements, a functional and esthetic treatment plan can be achieved. Orderly and systematic comparison of those aspects of a patient's occlusion to a physiologic and esthetic standard makes treatment decisions much easier. The first step is an evaluation of the centric relation position of the mandible. Second, the vertical dimension of occlusion (VDO) must be evaluated. Third, the patient should be restored with an appropriate posterior occlusal plane. The fourth element to evaluate is the maxillary anterior incisal edge location, Fifth, in conjunction with the lingual contours of the maxillary anterior teeth Finally, a protective posterior occlusal surface design must be established. If approached in this sequence, a complicated set of dental problems becomes much easier to resolve. Once problems have been fully recognized, solutions are easier to devise.

David P. Sarment, Khalaf Al-Shammari, Christopher E. Kazor (2003)[16] illustrated with two advanced cases, demonstrating that the technique not only allows for the precise translation of the treatment plan directly to the surgical field, but also offers many significant benefits over traditional procedures.

Kevin C. Kopp, Alyson H. Koslow, and Omar S. Abdo (2003)[28] described facilitates precise dental implant placement. A barium-coated template with external guide wires used in conjunction with a computed tomography scan and interactive software may provide superior pre surgical diagnostics, treatment planning, and prosthetically directed implant placement.

The use of tomography and computed tomography (CT) provided practitioners with the ability to assess the quantity and quality of bone and critical anatomic structures before surgery. These advanced radiographic techniques allowed better bone evaluation; however, orientation to a specific implant site was difficult, and determining the relationship between the final restoration and available bone was not always possible. With CT scans, patients were scanned with an intra-oral template containing radiopaque markers indicating the relationship of available bone to the final prosthesis.

The location of implant placement is often critical to the success or failure of a particular restoration. A technique was presented in which implants were placed with more favorable esthetic and occlusal outcomes. Placing a wire on the buccal allows for the marker to remain intact and not be obliterated when preparing the template for the surgical phase. With this method, the buccolingual and mesiodistal positions can be maintained throughout the surgery.

This is accomplished by affixing an external guide wire that remains with the template from diagnostic CT imaging to surgical placement of the implant. The use of a diagnostic/surgical template may allow predictable implant placement and is simple and inexpensive to fabricate.

Stefan Holst, Markus B. Blatz, Manfred Wichmann, and Stephan Eitner (2004)[49] described the clinical application of surgical micro fixation screws for stabilization and support of radiographic and surgical templates in edentulous patients. These screws provide fixed reference points for exact positioning of a diagnostic device.

Implant position and restoration must be well planned and require a team approach involving the restorative dentist, the dental technician, and the implant Surgeon. Surgical templates and guides are necessary for precise execution of the planned treatment. A variety of surgical guides have been described in the literature, but a major disadvantage of most surgical guides is a lack of stability in the edentulous patient, especially when the guides are supported only by the remaining soft tissues and relieved from the lingual or palatal aspect for surgical access. Accurate positioning of each implant is important for fixed restorations and essential when an immediate provisional restoration is fabricated according to a diagnostic arrangement and inserted directly after implant placement.

This technique article described the clinical application of surgical micro fixation screws to stabilize radiographic and surgical templates in the completely edentulous patient. The screws serve as intraoral fixed reference points. Positioning screws in a tripodal manner increases accuracy and precision of diagnostic procedures and implant placement.

S.W. Meitner,and R.H. Tallents (2004)[53] described a prosthetically guided method for the fabrication of surgical templates for partially edentulous patients. A number of stainless steel components are used to capture the optimal prosthetic position for the placement of the implant determined from a diagnostic arrangement. A radiopaque stainless steel guide sleeve isused to guide the drill in preparation of the osteotomy after radiographs are made to verify the position and proposed trajectory of the guide sleeve.

A prosthetically guided method of template fabrication (Guide Right; De Plaque, Inc, Victor, NY) has been developed that utilizes multiple components made of surgical stainless steel. A surgical template for a single implant, made using the Guide Right components, requires about 15 minutes to fabricate. The template must be evaluated radio graphically prior to the surgery. The template, if not acceptable radio graphically, can easily and quickly be remade in the dental office.

The template is made from the image of the alveolar bone and rests on the irregularities of the alveolar bone after the soft tissue has been reflected if the patient is edentulous. While this is useful for situations requiring multiple dental implants, it is relatively expensive to use when placing a single dental implant.

Technique in this article is described for the construction of a prosthetically-guided, surgical template that can be made in the dental office or by a laboratory. The technique combines a diagnostic arrangement, reusable radiopaque template components, and polymerized acrylic resin. Guide sleeves are positioned utilizing a prosthetic tooth arrangement to optimize implant placement.

Fujio Tsuchida, Toshio Hosoi, Masahiro Imanaka, and Kaoru Kobayashi (2004)[20] described a technique for fabricating a diagnostic template with radiopaque materials commonly used in dentistry. The template can then be transformed into a surgical template for implant placement.

The use of diagnostic and surgical templates for implant placement may be helpful. Diagnostic templates modified for surgical purposes have the advantage of transferring radiographic information to the surgical template. The diagnostic template should indicate radiographic markers clearly and be easily attached or removed. Silicone materials used for impressions and maxilla mandibular records may be used as radiopaque contrast markers. Silicone material is advantageous because it does not produce radiographic artifacts as metal markers do. It is not necessary for the silicone material to adhere to the diagnostic template when using this method. The radiographic component of the template is easily separated from the surgical component after the necessary radiographs have been made. Silicone materials serve as clear radiopaque markers on the CT similar to gutta percha.

The CT is a helpful guide for surgeons to make a diagnosis because it provides pictures in a 1:1 format. The surgical template and CT images are useful for modifying the location and angle of the implant.

A radiopaque silicone marker on a template serves as a guide for achieving a 3-dimensional evaluation of bone without artifacts using a CT scan. It can be easily transformed into a surgical guide by removing the marker. The 3-dimensional template design and marker provide guidance for accurate implant placement.

G. Widmann, R. Widmann, E. Widmann, W. Jaschke, R. J. Bale (2004)[21] demonstrated the concept of IGTP, the dentist or dental technician does not need to buy a navigation system, positioned /reference table, software or tools. The existing equipment of a university hospital can be used with only minimal additional costs. In an interdisciplinary team approach, state of the art backward planning could be integrated as close as possible to the standard procedure. There is no need for radiographic templates, reference templates and modifications of the standard dental casts as seen for all the other techniques.

Carsten Westendorff, Jurgen Hoffmann, German Gomez-Roman, Dirk Bartz, Tina Herberts, SiegmarReinert (2005)[7] discussed about the three-dimensional accuracy of navigation-guided (NG) socket drilling before implant installation was compared to the conventional free-hand (CF) method in a synthetic edentulous lower jaw model. The drillings were performed by two surgeons with different years of working experience. The inter-individual outcome was assessed. NG drillings were performed using an optical computerized tomography (CT) based navigation system. CF drillings were performed using a surgical template. The coordinates of the drilled sockets were determined on the basis of CT scans. A total of n =224 drillings was evaluated. Inter-individual differences in terms of the surgeons' years of work experience were without statistical significance. In conclusion, the benefit of the navigation technology relies on the ability to control depths, position and angle of the implant. The bone density can be evaluated within the CT-data intra operatively to avoid an implant mal positioning in a way that primary stability is not given.

Lyndon Cooper, Ingeborg J. De Kok, Glenn J. Reside, Preeda Pungpapong , and Fernando Rojas-Vizcaya (2005)[30] immediate loading of the edentulous maxilla is possible when sufficient bone is available to provide primary stability of implants located in positions congruent with an ideal prosthesis. Treatment planning, implant placement with immediate provisionalization, and final prosthodontic rehabilitation are best integrated by a process that uses the immediate provisional prosthesis as a surgical and restorative guide. Designating the planned tooth position is a prerequisite step to the identification of possible implant positions. The cervical contours of the planned prosthesis are critical determinants of this relationship. Defining the planned tooth/residual alveolar bone relationship aids in selecting both the possible type of prosthesis and implant locations. When the treatment plan is transferred directly from the tomographic template to the surgical template to the conversion prosthesis used for immediate loading, the surgical and prosthodontic management of this procedure is well defined.

Christopher B. Marchack (2005)[12] described the Teeth-in-an-Hour (Nobel Biocare, Yorba Linda, Calif) treatment provided for a patient. Dental implants have had a major impact on the treatment of edentulous patients. Fixed complete dentures have allowed removable complete dentures to be replaced with fixed prostheses. A new treatment modality using immediately loaded implants placed with a CAD/CAM surgical template using a flapless surgical technique, then loaded with a prefabricated restorative prosthesis, is presented. The success of immediate loading of implants has been well documented. Patient selection is critical and may predicate success of the surgery. Host factors, implant design, and occlusal loads may all impact osseointegration of the implants.

This report discussed a technique utilizing a computer-assisted surgical design, CAD/CAM surgical template, a flapless surgical procedure, and a prefabricated fixed complete denture or an immediately loaded restoration. The benefits of the procedure described include shorter surgery times, shorter treatment times, less-invasive surgical technique (flapless surgery, with less chance of swelling, less pain, and faster initial healing times), a prefabricated definitive prosthesis, and the immediate use of a fixed prosthesis. However, this treatment option is new and under investigation. Initial prospective studies of 8 patients with observation times of 12 months have shown all patients with stable and functional prostheses. Long-term studies are being performed to validate this procedure. This procedure may be contraindicated for patients with limited oral opening.

The surgical armamentarium is longer than traditional drill kits and access may be difficult. The disadvantages of this approach included possible implant loss for patients who clench and brux, complicated by the fact that patients cannot remove the prosthesis nocturnally.

An alternative approach to implant dentistry is presented for the completely edentulous arch. A CT scan and specialized surgical planning software is used to produce an accurate stereo-lithography cast. A fixed complete denture is fabricated prior to the surgical procedure so that the prosthesis may be inserted immediately after the implants are placed.

Saad A. Al-Harbi,and Ronald G. Verrett (2005)[43] described the fabrication of a surgical template that permitted the use of staged tooth extraction to facilitate predictable immediate implant placement in a patient with a non restorable dentition. When implants are placed immediately following complete odontectomy in an arch, the use of a surgical template is an important adjunct to the restorative outcome. Conventionally made surgical templates may lack stability in this situation and may be less predictable. The surgical template described permitted the use of staged tooth extraction to facilitate immediate implant placement in a patient with a non restorable dentition.

Treatment planning for multiple implant placement in an arch often requires diagnostic radiography that provides a cross-sectional image of the osseous contours at the desired implant sites. Each implant should be placed in a position that minimizes loading forces and facilitates an implant supported restoration with a satisfactory functional, esthetic, and hygienic outcome. Presurgical prosthetic treatment planning should result in fabrication of an accurate surgical template to be used by the surgeon at the time of implant placement. The use of cross-sectional radiography, such as computed tomography (CT), allows evaluation of implant placement in relation to available bone, anatomic structures, and proposed tooth positioning.

Establishing proper implant sites and angulation is facilitated by the use of a radiographic guide with radiopaque markers. The radiographic guide can be converted to a surgical template or a stereolithographic template (Materialise, Glen Burine, Md) can be created based on the digital information obtained from the CT scan.

Dusan V. Kuzmanovic, and J. Neil Waddell (2005)[18] described the fabrication of a surgical template that may facilitate accurate surgical dental implant placement for the partially edentulous patient, fulfilling the esthetic and functional objectives of the definitive prosthesis. Relining the surgical template with a silicone material and engaging the undercuts of the remaining teeth achieves retention of the template intraorally. The reline material used in this article is based on vinyl poly siloxane. These silicone materials require the use of a primer to act as an adhesive to the poly methyl meth acrylate base of the surgical template.

For the partially edentulous patient, proper intraoral stability may not be easily achieved by using conventional acrylic resin without additional means of retention. For partially edentulous patients, stability maybe best achieved when the template is firmly supported by the remaining dentition without utilizing stabilization from the palate. Elimination of the palatal coverage reduces the bulkiness of the template and provides the surgeon with an optimal visualization of the most favorable implant site.

Scott D. Ganz (2005)[45] illustrated the advantages of using CT scan-based templates, but does not attempt to cover all available methods for fabrication, nor review navigational or robotic technology which, although innovative, may not be at the point where they are practical or efficient solutions. Even with CT imaging,clinicians have labored to link the information from the scan data to the surgical site, transferring angles and positions manually. This is totally overcome with interactive software applications that provide this information seamlessly. Based on information contained within, templates derived from CT scan planning data, which embedded stainless steel tubes are highly accurate, and easy to use in either bone-borne, tooth-borne, or soft tissue-borne(not shown) configurations. It is quite simple to place the drill through the tube and precisely drill into the bone, creating the desired osteotomy, when all of the planning and decision making is completed in advance of the procedure. Procedures were illustrated for single and multiple tooth applications, in both mandibular and maxillary arches.

Using CT imaging to assess bone anatomy and determine implant receptor sites additionally allows for improved techniques for flapless surgical procedures (when appropriate), which can be performed with greater levels of confidence and are less invasive to the patient.

Coen Pramono (2006)[13] described a surgical technique for achieving implant placement parallelism and presents an equation concept to predict the bone depth available for implant placement by measuring the discrepancy of the panoramic radiograph compared with a clinical situation in cases in which a wide edentulous area was present. Some advanced techniques such as a 3-

dimensional model fabricated according to computed tomography, micro-focus x-ray computed tomography (micro-CT), and compact computed tomography can be used in implant placement prediction because those techniques have been known to be highly accurate These advanced techniques are considered to be too expensive in many settings; therefore, an alternative method using a panoramic radiograph in combination with a measurement of the vertical dimension of the bone available in the jaw and the use of surgical template with tube technique to guide the implant placement are 3 important related points that can be used as tools to achieve appropriate orientation for the implant placement. Problem of magnification factor in panoramic radiograph may lead to misinterpretation in prediction of the implant site available for implant placement and in determining the length of the dental implant.

Successful treatment of edentulous patients using dental implant systems may be predicted when an established treatment protocol is followed, with consideration of the tissue properties at the implant site, as well as the mechanical and specific surface properties of the implant, which can increase the implants stability and load-bearing capacity in the bone, as the surface property is related to the higher bone-to-implant contact and stability. Evaluating and identifying the available jaw bone quantity during implant placement is an important task, as already pointed out by Lekholm and Zarb.

Marker to verify the magnification factor of the panoramic radiograph has been described by some authors and widely accepted, this technique can be used as an alternative method in cases where wide edentulous spaces are present.

In regard to the position of important areas such as the inferior alveolar nerve and maxillary sinus cavity, the partial denture template technique with Coen's drill tube in combination with the equation to find the clinical-radiographic discrepancy can be used as an alternative method in the surgical treatment planning and placement guidance in the dental implant insertion.

Paulo Cezar Simamoto, Leticia Resende Davi, Vanderlei Luiz Gomes, Mauro Antonio de Arruda Nobilo, and Flavio Domingues Neves (2006)[39] described a technique for replacement of a lost implant. The procedure involves the use of templates, drill guides, and drills of the system to replace a 4.5-mm-wide lost implant with a 5.0-mm-wide implant. The surgical procedure was simplified to optimize the healing process and to be more comfortable for the patient. The accuracy of the templates and guides allowed for ideal position of the implant and the immediate use of the original fixed implant-supported prosthesis.

This technique presented for replacement of a lost implant allowed ideal positioning of the new implant and immediate use of the original fixed implant supported prosthesis. It was possible to use the original set of commercially available components for the Novum protocol as prefabricated guides and templates. Although this procedure has been successful initially, continual follow-up is necessary to ensure the longevity of the implants.

Alan L Rosenfeld, George A Mandelaris and Philippe B Tardieu (2006)[1] discussed the use of scanning appliances to transfer clinically relevant prosthetic outcome information to a CT data set. With Sim Plant software, this information can be used to provide a pretreatment outcome analysis, which can be used for fabrication of stereolithographic models and surgical drilling guides used during osteotomy preparation.

Alan L Rosenfeld,George A Mandelaris and Philippe B Tardieu (2006)[2] introduced the concept of rapid prototype medical modeling as well as describe the utilization and fabrication of computer generated surgical drilling guides used during implant surgery. The placement of dental implants has traditionally been an intuitive process, where by the surgeon relies on mental navigation to achieve optimal implant positioning. Through rapid prototype medical modeling and the stereolithographic process surgical drilling guides (eg. Surgi guide) can be created. These guides are generated from a surgical implant plan created with a computer software system that incorporates all relevant prosthetic information from which the surgical plan is developed. The utilization of computer generated planning and stereolithographically generated surgical drilling guides embraces the concept of collaborative accountability and supersedes traditional mental navigation on all level of implant therapy.

Alan L Rosenfeld, George A Mandelaris and Philippe B Tardieu (2006)[3] discussed the use of gradient density scanning appliance which make it possible to place prosthetically directed dental implants without bone exposure. Rapid prototyping and stereolithographic medical modeling applications have opened an entirely new approach to the field of implant dentistry. The fact that Surgi guides have such universal applicability make there use simple and efficient. In fact, report have shown that laboratory cost over runs resulting from poor implant placement via traditional “mental navigation” are reduced by up to 30% when computer guided implant placement is used.

Harald Eufingera, Christian Raschea, JuttaLehmbrock, Michael Wehmoller, Stephan Weihe, Inge Schmitz, Carsten Schiller, Matthias Epple (2006)[24] prepared biodegradable functionally graded skull implants on the basis of polylactides and calcium phosphate/calcium carbonate in an individual mould using a combination of different processing techniques. A geometrically corresponding resection template was designed to enable a craniectomy and cranioplasty with the prepared implant in the same operation. The use of the TICC-processing chain will allow the individual prefabrication of these implants with the same functional and aesthetic advantages which individual prefabricated titanium implants already show clinically at present. This additional expense is justified in these complex and aesthetically exposed craniofacial defects.

Curcio R, Perin GL, Chilvarquer I, Borri ML, Ajzen S (2007)[14] performed on 14 patients with a total of 56 implants placed. It was proposed a technique for the rehabilitation of edentulous mandible with osseous integrated implants of immediate loading, using anatomical replicas derived from computerized tomography scan linked to the rapid prototyping technique of stereolithography in reverse planning, elaborating the definitive fixed prosthesis, with rigid union of the implants on the same day. The patients' mandible models were divided in two groups. In the first one, there were patients with edentulous mandible models and with models elaborated after exodontics procedures (Group 1). In the second (Group 2), patients with dentulous mandible models, which allow an evaluation of difficulty in the surgery.

The model in the reverse planning of oral rehabilitations had 100% of less difficulty compared to dentulous prototypes, which had 83,3% of more difficulty.

Paulo Malo, Miguel de Araujo Nobre, and Armando Lopes, (2007)[40] evaluated the preliminary clinical outcomes of survival and bone loss for prosthodontic rehabilitation using computer-guided flapless implant surgery and 4 implants placed in immediate function to support a fixed denture.

The results of this preliminary study indicated that, within the limitations of this study, this treatment modality for completely edentulous jaws is predictable with a high survival rate. By combining 3-D planning and immediate loading, it is possible to gain the advantages of each, resulting in an accurate, safe, and predictable technique for rehabilitating the complete edentulous jaw without bone grafting in a majority of situations.

Sukumaran Anil, Hamdan S. Al-Ghamdi (2007)[52] described the use of radiographic imaging software to calibrate and measure anatomical landmarks to overcome inherent distortions associated with dental radiographs. The procedure along with its potential use as an adjunct to radiographic interpretation in routine clinical implant practice was presented.

Jaime Gateno, James J. Xia, John F. Teichgraeber, Andrew M. Christensen, Jeremy J. Lemoine, Michael A.K. Liebschner, Michael J. Gliddon, and Michaelanne E. Briggs, (2007)[26] established clinical feasibility of our 3-dimensional computer aided surgical simulation (CASS) for complex cranio maxillofacial surgery.

The results described the clinical feasibility of our CASS planning method. Using our CASS method, we were able to treat patients with significant asymmetries in a single operation that in the past was usually completed in 2 stages. We were also able to simulate different surgical procedures to create the appropriate plan. The computerized surgical plan was then transferred to the patient in the operating room using computer-generated surgical splints. To minimize the potential risks to the patients, the surgeries were also planned following the current clinical routine using cephalometric analysis, prediction tracings, plaster dental model surgery, 3D CT visualization, and a stereolithographic model, if necessary. Conventional acrylic surgical splints were fabricated from plaster dental models. The surgical plan and acrylic surgical splints generated by conventional planning methods were available as backup during the surgery.

Stefan Holst, Markus B. Blatz, and Stephan Eitner, (2007)[50] described the application of screws as fixed intraoral reference points for stable, precise, and repeatable positioning of diagnostic and surgical templates for implant placement. Precision and accuracy of computer-based or -supported implant placement is valuable only if an exact transfer to the intraoral situation is granted. Depending on the clinical patient situation, fixed intraoral reference points can improve precision in an efficient manner.

Christopher B. Marchack (2007)[11] described a computer-guided surgical technique for the partially edentulous patient, with a restoration fabricated prior to implant placement, for immediate loading. The treatment planning, placement, and restoration of dental implants for the partially edentulous patient can be challenging. Anatomical limitations can make implant location difficult to determine. The use of CT scans and surgical planning software to produce a CAD/CAM surgical template, as well as the use of a flapless surgical technique, can make implant placement more predictable, safer, and easier for patients.

The conventional treatment of the partially edentulous patient with dental implants involves a thorough diagnosis, treatment planning, a diagnostic waxing, and a surgical template for implant placement. The position and number of implants placed are based upon radiographic diagnosis, anatomical landmarks, the quantity and quality of bone, tooth position, and biomechanics. Using computer-assisted tomography (CT scan) can assist in determining bone quantity and quality, but transferring the exact position of the planned implants to the patient can be difficult, imprecise, and require extensive laboratory procedures. The advantages of this procedure, for the completely edentulous arch, included:

(1) Shorter surgery times,

(2) Shorter treatment times,

(3) Less invasive, flapless surgery and, therefore, less chance of swelling, less pain, and faster initial healing times,

(4) Placement of a prefabricated definitive or provisional prosthesis,

(5) Use of the fixed prosthesis immediately.

Hans-Joachim NICKENIG, Stephan EITNER (2007)[23] evaluated the reliability of implant placement after virtual planning of implant positions using cone-beam CT data and surgical guide templates. Implant placement after virtual planning of implant positions using cone beam CT data and surgical templates can be reliable for preoperative assessment of implant size, position, and anatomical complications. It is also indicative of cases amenable to flapless surgery. Surgical templates based on virtual planning data promise an additional advantage of precise guidance for implant placement. The position and angle of implants are as expected with only a small transfer error of less than 1mm (in vitro studies).

The results suggested that implant placement after computer-assisted, virtual planning of implant positions using cone-beam CT data and surgical templates is reliable. The process facilitated preoperative assessment of implant size, position, and anatomical complications and is also indicative of cases suitable for flapless surgery.

Jelena Milovanovic, Miroslav Trajanovic (2007)[27] discussed the most interesting and challenging applications of rapid prototyping technologies are in the field of medicine. RP medical models have found application for planning treatment for complex surgery procedures, training, surgical simulation, diagnosis, design and manufacturing of implants as well as medical tools. This paper presented the procedure for making medical models using RP, medical rapid prototyping technologies application in different fields of medicine and the future trends in this area.

This paper discussed possibilities of using RP technologies as a multi-discipline area in the field of medicine. Using RP in medicine is a quite complex task which implies a multi disciplinary approach and very good knowledge of engineering as well as medicine; it also demands many human resources and tight collaboration between doctors and engineers. After years of development rapid prototyping technologies are now being applied in medicine for manufacturing dimensionally accurate human anatomy models from high resolution medical image data. The procedure for making medical models using RP technologies is also presented in this paper.

PA Monsour, R Dudhia (2008)[41] discussed in some detail about advantages and disadvantages of the imaging modalities currently available for pre-implant imaging. Intra-oral and extra-oral radiographs are generally low dose but the information provided is limited as the images are not three-dimensional. Tomography is three-dimensional, but the image quality is highly variable. Computed tomography (CT) has been the gold standard for many years as the information provided is three-dimensional and generally very accurate. However, CT examinations are expensive and deliver a relatively high radiation dose to the patient. The latest imaging modality introduced is cone beam volumetric tomography (CBVT) and this technology is very promising with regard to pre-implant imaging. CBVT generally delivers a lower dose to the patient than CT and provides reasonably sharp images with three-dimensional information. A comparison between CT and CBVT is provided.

Magnetic resonance imaging is showing some promise, but the examinations are not readily available, generally expensive and bone is not well imaged. Magnetic resonance imaging is excellent for demonstrating soft tissues and therefore may be of great use in identifying the inferior dental nerve and vessels. All of the above structures, of particular interest is the inferior dental canal, incisive canals of the mandible, genial foramina and canals, maxillary sinus and the incisive canal and foramen of the maxilla. Technology is of little value if the information required is not obtained and so information is also provided on imaging of some of the vital

Nagarjan Tukuru, Shivalinge Gowda KP, Syed Mansoor Ahmed and S Badami (2008)[37] used of RP technology in medical industries, coupled with the other techniques has led to improvement in services offered to patients by improvement in such areas as 3D visualization of a specific anatomy, surgical planning, implant design, prosthesis production, and polymeric drug delivery devices. In this article the current technologies available in RPT and its application in different fields of medicine and future trends in this area were reviewed.

Hakan T., Murat Akkaya, Oguz Ozan (2009)[22] evaluated a patient that was treated with an implant-supported fixed prosthesis with help of computer-assisted three-dimensional planning. A 52-year old edentulous man underwent computerized tomographic (CT) scanning, and the cross sections were reformatted. The cross sections were used to construct a surgical guide. Eight dental implants were placed using a series of supra mucosal surgical stents. Following a 5-months healing period, the stability of the implants was confirmed with use of an Osstell device. After 6-months, a second CT evaluation was carried out and the positions of the implants were compared with the treatment planning data. The author contributed his success to CT-based software programme and surgical stents.

MATERIALS

The materials used in the present study:

1. High end multimedia computer with minimum 4GB of RAM
2. Software – Implant 3D, Media Lab Limited.
3. Rapid prototype model.
4. Surgical guide.
5. 316L Stainless steel sleeves of 2mm, 3mm, 4mm, 5mm & 6mm

METHODOLOGY

The following methodology was adopted for the study:

Selection of patients

↓

Clinical examination

↓

Radiological diagnosis

Computerised spiral tomography scans (0.5 mm cuts, in DICOM format in a compact disc)

↓

Import of data in the implant simulation software

↓

Evaluation of available bone height, width, density and adjacent vital structures

↓

Positioning of virtual implants

↓

Export of data in STL format

↓

Fabrication of rapid prototype model

↓

Preparation of surgical guide

↓

Implant placement through guide

↓

Post-operative evaluation of implant position and angulation to their pre-operative values.

This clinical study was conducted in the department of Oral & Maxillofacial Surgery, Ragas Dental College & Hospital, Chennai, India. The recruitment of patient and subsequent treatment was conducted under an informed consent document.

Approval of the study protocol was obtained from the Institutional Review Board (The Ethical Committee) of the Ragas Dental College & Hospital, Chennai, India.

Selection of patients

Selection of all the patients for this study was done under the following standard protocol:

Inclusion criteria:

- Patients willing and able to complete the study after obtaining informed consent in accordance with ethical clinical policies.
- Edentulous and/or partial edentulous maxillary and/or mandibular ridge.
- Acceptable oral hygiene.

Exclusion criteria:

- Alcohol or drugs, or have a daily smoking habit.
- Uncontrolled periodontal disease.
- Radiation therapy to the head and neck region.

- Patients with any disease or condition or on any medication that might compromise healing or osseointegration.
- Patients with para functional habits/severe bruxism.

During the initial consultation, patient's chief complaint and the expectations were elicited and noted regarding treatment requests for all the patients screened and included in the study.

CASE 1

A 25 year old male patient came with chief complaint of missing lower posteriors (Fig.1b) and wanted replacement with permanent teeth.

On examination, inter occlusal clearance was found to be 4 mm because of supraeruption of maxillary left posteriors (Fig.1a). In such situation surgical correction is always preferred as it offers advantage of correcting alignment of the segment also.

Patient was made aware of the existing situation.

CT scan was taken and data imported for reconstruction (Fig.2). The right mandibular posterior teeth were mirrored and aligned on the left side and implants were simulated along the long axis of posterior teeth (Fig.3a). The left posterior maxillary segment was osteotomised and intruded so that it aligns properly with lower left segment of mandible (Fig.3b). An stereolithographic file (Fig.3a,b) was produced in the same position. A rapid prototype model (Fig.4) was created. Splint to position upper maxillary segment was prepared (Fig.5).

In the lower jaw a surgical guide was created using implant extensions (Fig.6) as described earlier. Case was posted under general anaesthesia and left posterior maxillary osteotomy done to reposition the segment (Fig.7) and 3 implants in the planned positions were placed in mandibular arch using the surgical guide(Fig.8,9,10). Prosthetic rehabilitation was done 6 months post operatively (Fig.15b, 16).

CASE 2

A 59 year old female patient with several missing teeth and poor periodontal status (Fig.17) was presented from the department of Prosthodontics to the department of Oral and Maxillofacial Surgery, Ragas Dental College, Chennai for discussion.

Patient wanted replacement of missing teeth. On clinical and radiological examination several edentulous spaces in upper and lower arch, periodontially compromised anteriors, inadequate width in 46 region and sinus level was found too low bilaterally (Fig.17b-g)

Case was discussed and planned for bilateral sinus lift and bone ridge augmentation in 46 region, removal of compromised teeth and later rehabilitation using endosseous implants.

Case was posted under general anesthesia, autogenous bone graft was harvested from right iliac crest. Bilateral sinus lift (Fig.18, 19) and ridge augmentation in 46 region was done using the bone graft (Fig.20)

Six months later CT scan was taken to evaluate present situation and virtual planning for implant placement was done (Fig.22). Data was imported in stereolithographic file, a maxillary rapid prototype model with implant extensions was obtained (Fig.23), surgical guide was prepared as discussed earlier (Fig.24) and 8 implants were placed in maxillary arch. Implants in mandible were placed using conventional technique. (Fig.25) Patient recalled for regular follow up.

Seven months later prosthetic rehabilitation was done with implant supported fixed bridge in both upper and lower jaw (Fig.34b, 36).

CASE 3

A 40 year old, male patient was presented with edentulous region in both upper and lower jaw and periodontially compromised posteriors (Fig.37). Patient was planned for implant supported fixed bridges, initially with mandible and then the maxilla. A maxillary denture was prepared and 5 implants were planned in the mandible. Pre operative planning and simulation of virtual implants (Fig.38), rapid prototype model with implant extensions (Fig.39) were done and surgical guide (Fig.40) was prepared as described earlier. Implants were placed in pre operative planned position using surgical guide under local anesthesia (Fig41). Prosthetic rehabilitation was done 6 months post operatively (Fig.48c, 50)

CASE 4

A 67 year old, male patient with edentulous maxilla, maxilla was severely resorbed, causing inadequate retention of maxillary denture (Fig.51). The situation demanded implant placement without using bone graft to support the upper denture for retention. So it was planned to place two implants in nasal buttress and one in midline to give an implant supported hybrid denture. A CT scan was taken, pre operative virtual planning and implant simulation (Fig.52) was done to place one implant in the midline above the incisive foramen and canal and 2 in nasal buttresses. Rapid prototype models were obtained (Fig.53a, b). Surgical guide was prepared (Fig.54) as described earlier and used to place implants in the planned position (Fig.55c, 56). Patient has to be rehabilitated.

CASE 1

Name : Mr. Siva Subramaniam

Age : 26 years

Sex : Male

Arch : Mandibular arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	-11	0	-11	-3	0	3
2	-11	0	-11	0	0	0
3	-11	0	-13	2	2	2

Total number of implants: 3

CASE 2

Name : Mrs. Muthumal Peter

Age : 61 years

Sex : Female

Arch : Maxillary arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	18	178	18	178	0	0
2	17	183	17	180	0	3
3	12	192	12	185	0	7
4	11	196	11	190	0	6
5	-6	192	-5	182	1	10
6	-11	187	-11	180	0	7
7	-10	182	-10	179	0	3
8	-18	171	-18	171	0	0

Total number of implants : 8

CASE 3

Name : Mr. Kanthappan

Age : 42 years

Sex : Male

Arch : Mandibular arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	31	8	31	0	0	8
2	23	0	20	344	3	16
3	22	353	21	357	1	4
4	-29	9	-10	328	19	41
5	-34	358	-24	345	10	13

Total number of implants : 5

CASE 4

Name : Mr. Viswanathan

Age : 67 years

Sex : Male

Arch : Maxillary arch

Number of implants	Pre – op Virtual position		Post – op Actual position		Difference	
	Pan angle	Sec angle	Pan angle	Sec angle	Pan angle	Sec angle
1	-8	190	-8	185	0	5
2	6	187	6	187	0	0
3	0	190	0	188	0	2

Total number of implants : 3

A total of 19 implants were placed in the planned positions that were used for rehabilitation. No complication as nerve injury has occurred.

2 out of 19 implants showed minor deviations in angulation from the planned angulation, being compensable by standard angle abutments.

1 out of 19 implants showed major deviation in angulation from the planned angulation which required correction by, custom milled abutment during rehabilitation.

Data was entered and analysed using SPSS 10.5 (Statistical package for social science). Paired-t test was used to compare the variables (Pan angle & Sect. angle) between pre operative and post operative conditions.

The p value less than 0.05 is considered statistically significant.

VARIABLE	GROUP	SAMPLE (N)	MEAN	STANDARD DEVIATION	P - VALUE
PAN ANGLE	**PRE OP**	**19**	**-0.6842**	**18.2027**	**0.227**
	POST OP	**19**	**0.7368**	**15.5594**	
SEC ANGLE	**PRE OP**	**19**	**146.7368**	**112.9562**	**0.233**
	POST OP	**19**	**144.0526**	**115.4318**	

P value greater than 0.05 indicates there is no statistically significant difference between pre operative planned virtual position and post operative actual position of implants.

DISCUSSION

A Timeline of Dental Implant Dentistry [31,32]

Ancient history - Egyptians shaped seashells and hammered them directly into the gums for the purpose of replacing teeth. Ivory and the bones of animals were also sometimes used to replace missing teeth.

1700s - Lost teeth were often replaced with teeth from human donors. The process was mostly unsuccessful due to immune system reactions to the foreign material.

1800s-Gold, platinum and other metal alloys were used experimentally and placed into sockets where teeth had been freshly extracted in an attempt to create suitable replacements. Long - term success rates were extremely poor.

1952 - A doctor in Sweden accidentally discovered that titanium can bond irreversibly with living bone tissue. (Titanium is the same material that has been successfully used in knee and hip replacements for more than 30 years).

1965 - The Birth of Modern Implants! The process of purposely implanting titanium in bone for the purpose of rooting prosthetic teeth began.[BRANEMARK]

1982 - The Toronto Conference on Osseointegration in Clinical Dentistry created the first guidelines for what would be considered successful implant dentistry.

2002 - An ADA survey showed that oral and oral and maxillofacial surgeons, periodontists, and general dentists near doubled the number of implants performed per dentist between 1995 and 2002.

Today – Precision in implant placement resulting in good osseointegration, mini implants, prosthodontically driven implants, flapless implant surgeries and zygomatic implants are being accepted as an alternative protocol for placing dental implants other than conventional method.

Precise placement of implant, so that good quality and quantity of bone lies all around it and mechanical behavior of the surrounding bone is an important factor in the successful osseointegration. The bone density play an essential role in the success of dental implant therapy. Bone quality is a collective term referring to the mechanical properties, architecture, degree of mineralization of the bone matrix, and chemistry and structure of the bone mineral crystals, as well as the remodeling properties of bone. Several classification methods have been suggested for assessing the bone quality and predicting prognosis.

One of the method for bone density assessment was given by Carl E.Misch. in 1988 [33]. He proposed four bone density groups (D1, D2, D3 and D4) (Fig.63) independent of the regions of the jaws based on macroscopic cortical and trabecular bone characteristics.

Misch bone density classification:

Bone density	Description	Tactile analog	Typical anatomical location
D1	Dense cortical	Oak or maple wood	Anterior mandible
D2	Porous cortical and coarse trabecular	White pine or spruce wood	Anterior mandible Posterior mandible Anterior maxilla
D3	Porous cortical (thin) and fine trabecular	Balsa wood	Anterior maxilla Posterior maxilla Posterior mandible
D4	Fine trabecular	Styrofoam	Posterior maxilla

The term bone quality was used to refer these density types. With respect to their classification, this is the more objective type of bone classification method to evaluate the implant recipient sites.

Computed tomography (CT) scan can be used to determine bone density more precisely. [34] CT produces images of the patient's anatomy. Each CT image has certain pixels, and each pixel has a CT number (Hounsfield unit) related to the density of the tissues within the pixel. In general, the higher the CT number, the denser the tissue. Modern CT scanners can resolve objects less than 0.5mm apart. The Mish bone density classification may be evaluated on the CT images by correlation to a range of Hounsfield units (HU): D1 corresponds to values greater than 1250HU; D2, 850 to 1250HU; D3, 350 to 850 HU; D4, 150 to 350HU. [33]

The advance in CAD–CAM technology software has produced implant visualization and simulation. These softwares can import CT data into it and the images can be reformatted in panoramic view and they can also create 3D objects of the desired region (maxilla or mandible). A particular region can be simultaneously visualized in axial, panoramic, sectional and 3D views.

Different companies implant libraries are available with the software, a particular desired implant can be selected and placed in a particular position and can be visualized panoramically, axially, sectionally, and in 3D, evaluating the bone density in the implant placement region from alveolar surface till the apex of implant. The angulation may be calculated by panoramic and sectional angles. Repositioning tools are available to accurately place the implants in all the three sections. Inferior alveolar nerve can be simulated and visualized and the surrounding structure can be accurately evaluated. Tools for assessing the amount of bone required for a sinus lift is also available. The datas can be exported as a project sheet which gives in detail about the patient information, number of implants, 3D position and sequence with necessary pictures which will be useful for interacting with patient and for future record.

A ray set of implants, X, Y, Z coordination in 3 dimensions can be also exported which can be incorporated in a goniometer to prepare a flapless tissue borne surgical guide. The bone, the implant and implant extensions with their pre planned relationship can be exported into a STL file which can be used to produce a rapid prototype model on which a bone borne surgical guide can be prepared.

Implant configuration has long been considered as an essential requirement for implant success as a general concept, the screw implant design develops higher mechanical retention as well as greater stability to transfer compressive forces (Randow et al 1999; Shalak 1983; Wolfe & Hobkirk 1989).[29,47] The screw design not only minimizes the micromotion of the implant but also improves the initial implant stability. Additionally, the thread increases surface area (Misch CE).[35]

The implant length may also influence the outcome of immediate implant loading. For every 3 mm increase in length, the surface area of a cylinder-shaped implant increases by an average of 20-30% (Misch CE).[35] A study has reported 50% failure rate with immediate loading for implant lengths $\leq$ 10 mm (Schnitman et al. 1997).[44] The majority of studies suggested that implant should be $\geq$10 mm long to ensure high success rate (Tarnow et al. 1997).[54]

So bone density and implant type and length are essential for good osseointegration but for dental rehabilitation the prosthodontically driven implants are important as they are placed to approximate the occlusal load and to survive for long time to give good result.

After years of development rapid prototyping technologies are now being applied in medicine for manufacturing dimensionally accurate human anatomy models from high resolution medical image data.[27]

The term "rapid prototyping" refers to a number of different but related technologies that can be used for building very complex physical models and prototype parts directly from 3D CAD model. Among these technologies are,[37]

1. Stereolithography (SLA),
2. Selective laser sintering (SLS),
3. Fused deposition modeling (FDM),
4. Laminated object manufacturing (LOM),
5. Inkjet-based systems and three dimensional printing (3DP).

Whatever may be the technology used, all employ the common basic steps in fabricating the physical model.[27,37]

1. Create a CAD model of the design
2. Convert the CAD model to STL format
3. Slice the STL file into thin cross-sectional layers (Reslicing)
4. Construct the model one layer atop another
5. Clean and finish the model

RP technologies can use wide range of materials (from paper, plastic to metal and nowadays biomaterials) which gives possibility for their application in different fields. The material used in this study was starch based. The Z-crop. 3D printer uses a binding material to produce the model with starch, layer by layer.

Preparation of surgical guide:

The physical model with implant extensions (Fig.6b, 23) can be used to fabricate surgical guide using various materials. In the present study 316L stainless steel as the sleeve material (Fig.54) and clear acrylic was used for the surgical guide fabrication. All undercuts were blocked in the rapid prototype (RP) model using modelling wax and a thin coat of vaseline was applied over it. The 316L sleeves were placed progressively in sequence over the implant extensions concentrically such that minimum diameter sleeve fitting in the implant extension and maximum diameter sleeves towards periphery. The 316L sleeves used were of 2mm, 3mm, 4mm, 5mm and 6mm in their inner diameter. Once the sleeves were positioned over all the implant extensions, the outer most sleeve with largest diameter were stablised using cold cure acrylic material by sprinkle on method. After adequate curing the smaller diameter sleeves were removed first which resulted in easy retrieval of the surgical guide. It was then polished and cleaned to be used during implant placement. Since, only outermost sleeve of each implant extension was stablised, the other corresponding smaller sleeves were free to move, remove and reposition.

316L stainless steel is a proved biocompatible material by Wang G. et al.[46] So drilling through these sleeves may produce metal dust which otherwise could be a source of disturbance if the sleeves were created with other materials.

Implant placement

Once patient and the armamentarium are ready under local or general anesthesia depending upon the number of implants and jaw the treatment was done according to the pre planned sequence. The surgical guide was placed after raising a mucoperiosteal flap to guide the proper position of the surgical drill (Fig.8, 55c)

The first drill to be used was the 2mm pilot drill through the first (2mm) stainless steel sleeve (Fig.9a) and the parallel pins were positioned to check the angulation of the prepared implant site and to the desired depth. The depth drilled inside the bone coincided with the length of the pre planned virtual implant. The drill sequence followed after the 2mm pilot drill was as; 2.8mm, 3.2mm, 3.65mm, 4.2mm and 5.2mm.

The protocol followed for each implant were as follows:

Implant diameter	Drill sequence	Sleeve used
3.0 mm & 3.2mm	2.0mm,	2mm
	2.8mm	3mm
3.75mm	2.0mm,	2mm
	2.8mm,	3mm
	3.2mm	4mm
4.2mm	2.0mm,	2mm
	2.8mm,	3mm
	3.2mm,	4mm
	3.65mm	4mm
5.0mm	2.0mm,	2mm
	2.8mm,	3mm
	3.2mm	4mm
	3.65mm,	4mm
	4.2mm	5mm

Care was taken always to use an external irrigation (using 20ml syringe) along with the internal irrigation during the entire drilling sequence to prevent the bone heating. Cooled normal saline was used as the irrigant. According to Albrektsson et al 1986, [55] during the surgical procedure to thread the bone site, bone should not be heated beyond 43 degree C, otherwise alkaline phosphatase begin to breakdown and end up with failure of osseointegration. Therefore, very important to use sharp drilling equipment with low speed control (Branemark et al 1983).[6] As the fixture is inserted compression stresses will be created which may increase stability since a difference is maintained between the diameter of final drill and implant to be placed.

In real time when using the surgical guide for drilling sequence the problem encountered was the height of the sleeves, though reduced to minimum height to enhance drill through. If the implant length was more than 10mm, the initial sequence of drill (2mm to 4 mm), the flute length of drill was not enough to reach the desired full length as the guide takes about 5mm and most of the drill bits have flute length of 16mm. So in initial sequence of drills, after drilling 10mm, surgical guide has to be removed and rest of the drilling has to be done without it. So a modification of drill bits with lengthier flute will be of better use when using this type of customized surgical drill guides.

After implant placement, the mucoperiosteal flap was reapproximated and closed using 5-0 Ethilon suture material. Post op instructions were given to patient and drug regimen protocol of the department were followed. Patients were recalled for routine followup.

All patients included in this study were sent for a CT scan post operatively after 3 months. The post op CT data in DICOM format were once again imported in the Implant simulation software (IMPLANT 3D) and visualized panoramically, axially, sectionally, and in 3D views. The angulations were calculated by placing a fresh implant over the actual implant image and parallel to its long axis. Using panoramic and sectional angles pre operative planned angulations (Pan and Sect) were compared with post operative actual angulations (Pan and Sect) for each implant in all the patients (Fig.12a, b).

The repositioning tool, pan angle in the implant simulation software ranges from -90º to + 90º through 0°. This tool helps in mesiodistal adjustment of implant by positioning coronal or apical end points.

Other repositioning tool, the sectional (Sect.) angle in the software ranges from 0° to 360°. This tool helps to adjust the implant in cross sectional (bucco-lingual or bucco-palatal) view at any point. It is important to note that the difference between 0º and 357°, (as in case 1, implant 1) is only 3° in the anticlockwise direction (Fig.64). Similarly, sect angle deviation in case 4, implant 2 and implant 4 are 16° and 41° respectively from there planned virtual position.

Data was entered and analysed using SPSS 10.5 (statistical package for social science). Paired t test was used to compare the variables (Pan angle and Sect. angle) between pre operative and post operative conditions. It was found that there is no statistically significant difference between pre operative planned position of virtual implants and post operative position of actual implants in patient.

Although these procedures demand cost, as days goes by, the technology improves and these technique becomes a routine. It can bring down the cost to an affordable level. As computed tomography scan is becoming a routine diagnostic imaging, virtual implant simulation and surgical guide will also become a routine in advanced dental practice.

SUMMARY AND CONCLUSION

The conclusions drawn from this study conducted to simulate the virtual implant placement with computed tomography data using implant simulation software (IMPLANT 3D) and to construct a surgical guide with progressively diameter sleeves to accurately place implants, were that extensive pre operative planning and accurate execution of the plan is crucial for precise placement of implants which is necessary for long term treatment success. Imaging tools, implant planning software, precise surgical guide, good understanding of anatomy, surgical principles and post operative care are essential.

Students paired-t test was done to compare the variables (Pan angle & Sect. angle) between pre operative and post operative positions of all the implants.

No statistically significant difference were found between pre and post operative conditions which concludes that the surgical guide with progressive 316L stainless steel sleeves helped in accurate transfer of virtual implant position.

This method of treatment planning may not be necessary in simpler cases, as much planning is not required in cases having good ridge with adequate bone height and width. Conventional technique may be used in such cases as cost of treatment will be reduced.

But in difficult cases, such as inadequate bone width and height, nerve close to ridge, severe bone resorption and where conventional treatment procedures are not possible because of anatomical limitations or when patient does not agree for additional procedures such as bone grafting and ridge augmentation, this method proves to be efficacious in such circumstances.

This method of treatment planning helps in precise visualisation of existing situation and not only virtually but also can be seen physically as rapid prototype models and hence easy to work.

This technique establishes better understanding between Prosthodontist & Surgeon and helps in maintaining good rapport with patient. Also it is more interactive to students.

Only thing it consumes little time & cost factor involved with rapid prototype model and designing of 316L biocompatible sleeves.

Also, specialized drill bits are required because removing surgical guide and putting it back may cause little inaccuracy as required during initial drilling sequence.

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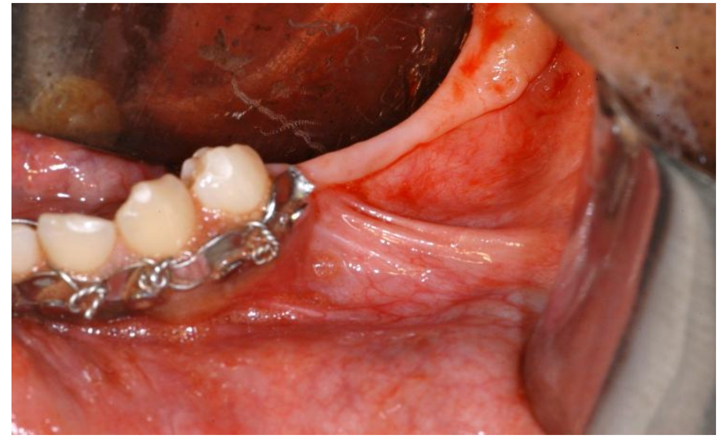
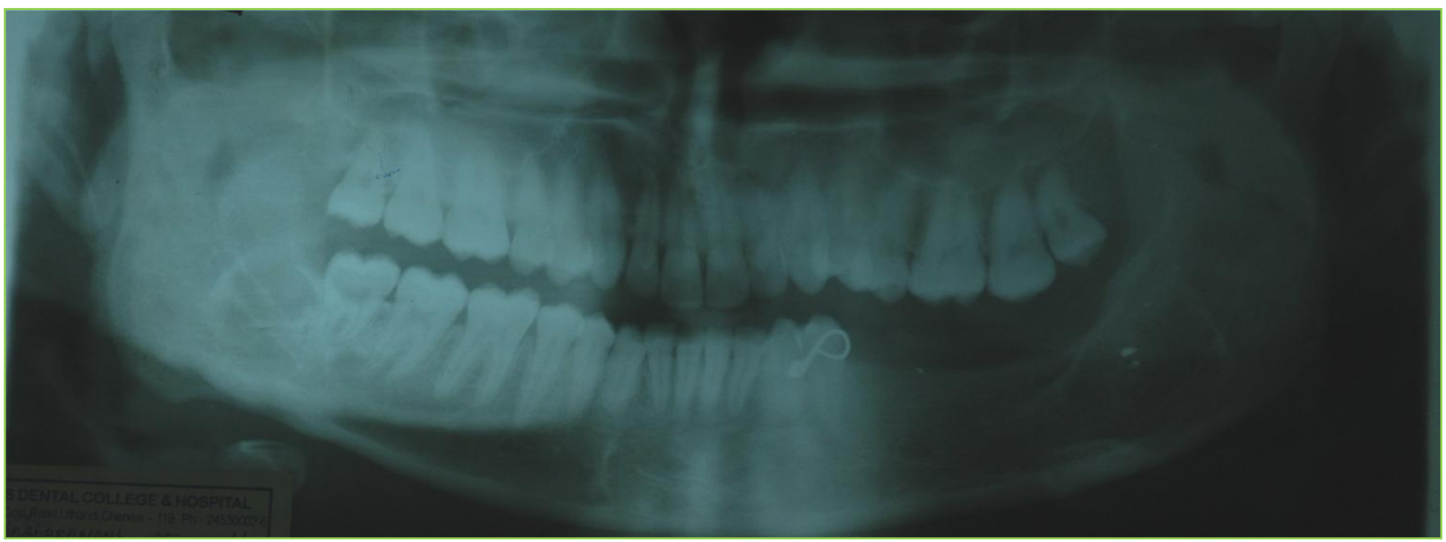
CASE 1

PRE OPERATIVE STATUS (Fig. 1)

a)Supra erupted maxillary posteriors

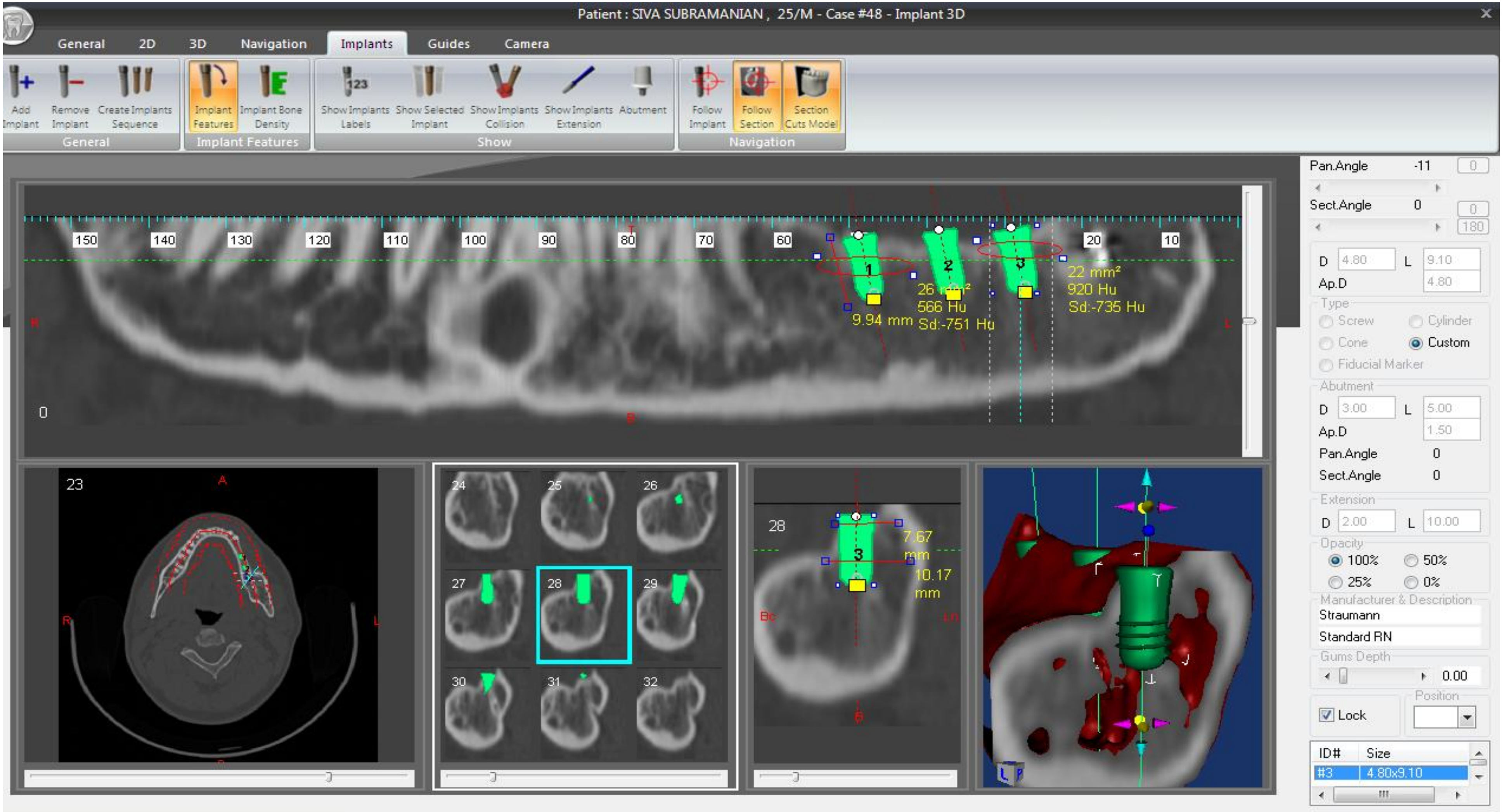


b)Posterior edentulous region in mandible

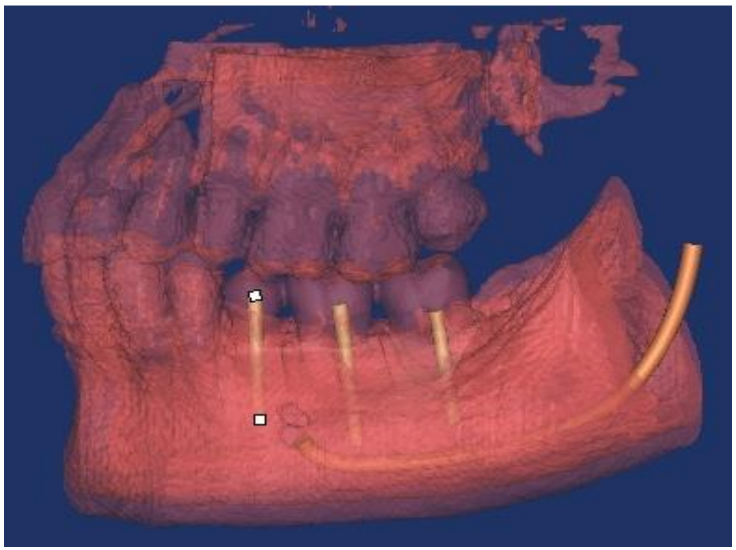


c)

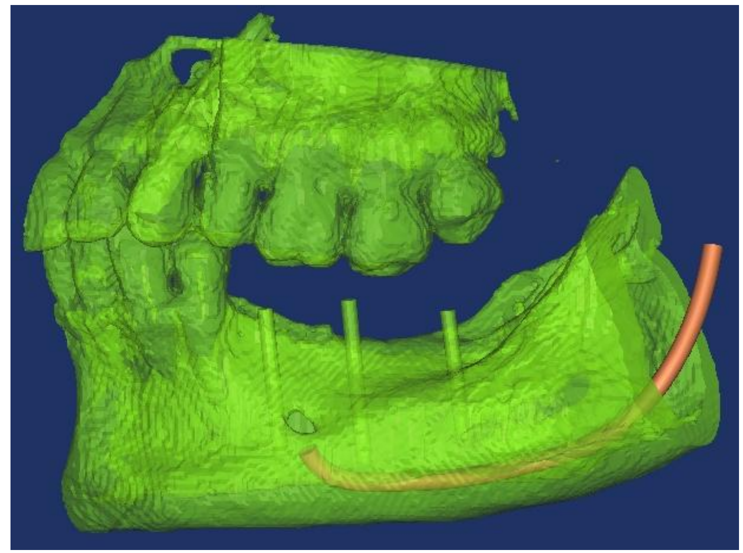
PRE OPERATIVE PLANNED POSITION OF VIRTUAL IMPLANTS WITH BONE DENSITY AND MEASUREMENTS (Fig. 2)



STEREOLITHOGRAPHIC FILE WITH PLANNED POSTERIOR MAXILLARY OSTEOTOMY , IMPLANT EXTENTIONS AND SIMULATION OF INFERIOR ALVEOLAR NERVE (Fig. 3)



a)



b)

STEREOLITHOGRAPHIC MODEL WITH PLANNED POSTERIOR MAXILLARY OSTEOTOMY AND IMPLANT EXTENTIONS (Fig. 4)

SURGICAL SPLINT FOR POSTERIOR MAXILLARY OSTEOTOMY (Fig. 5)

PREPARATION OF SURGICAL GUIDE ON STEREOLITHOGRAPHIC MODEL OF MANDIBLE (Fig. 6)

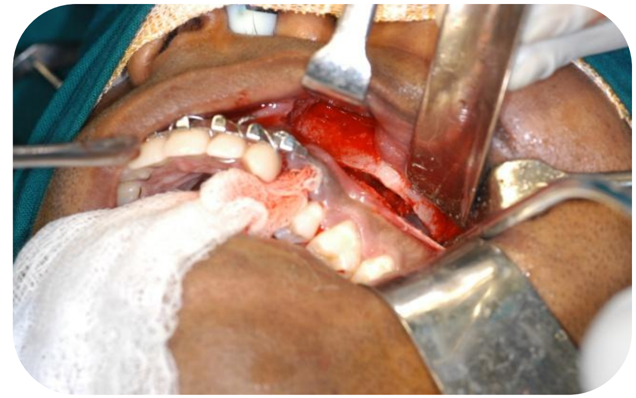
a)

b)

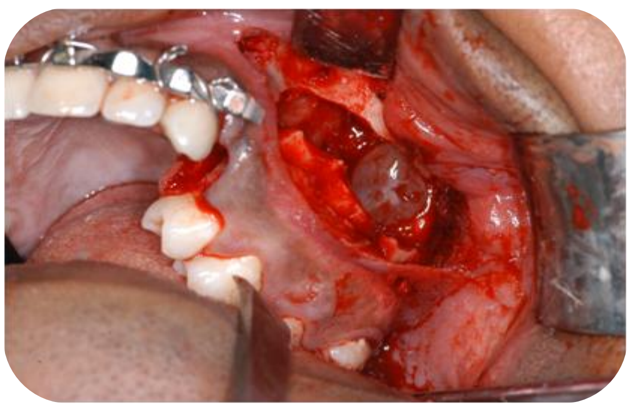
POSTERIOR MAXILLARY OSTEOTOMY (Fig. 7)

a)Extraction of 1st premolar

b)Mucoperiosteal flap raised



c)Osteotomy

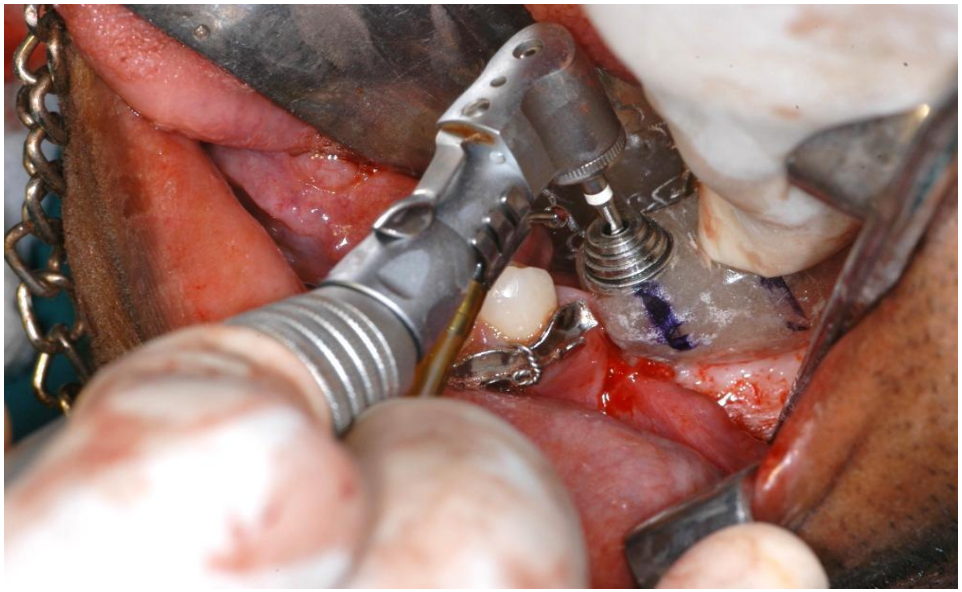


d)Mobilisation of the segment

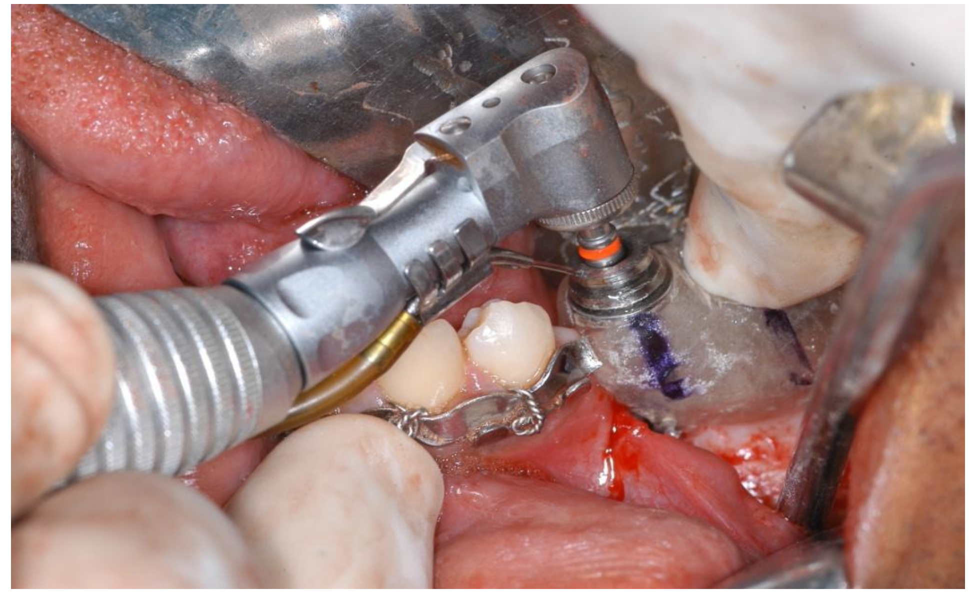
e)Fixation guided by splint

SURGICAL GUIDE IN POSITION (Fig. 8)

SEQUENTIAL DRILLING THROUGH SURGICAL GUIDE (Fig. 9)

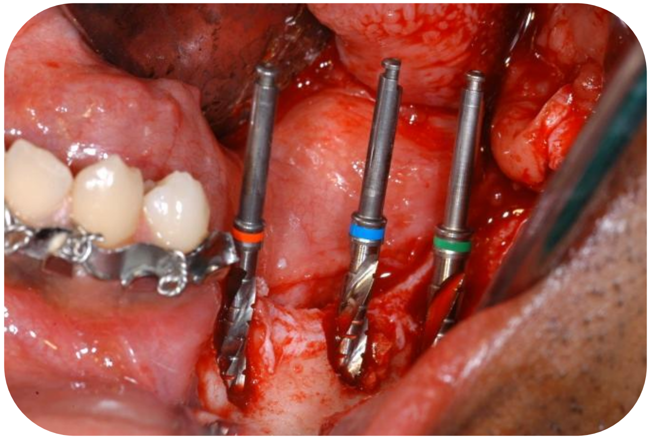


a)



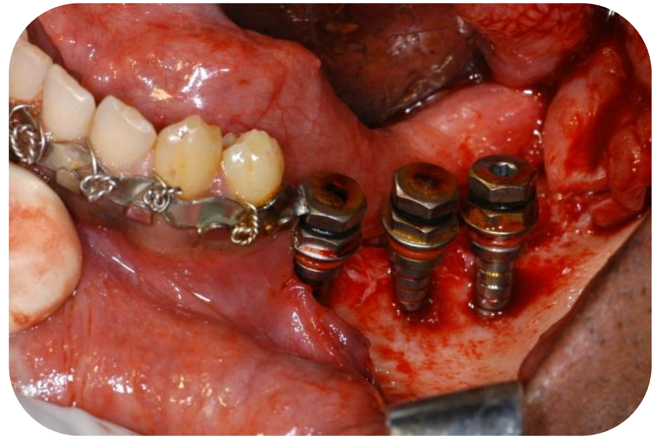
b)

IMPLANT PLACEMENT (Fig. 10)

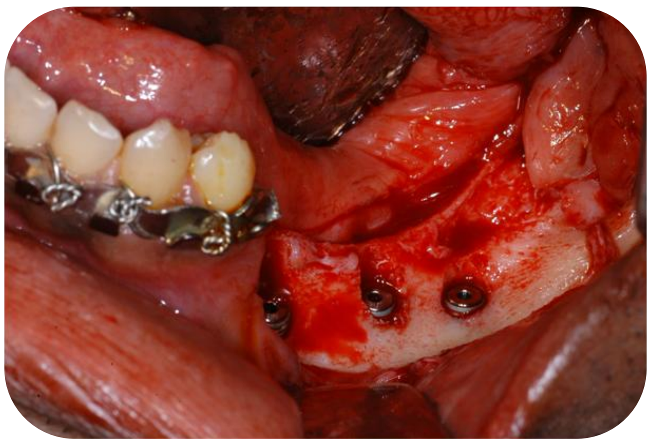


a)Osteotomy achieved as planned

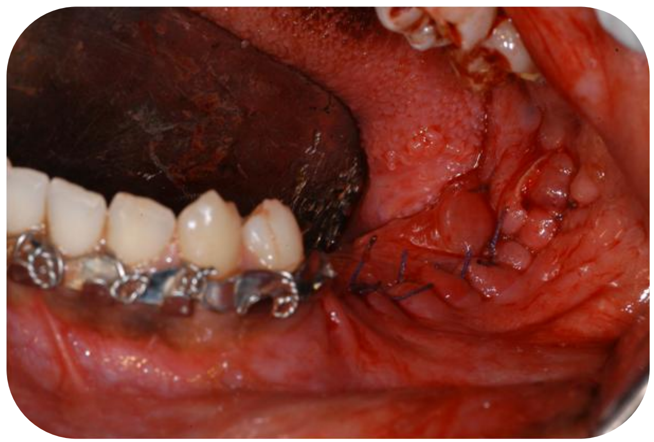
b)Drill holes



c)Implants in planned position



d)Cover screw placed

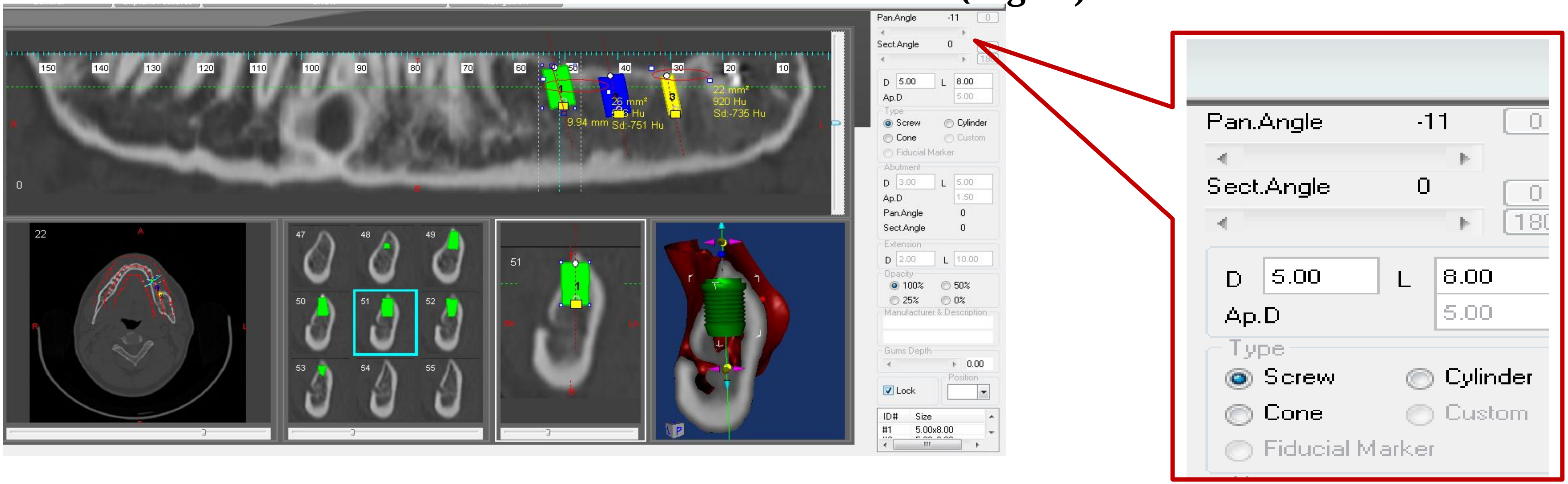


e)Reapproximation of flap

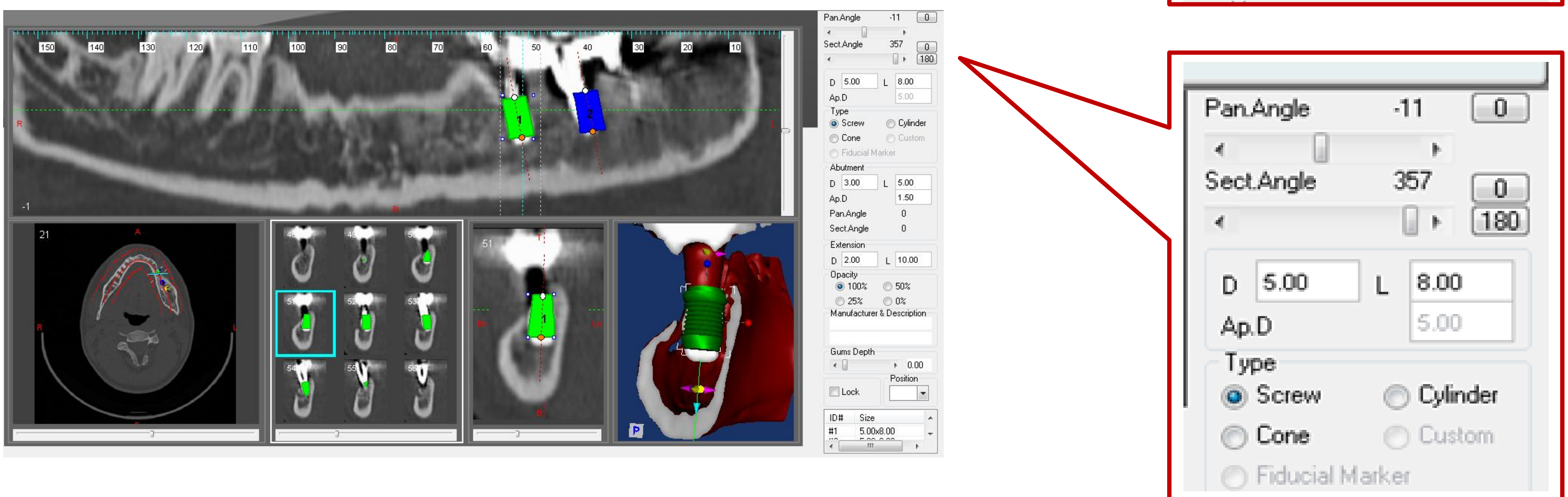
POST OPERATIVE ORTHOPANTOMOGRAPH (Fig. 11)

COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 1 (Fig.12)

a)

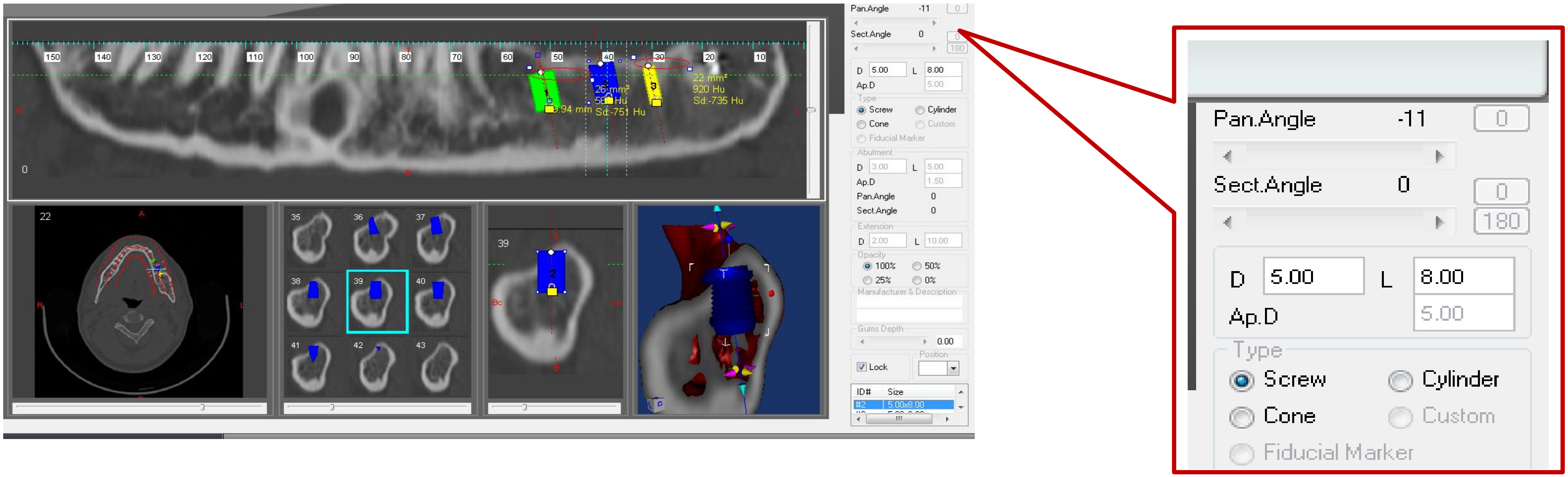


b)

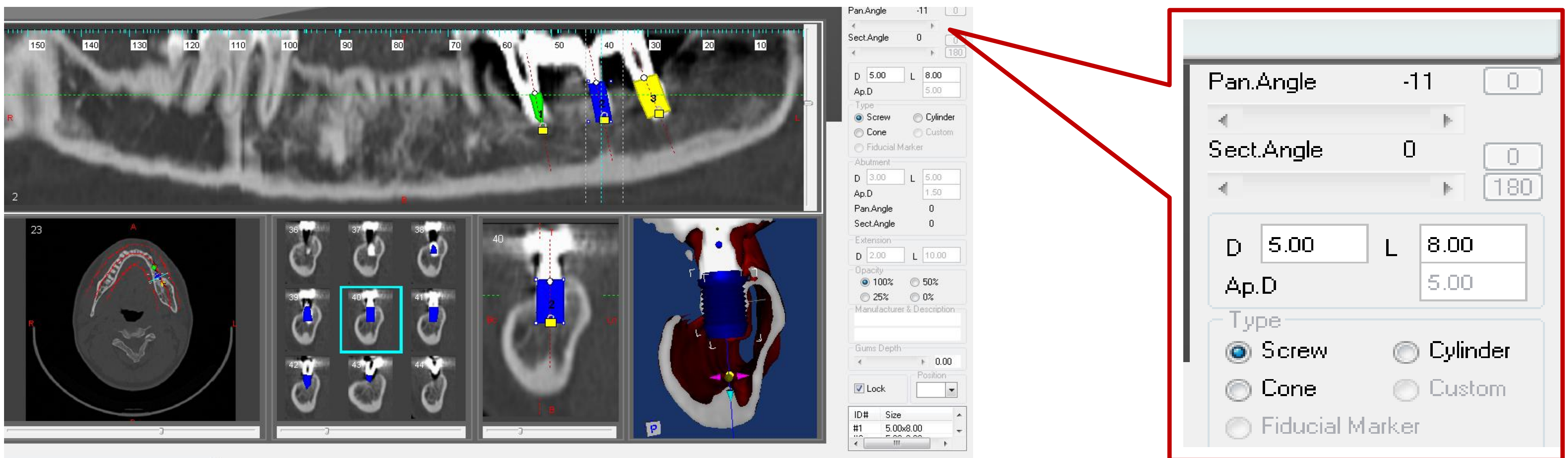


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 2 (Fig. 13)

a)

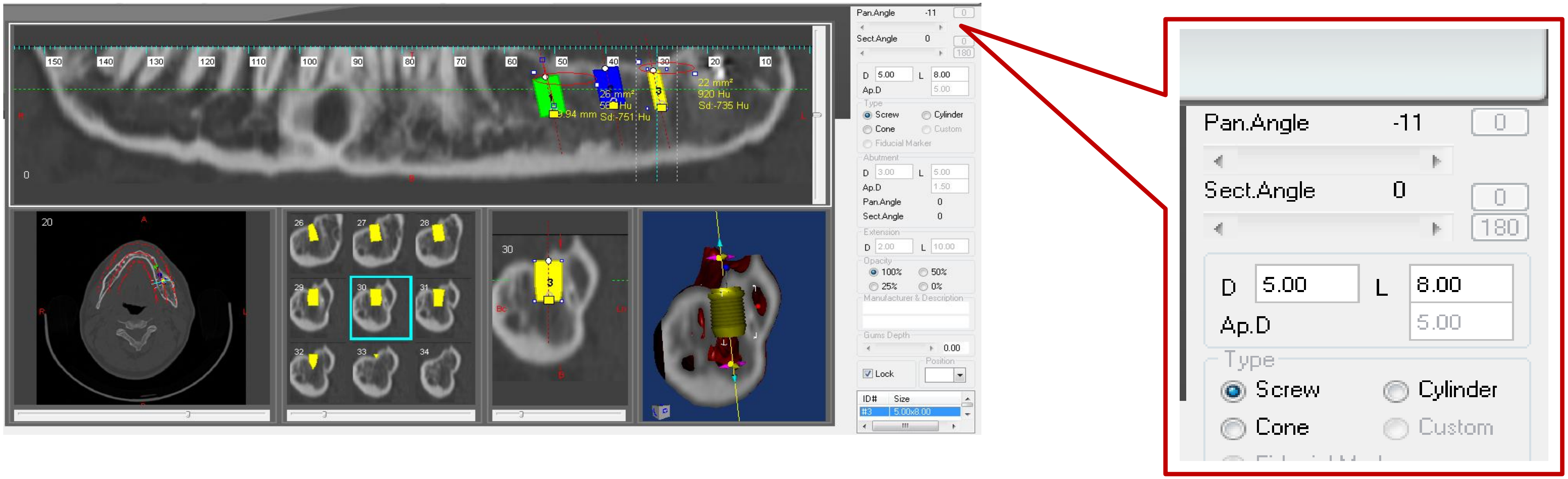


b)

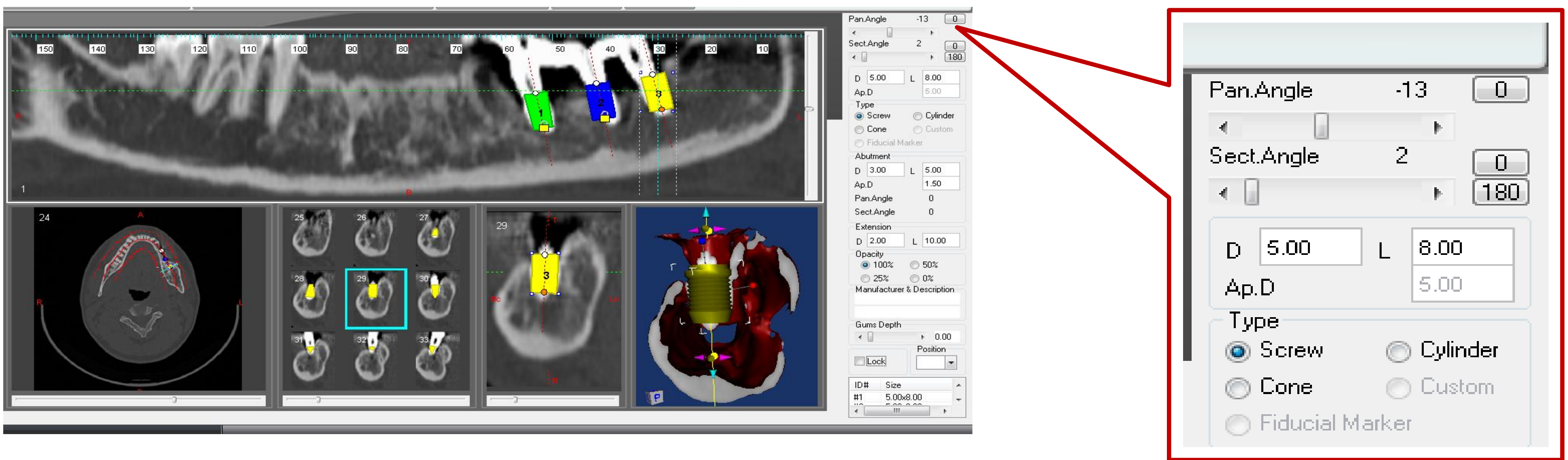


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 3 (Fig. 14)

a)



b)



COMPARISION OF PRE TREATMENT AND AFTER POSTERIOR MAXILLARY OSTEOTOMY AND PROSTHETIC REHABILITATION (Fig. 15)

a) PRE TREATMENT

b) AFTER TREATMENT

LOWER TEETH PLACED IN LINGUAL OCCLUSION

PATIENT AFTER TREATMENT (Fig. 16)

a)

b)

c)

CASE 2

PRE OPERATIVE STATUS (Fig. 17)

b)

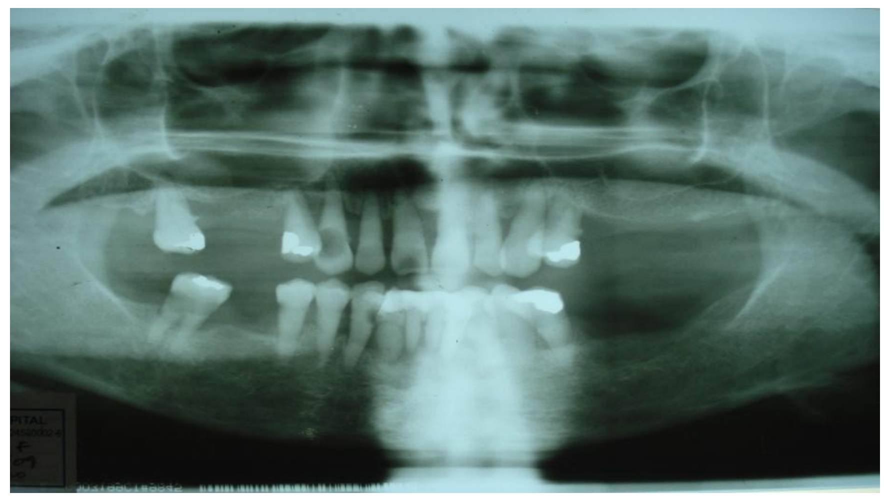
c)

d)

a)

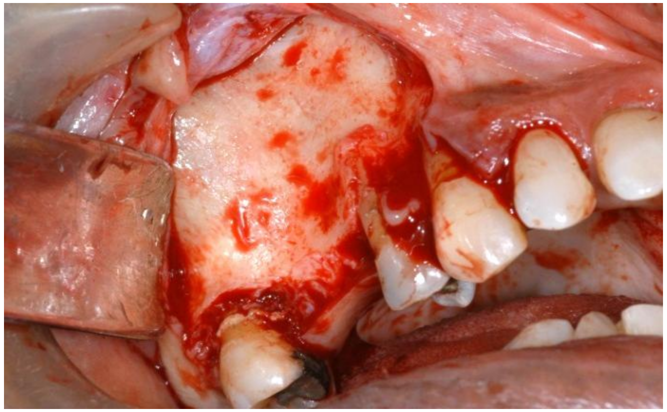
e)

f)

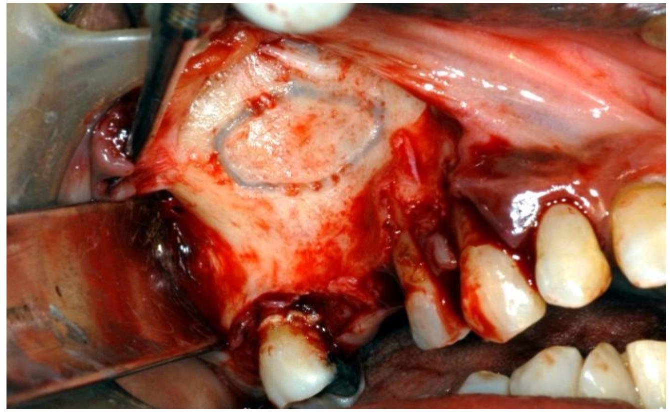


g)

SINUS LIFT & BONE GRAFTING IN FIRST QUADRANT (Fig. 18)



a)



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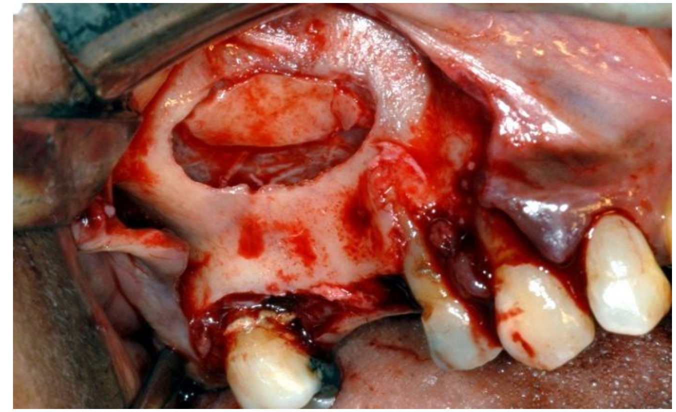
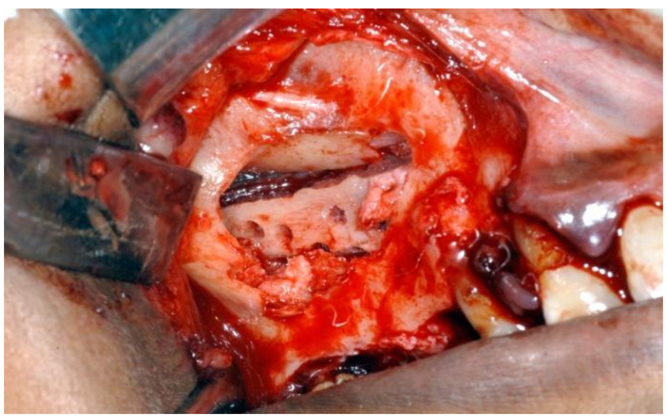


c)

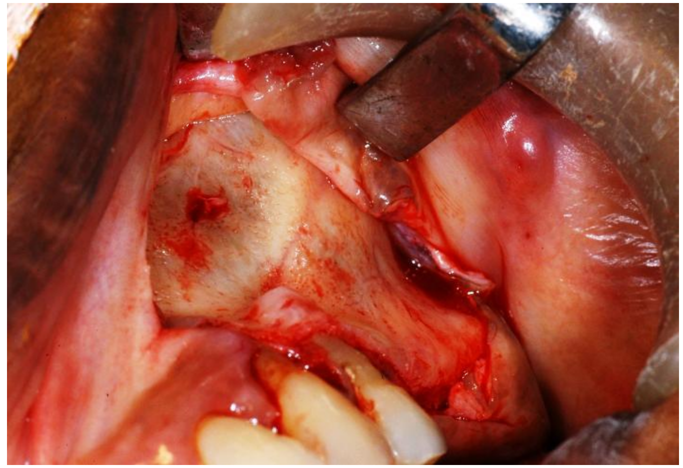


d)

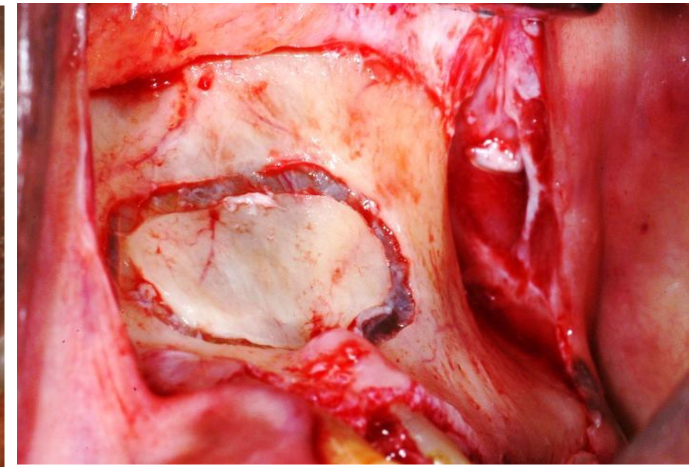
e)

SINUS LIFT & BONE GRAFTING IN 2ND QUADRANT (Fig. 19)

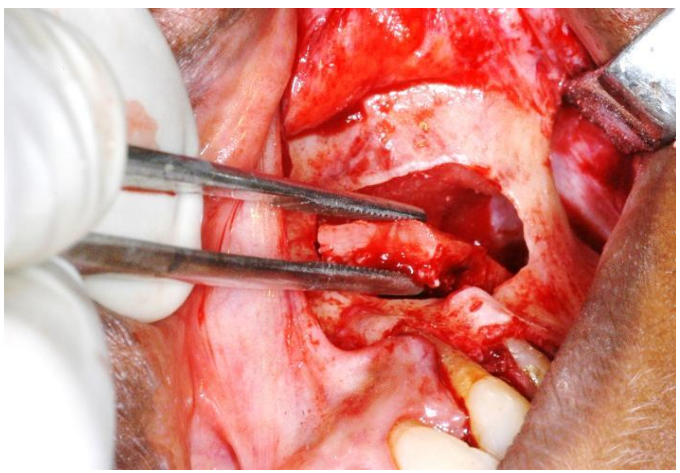
a)



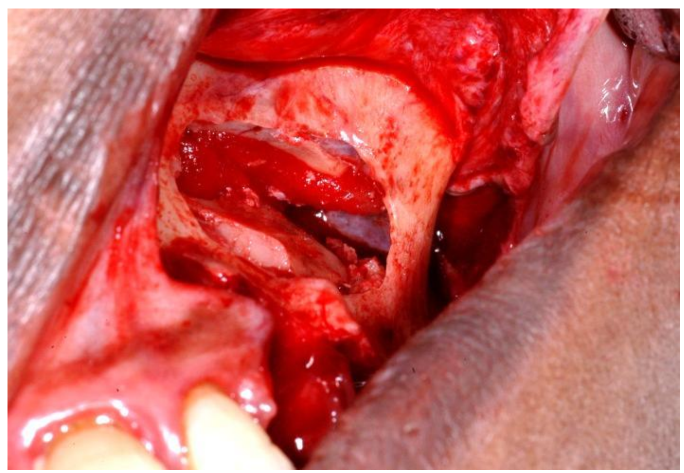
b)



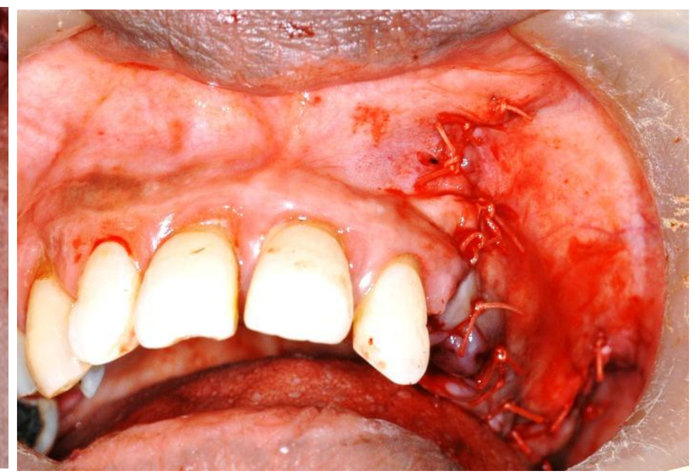
c)



d)

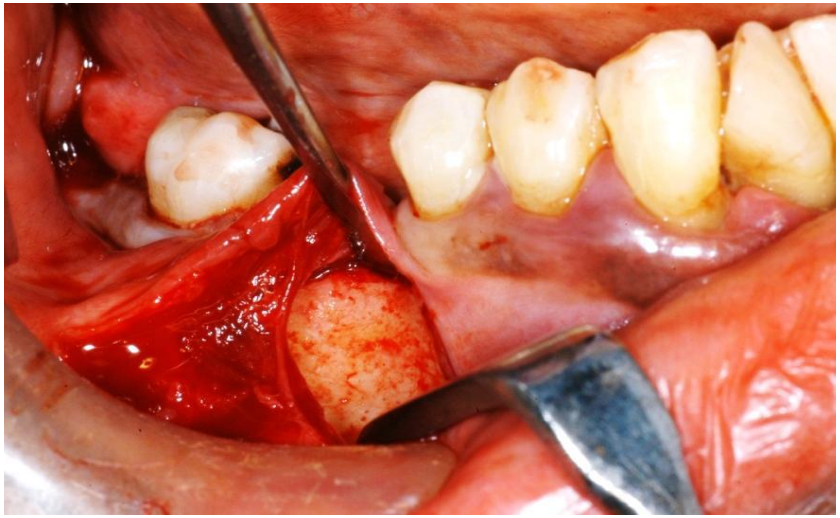


e)

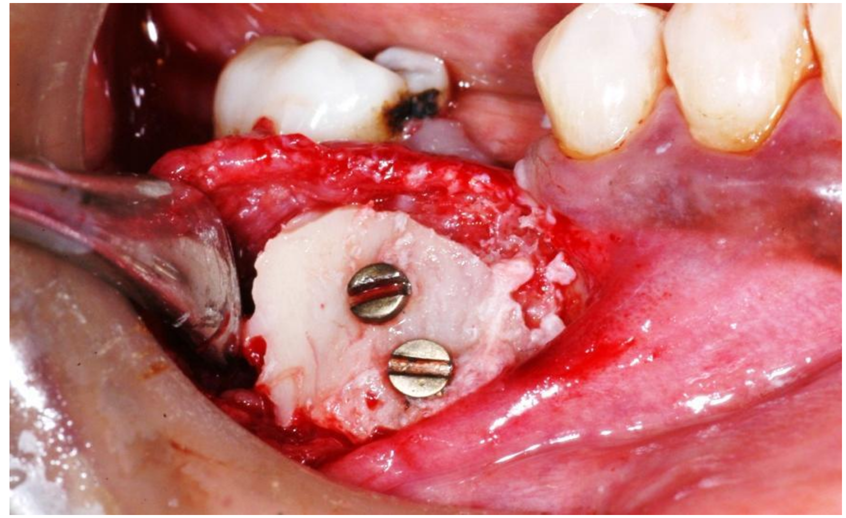


f)

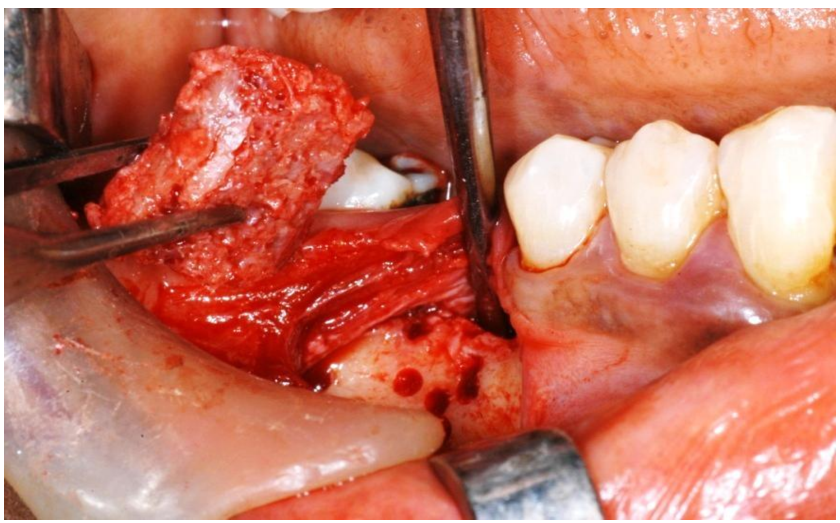
MANDIBULAR RIDGE AUGMENTATION TO INCREASE WIDTH (Fig. 20)



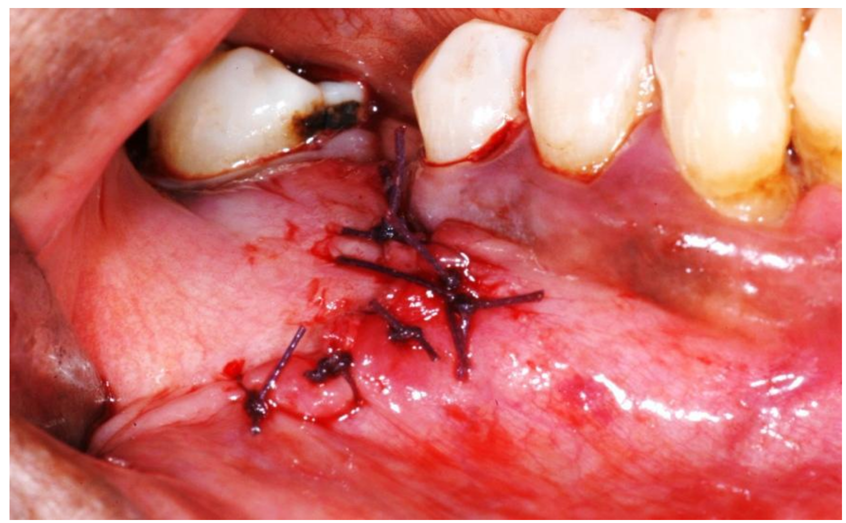
a)



b)

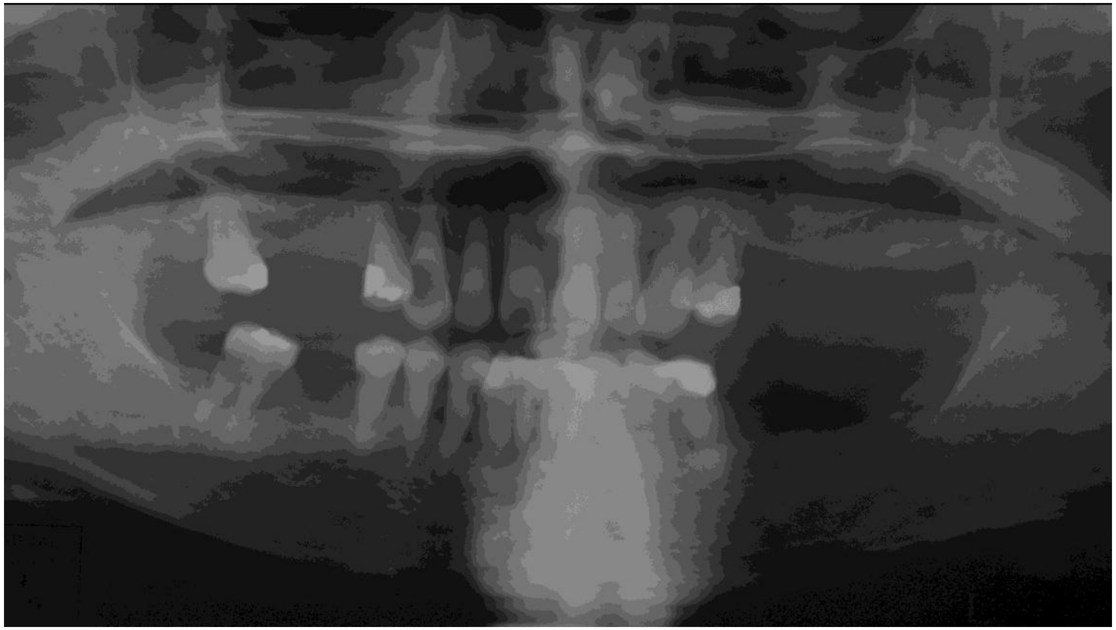


c)

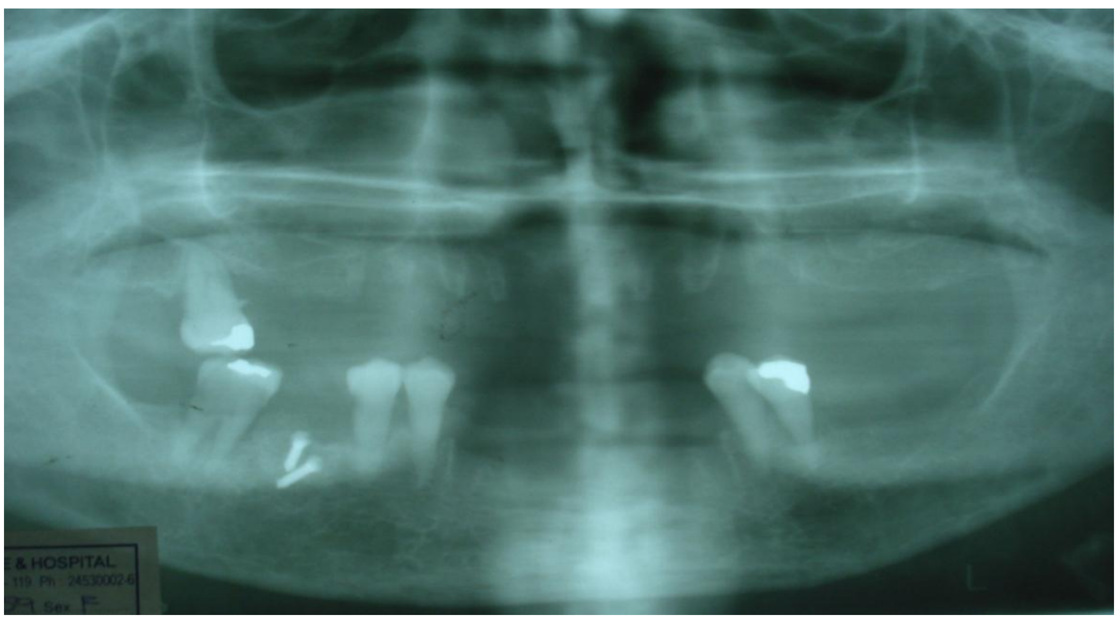


d)

BILATERAL SINUS LIFT & RIDGE AUGMENTATION IN 4TH QUADRANT (Fig. 21)

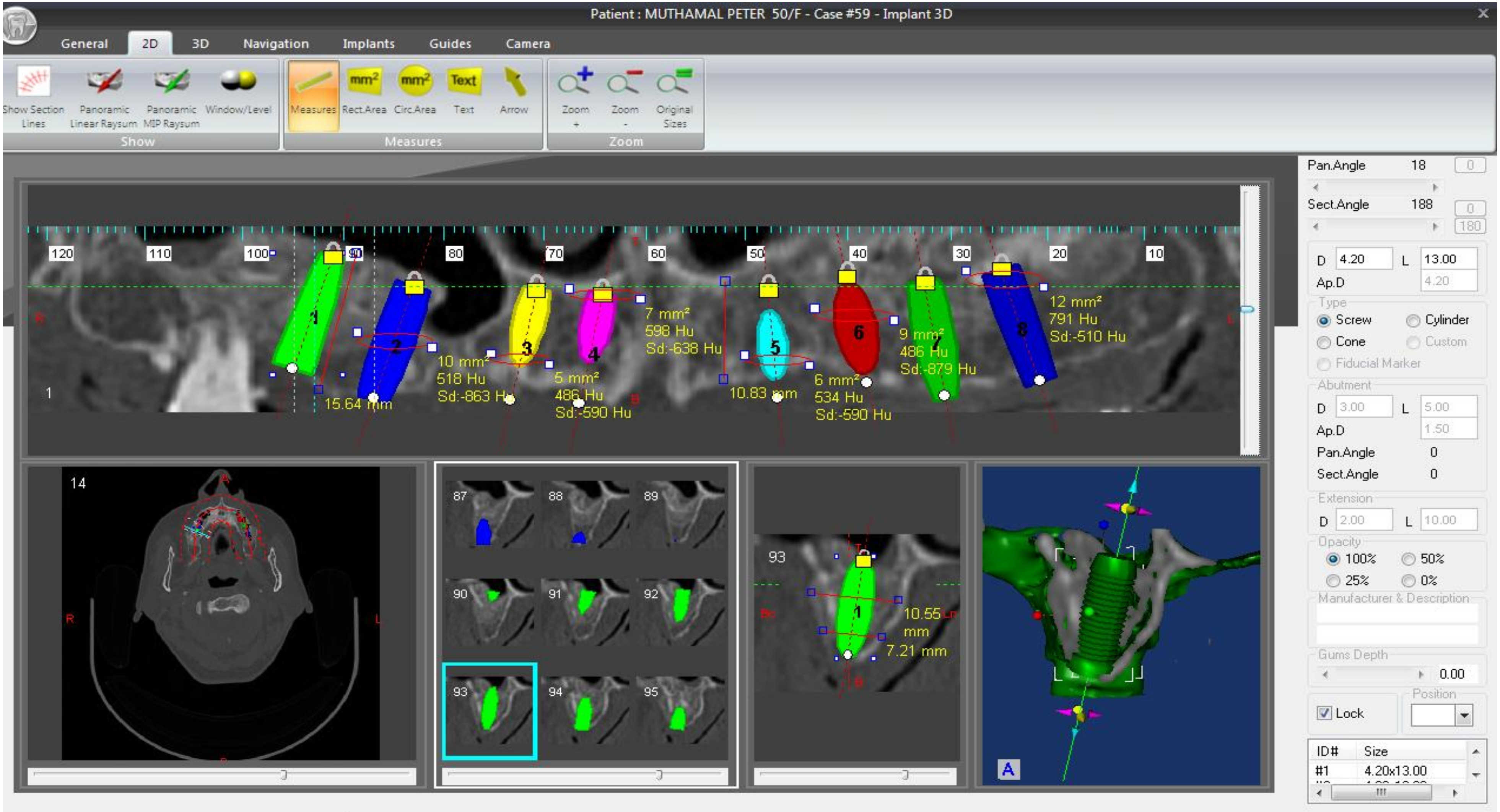


A) BEFORE SINUS LIFT AND AUGMENTATION

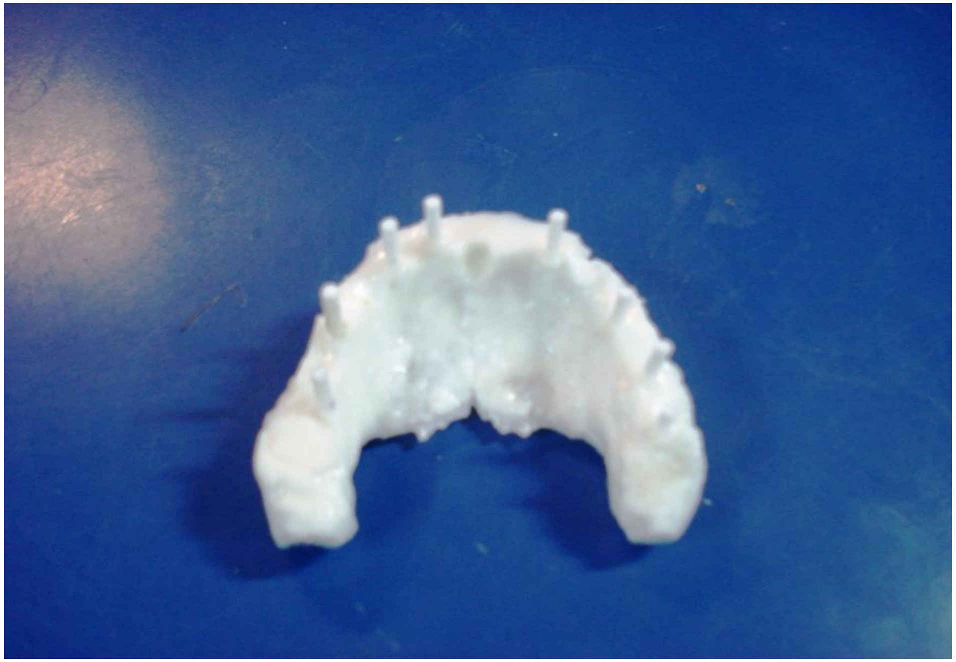


B) AFTER SINUS LIFT AND AUGMENTATION

PRE OPERATIVE PLANNED POSITION OF VIRTUAL IMPLANTS WITH BONE DENSITY AND MEASUREMENTS (Fig. 22)



3D STEREOLITHOGRAPHIC MODEL (Fig. 23)

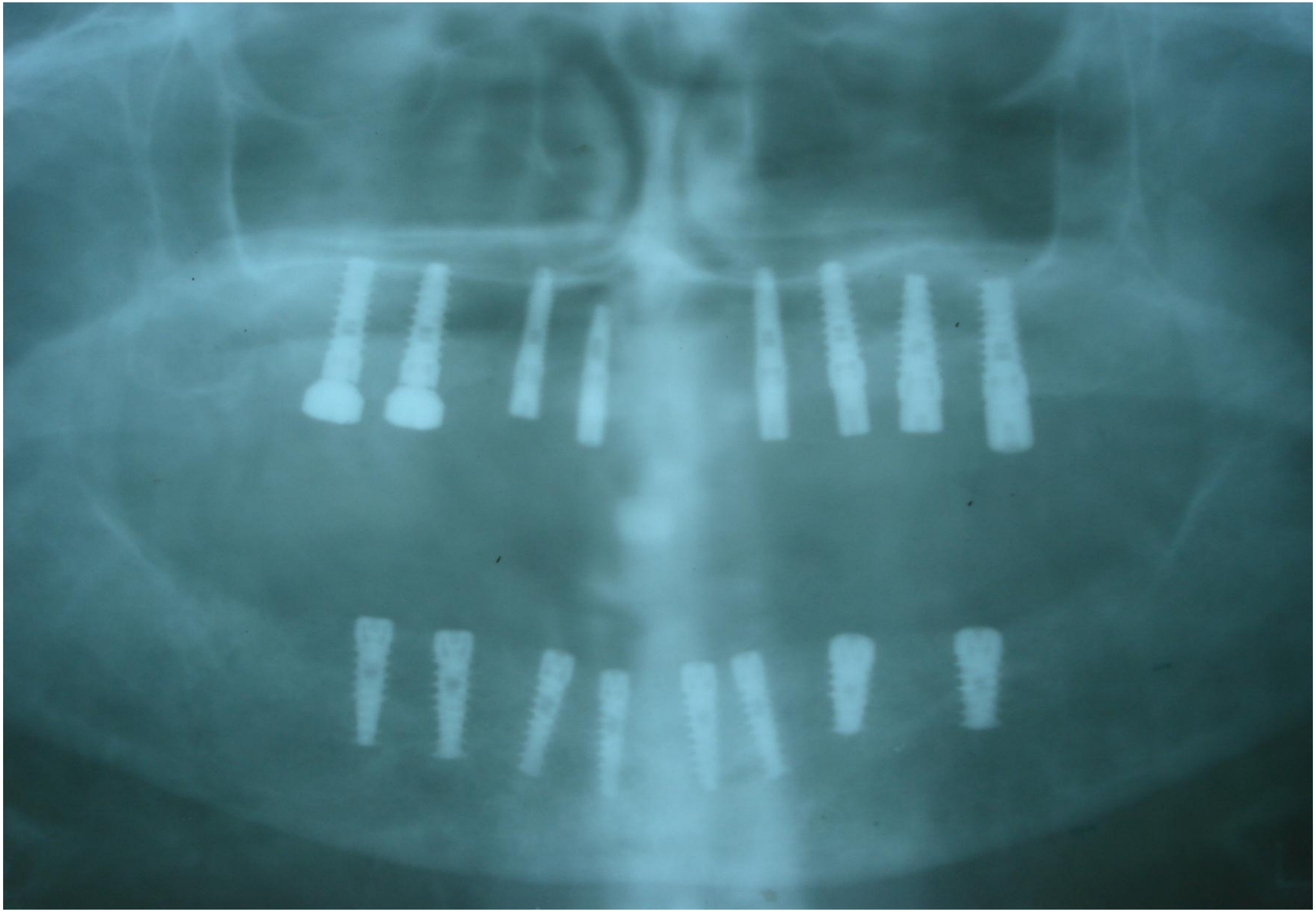


3D STEREOLITHOGRAPHIC MODEL AND SURGICAL GUIDE (Fig. 24)

a)

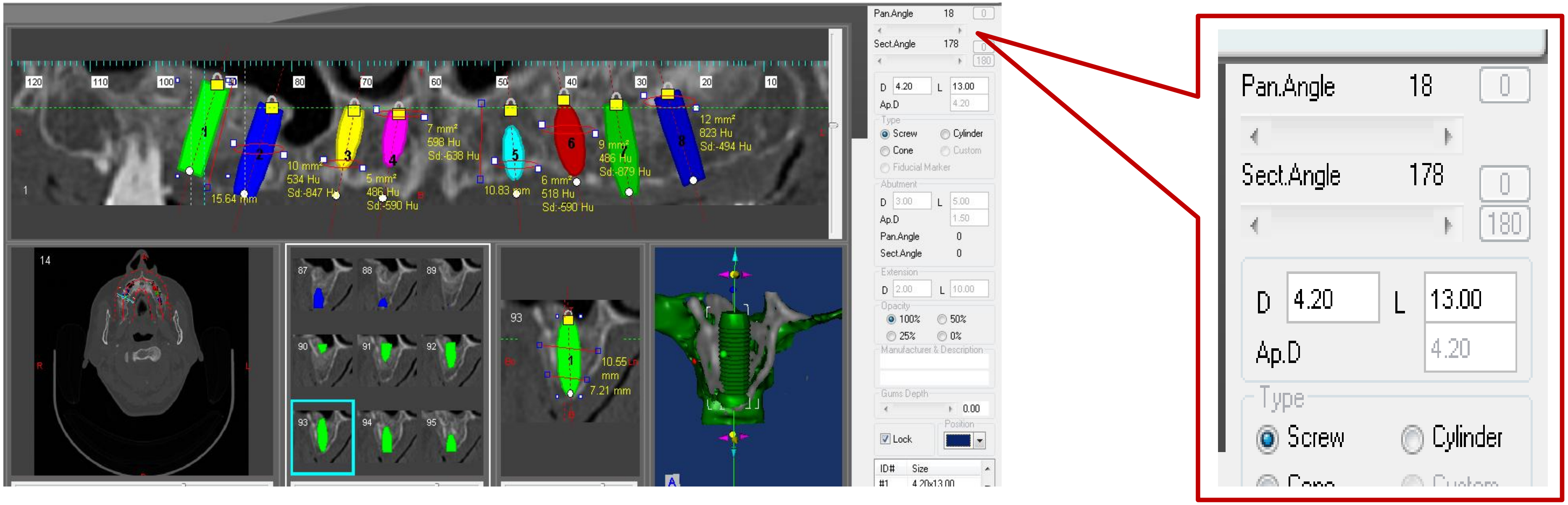
b)

POST OPERATIVE ORTHOPANTOMOGRAPH (Fig. 25)

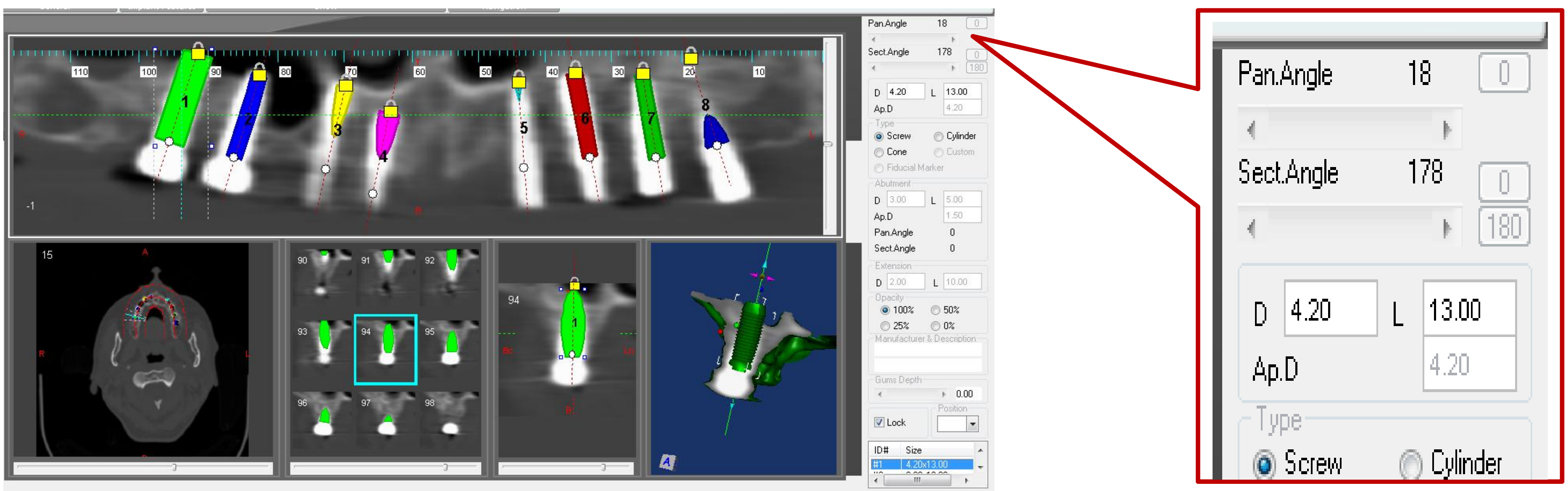


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 1 (Fig. 26)

a)

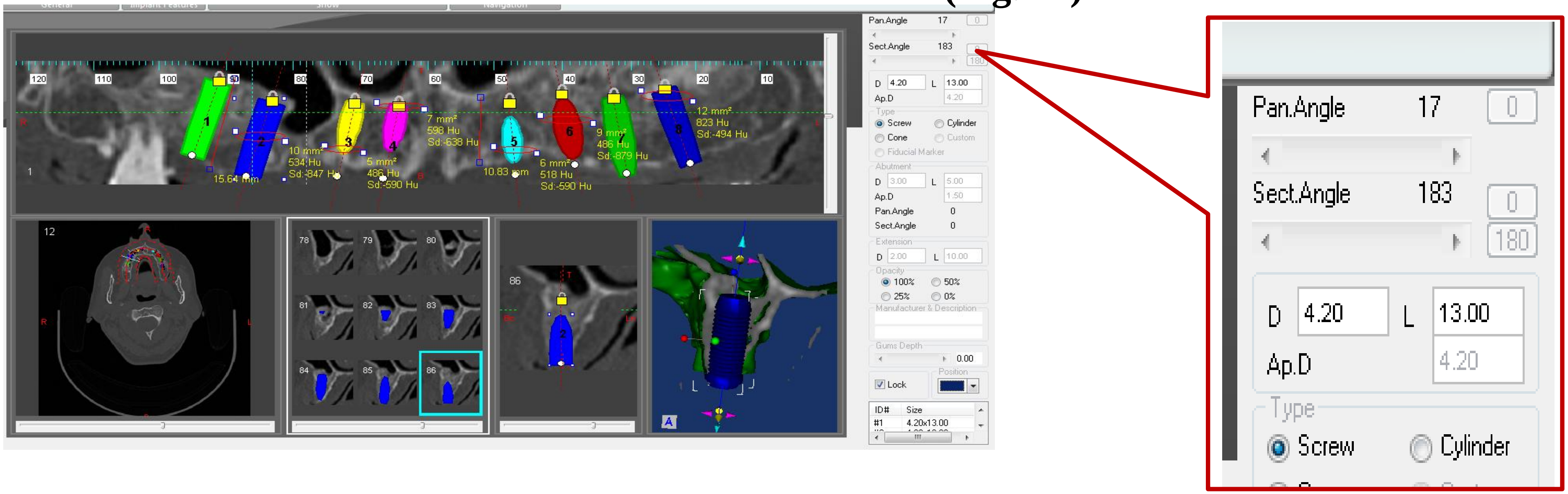


b)

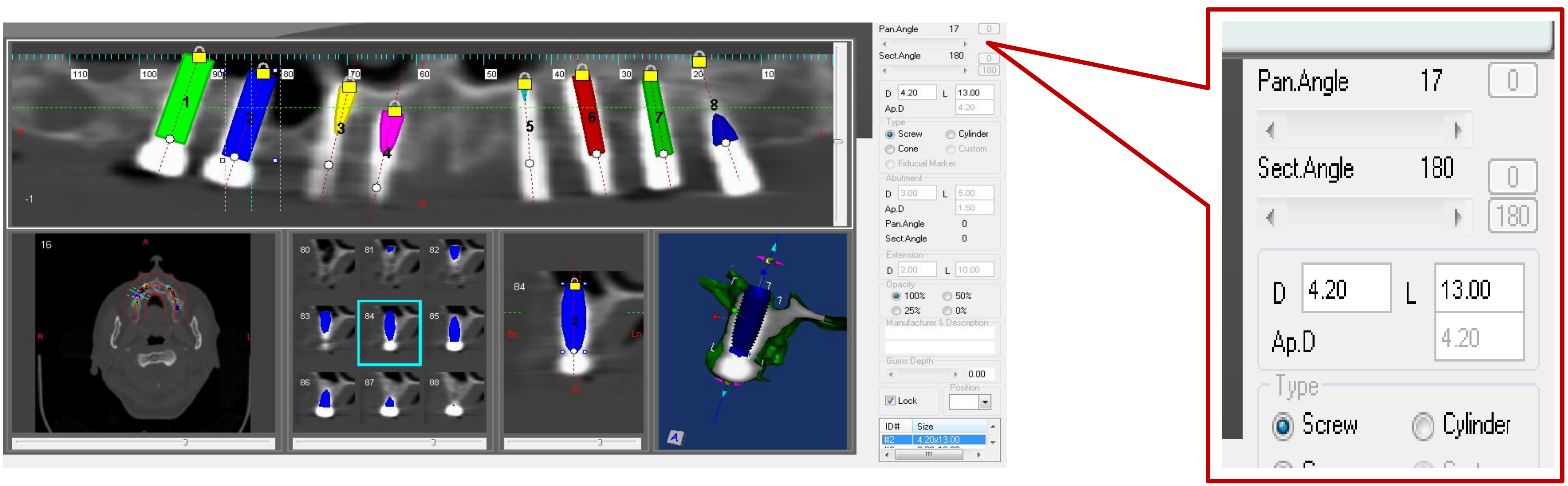


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 2 (Fig. 27)

a)

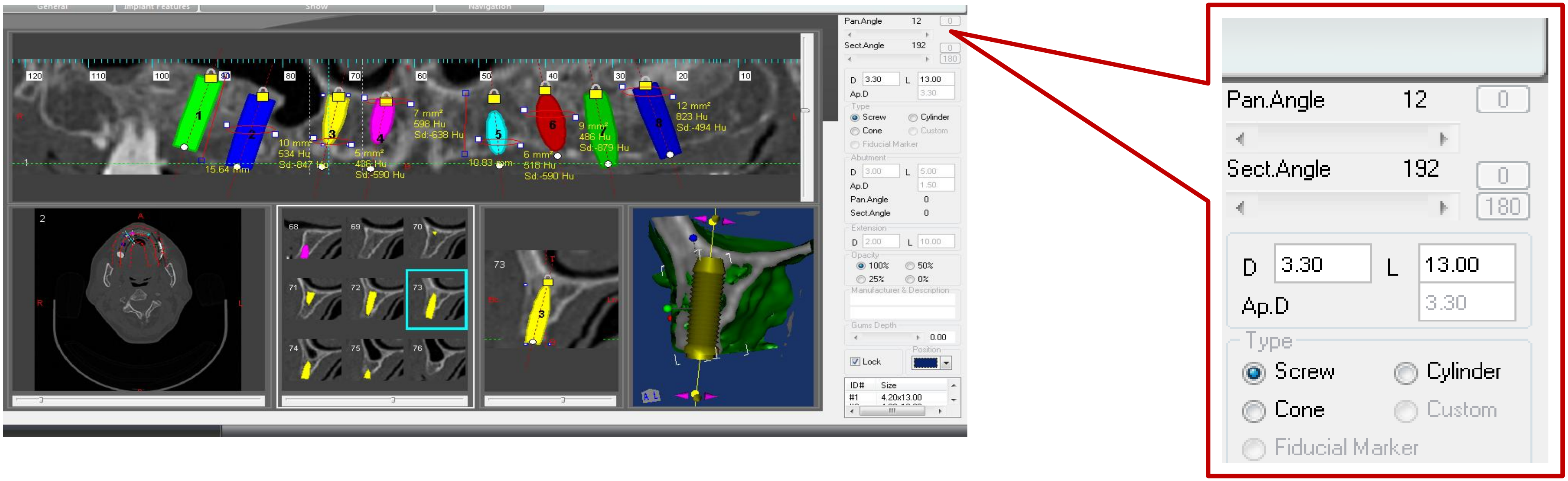


b)

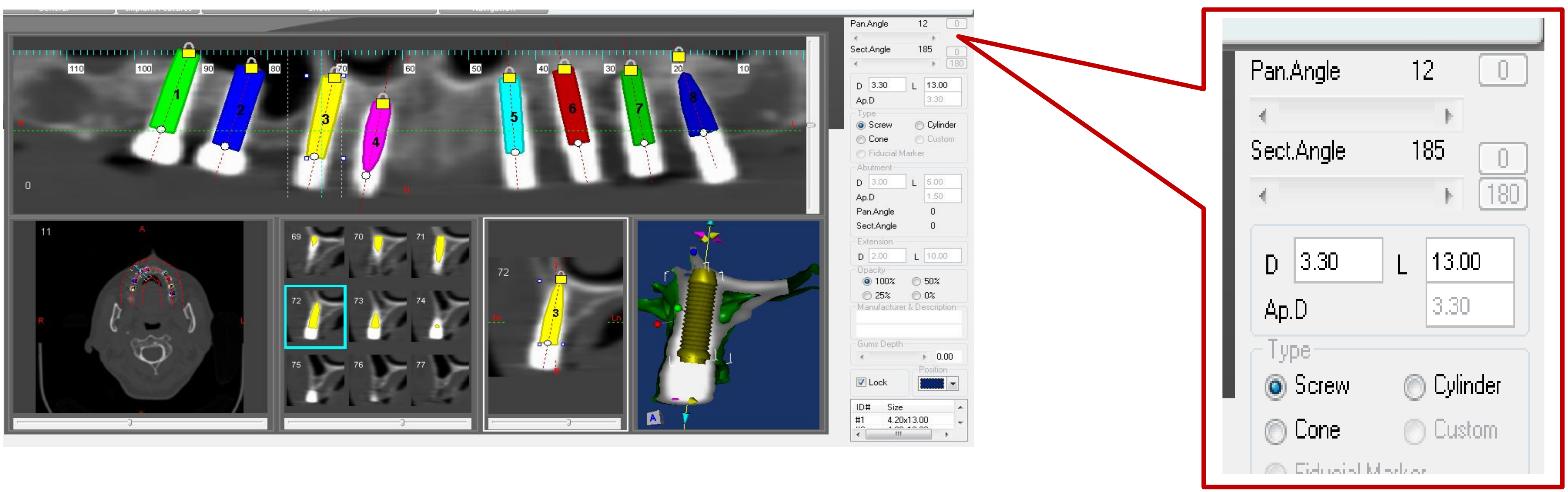


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST- OP ACTUAL POSITION OF IMPLANT 3 (Fig. 28)

a)

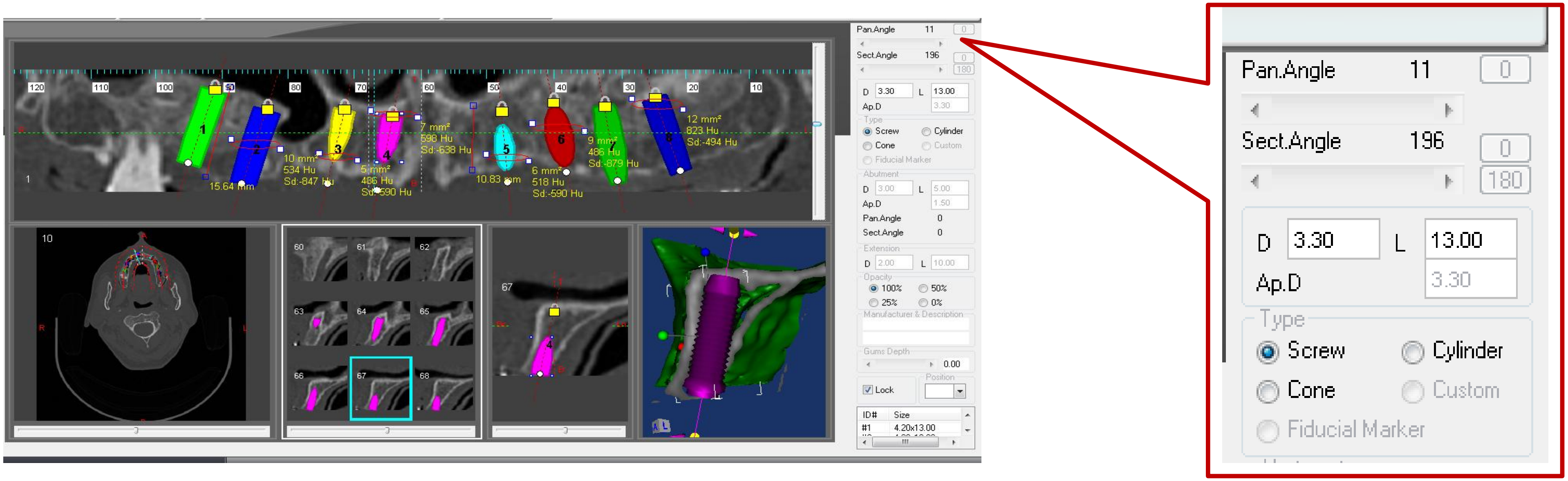


b)

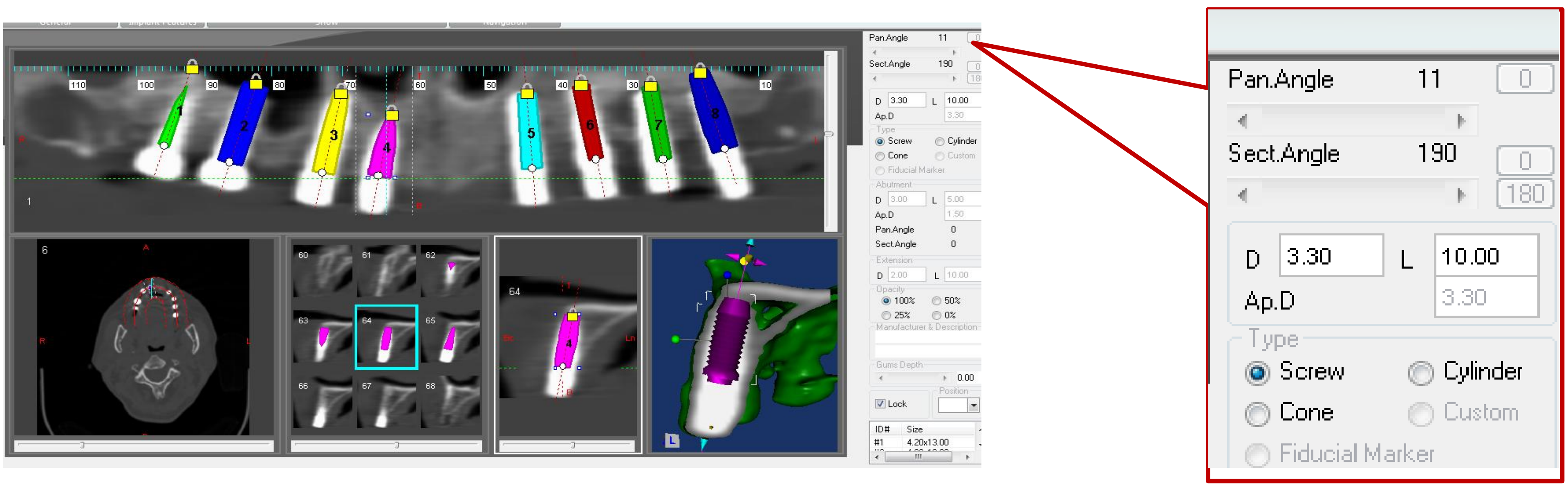


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 4 (Fig. 29)

a)

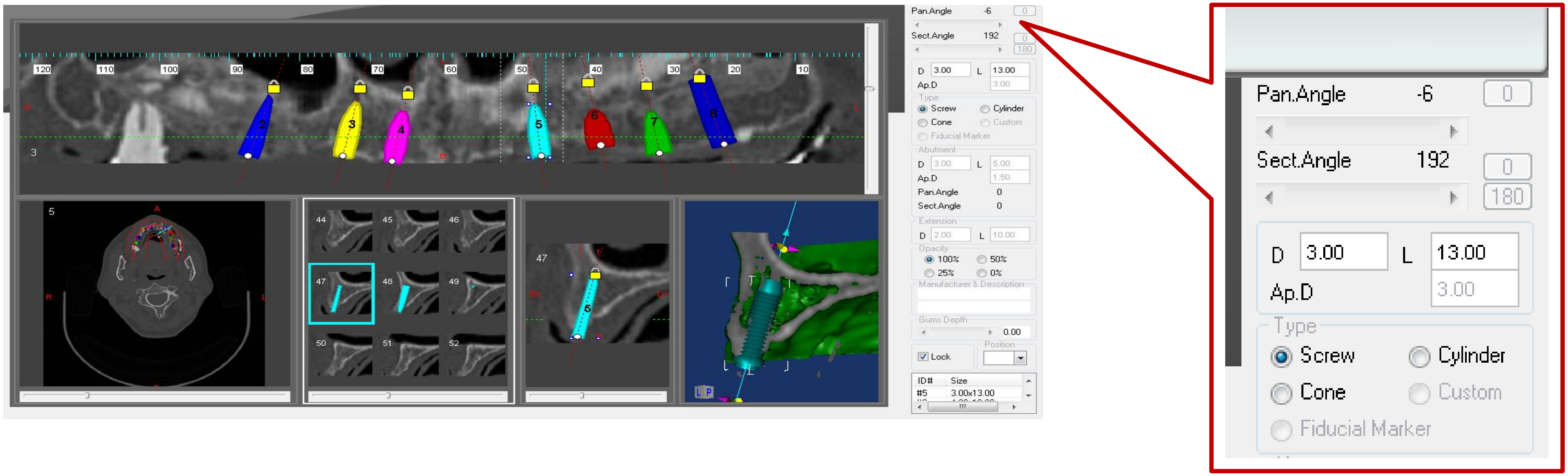


b)

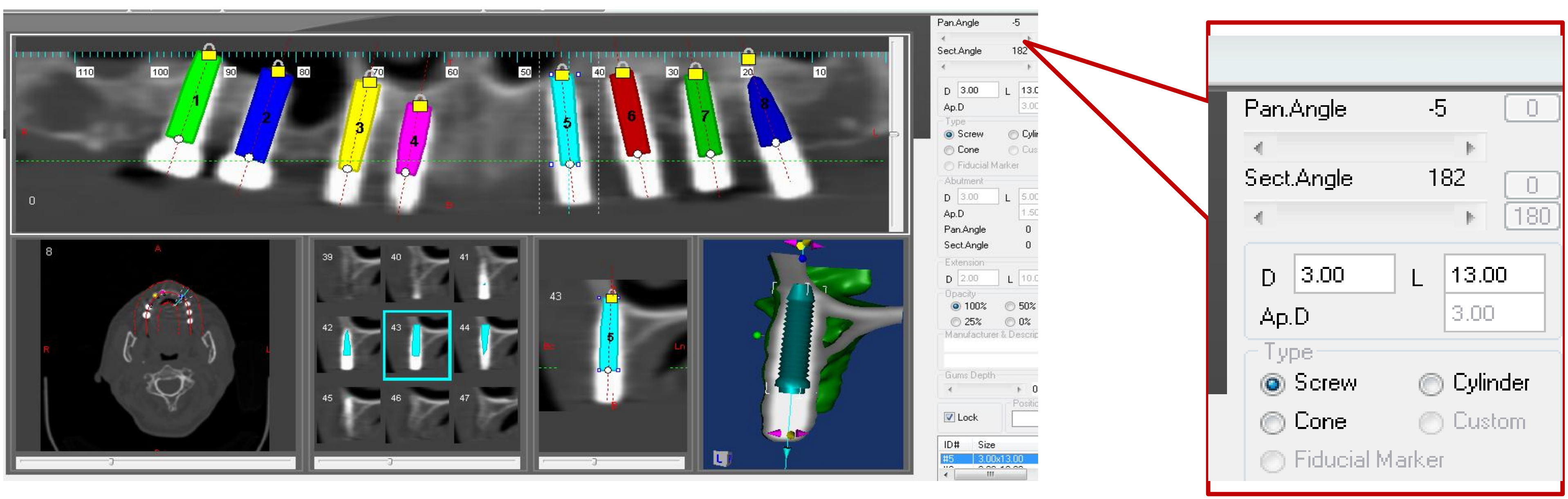


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 5 (Fig. 30)

a)

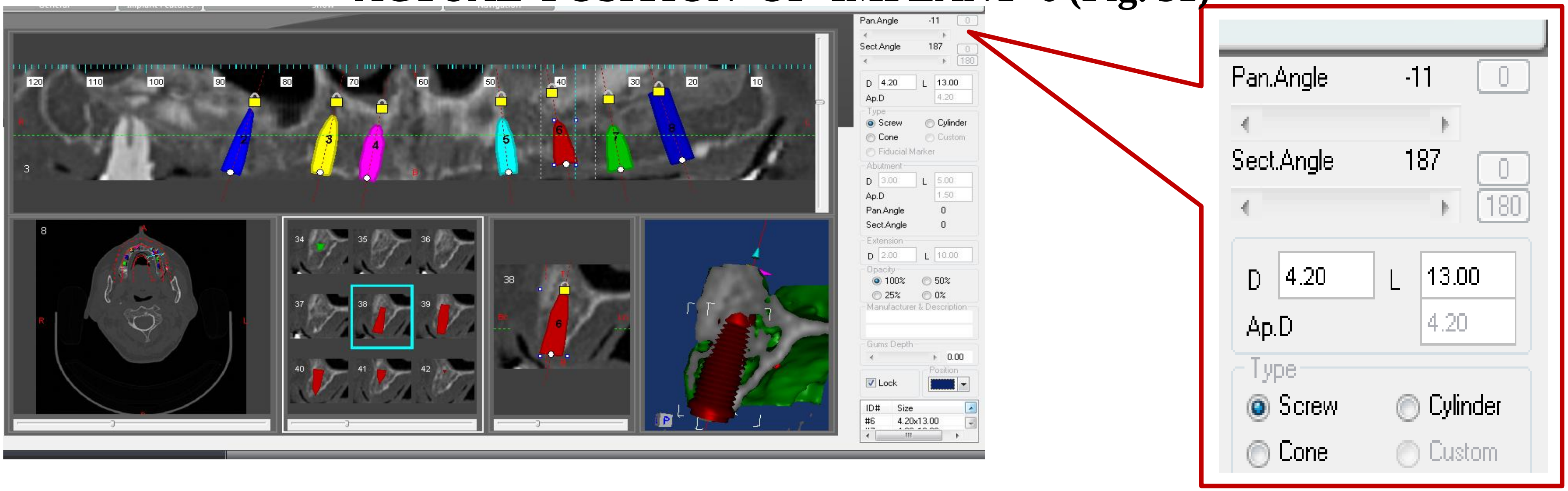


b)

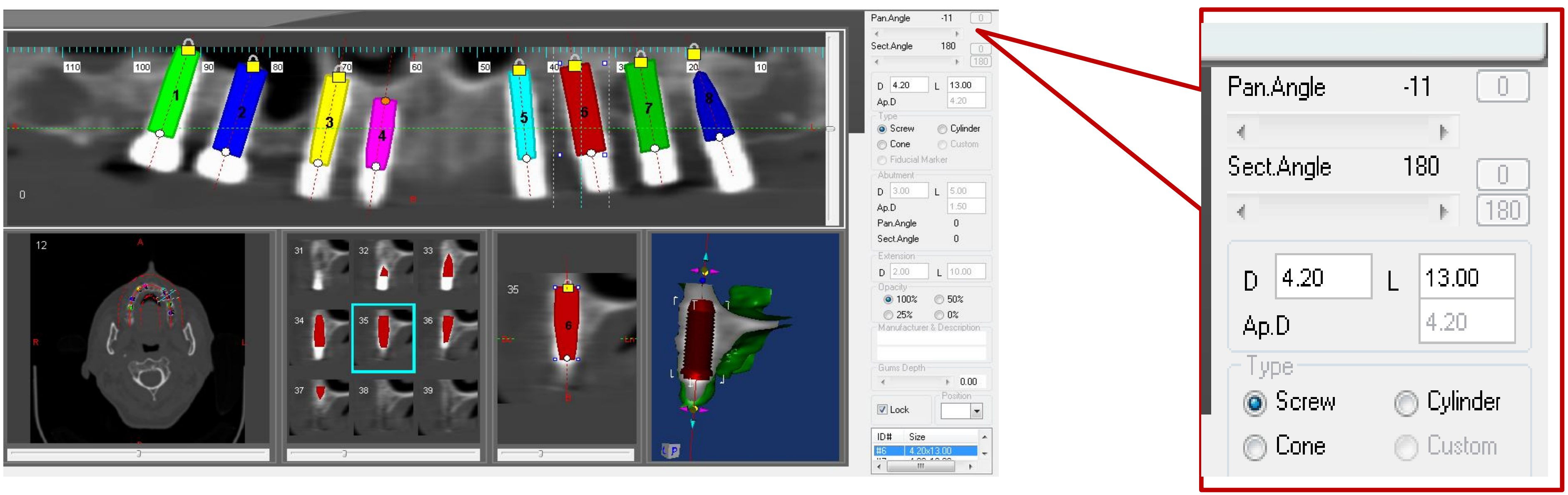


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 6 (Fig. 31)

a)

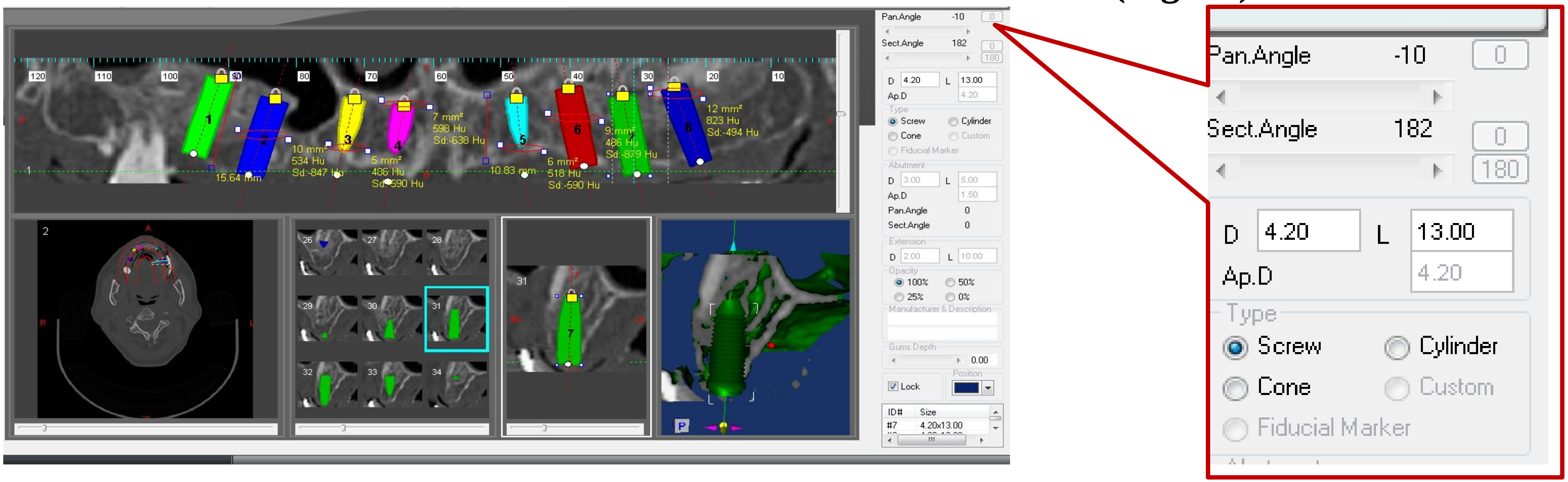


b)

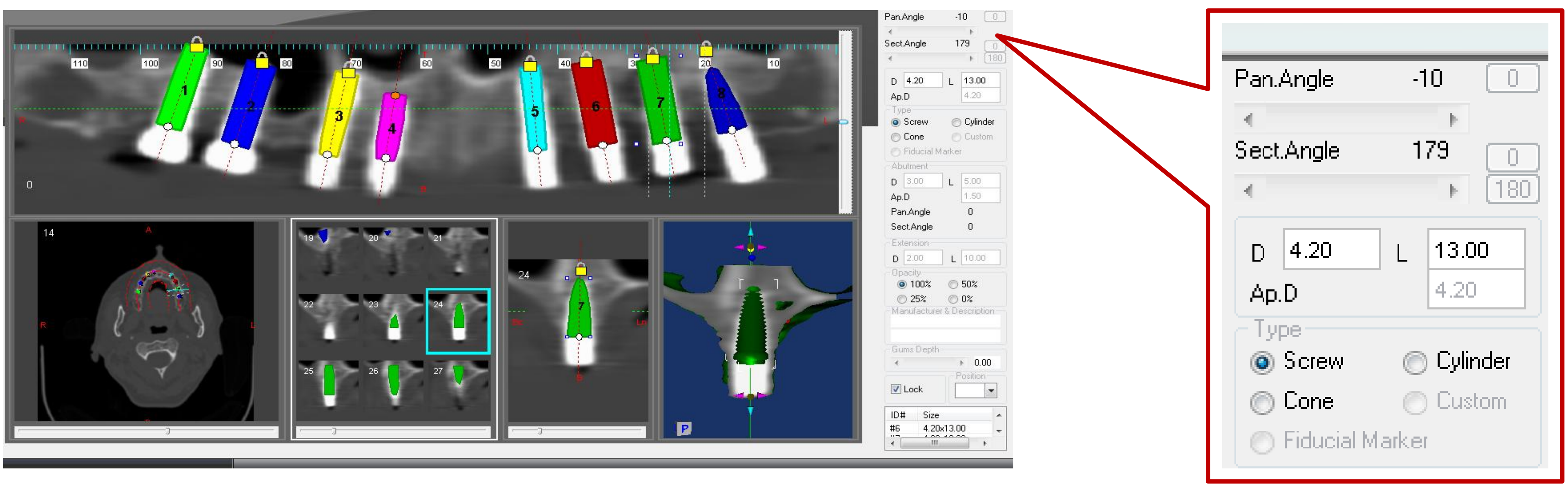


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 7 (Fig. 32)

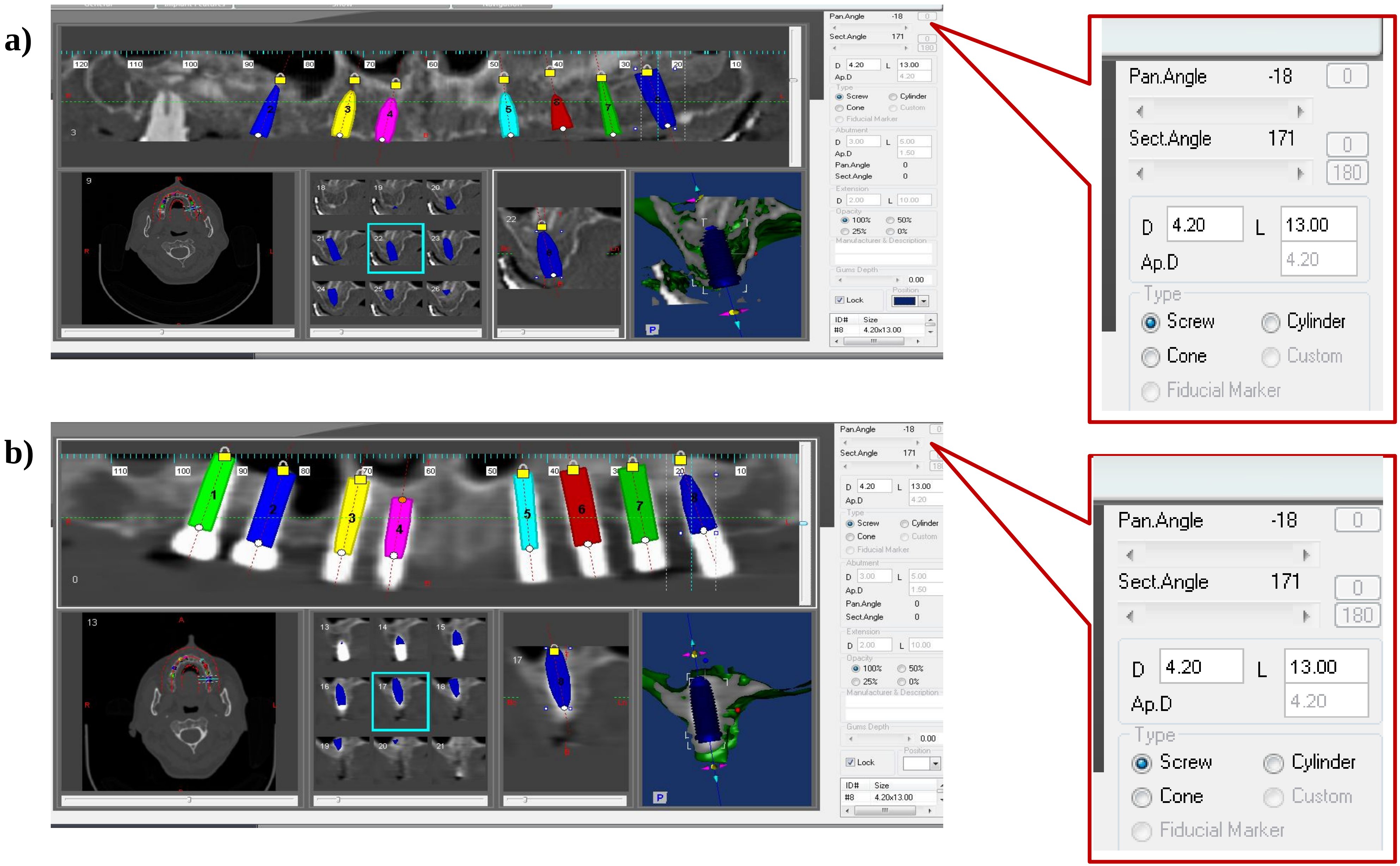
a)



b)



COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 8 (Fig. 33)



COMPARISION OF PRE TREATMENT AND AFTER PROSTHETIC REHABILITATION (Fig. 34)

a) PRE TREATMENT

b) AFTER TREATMENT

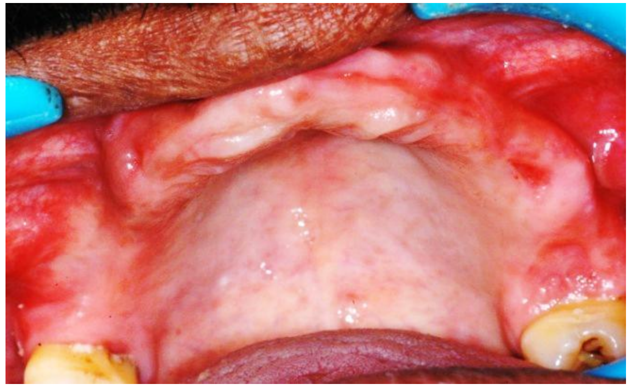
BEFORE TREATMENT (Fig. 35)

AFTER TREATMENT (Fig. 36)

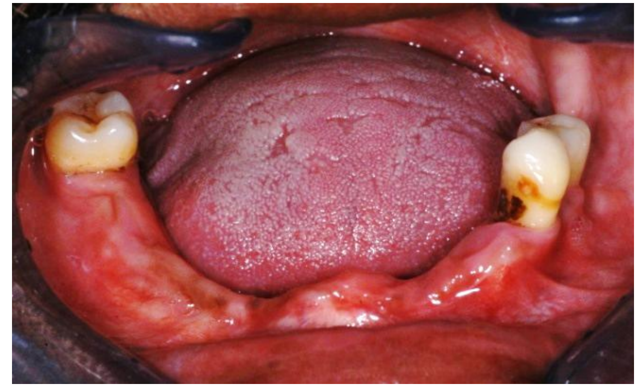
CASE 3

PRE OPERATIVE STATUS (Fig. 37)

a)



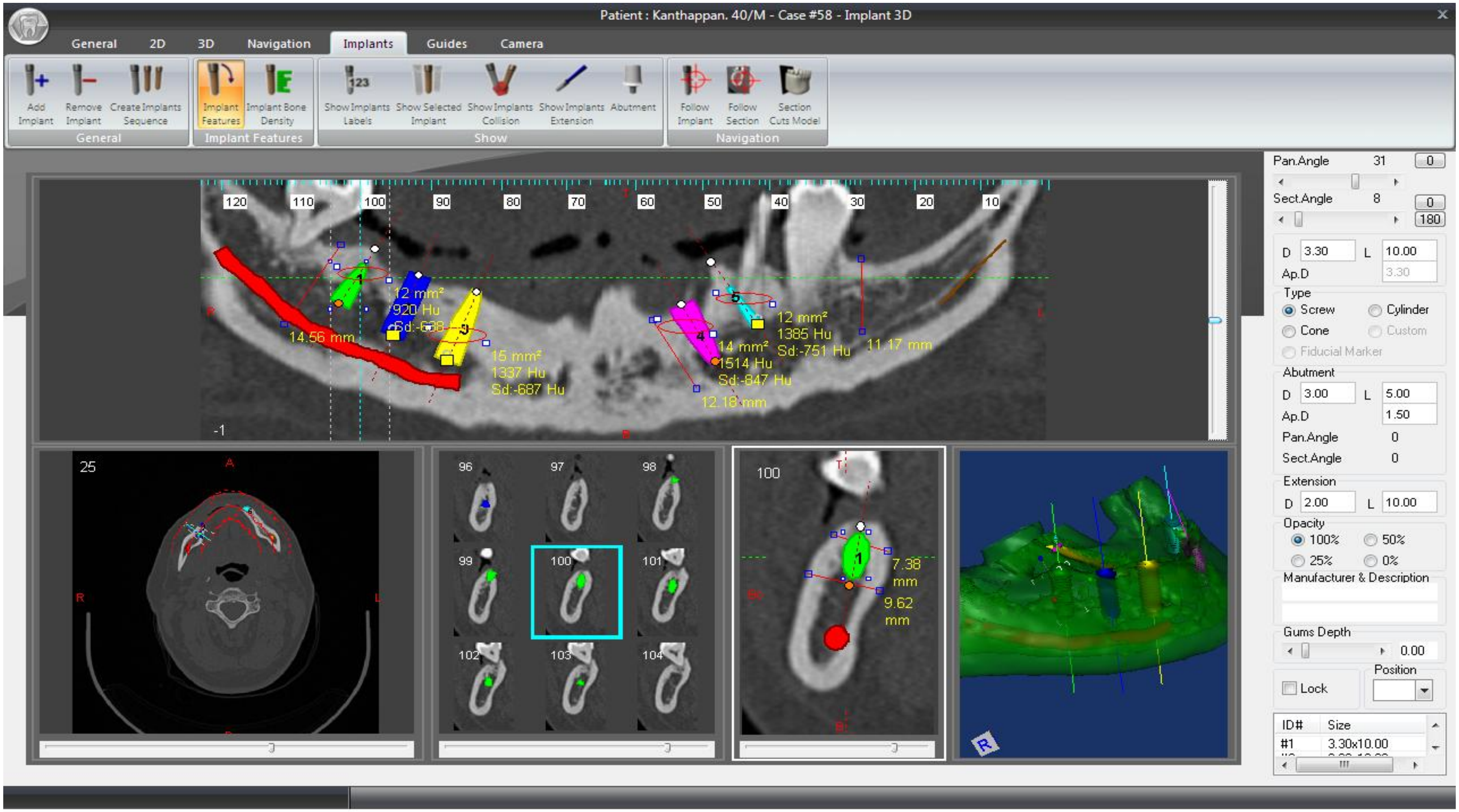
b)



c)

d)

PRE OPERATIVE PLANNED POSITION OF VIRTUAL IMPLANTS WITH BONE DENSITY, MEASUREMENTS AND NERVE SIMULATION (Fig. 38)



STEREOLITHOGRAPHIC MODEL

SURGICAL GUIDE

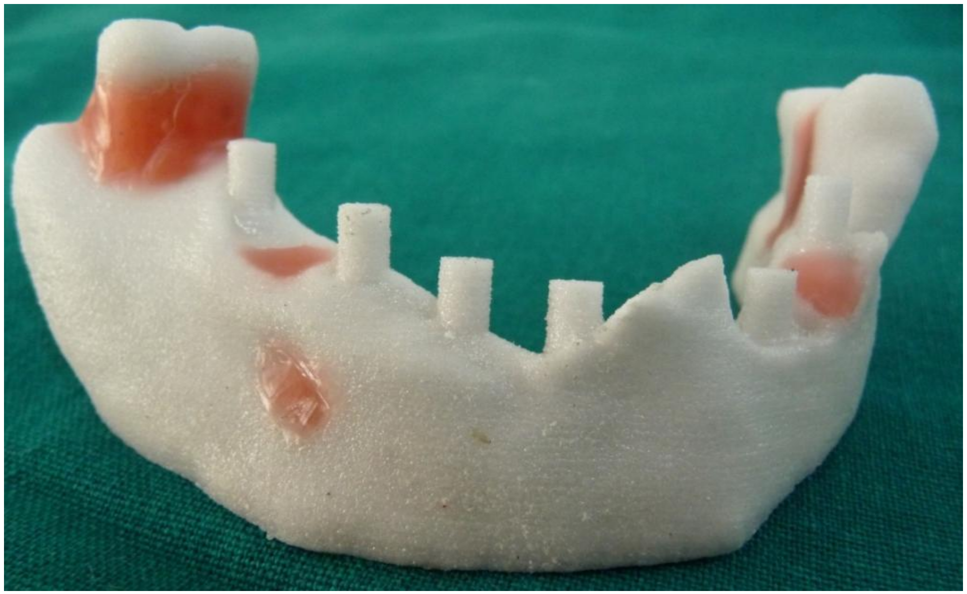
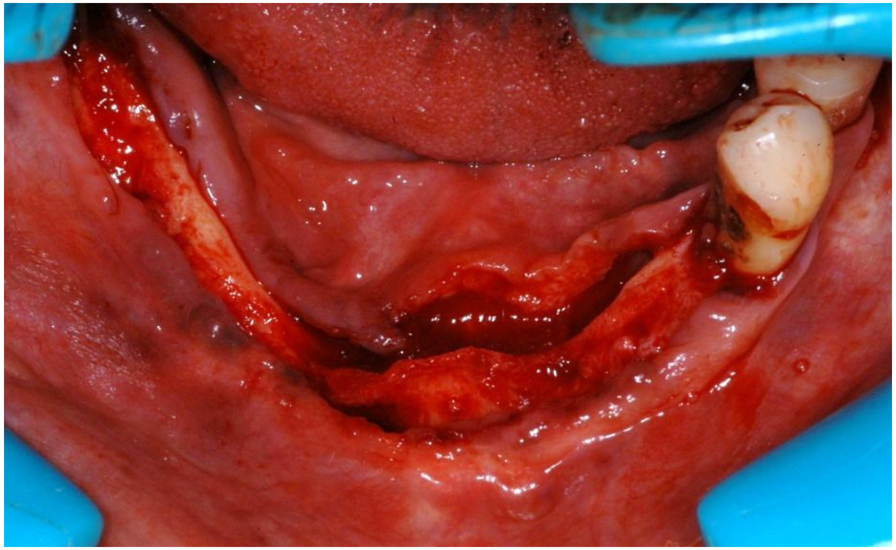


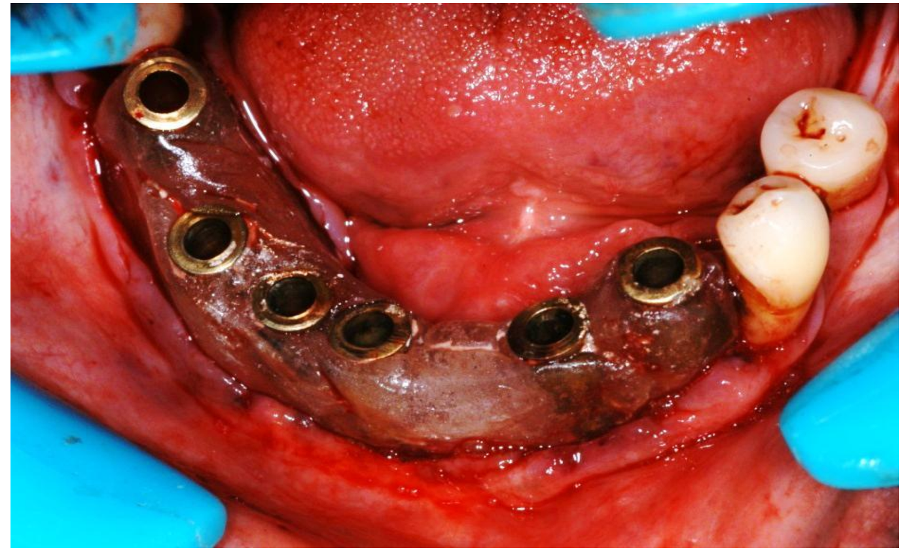
Fig. 39

Fig. 40

INTRA OPERATIVE PICTURES (Fig. 41)



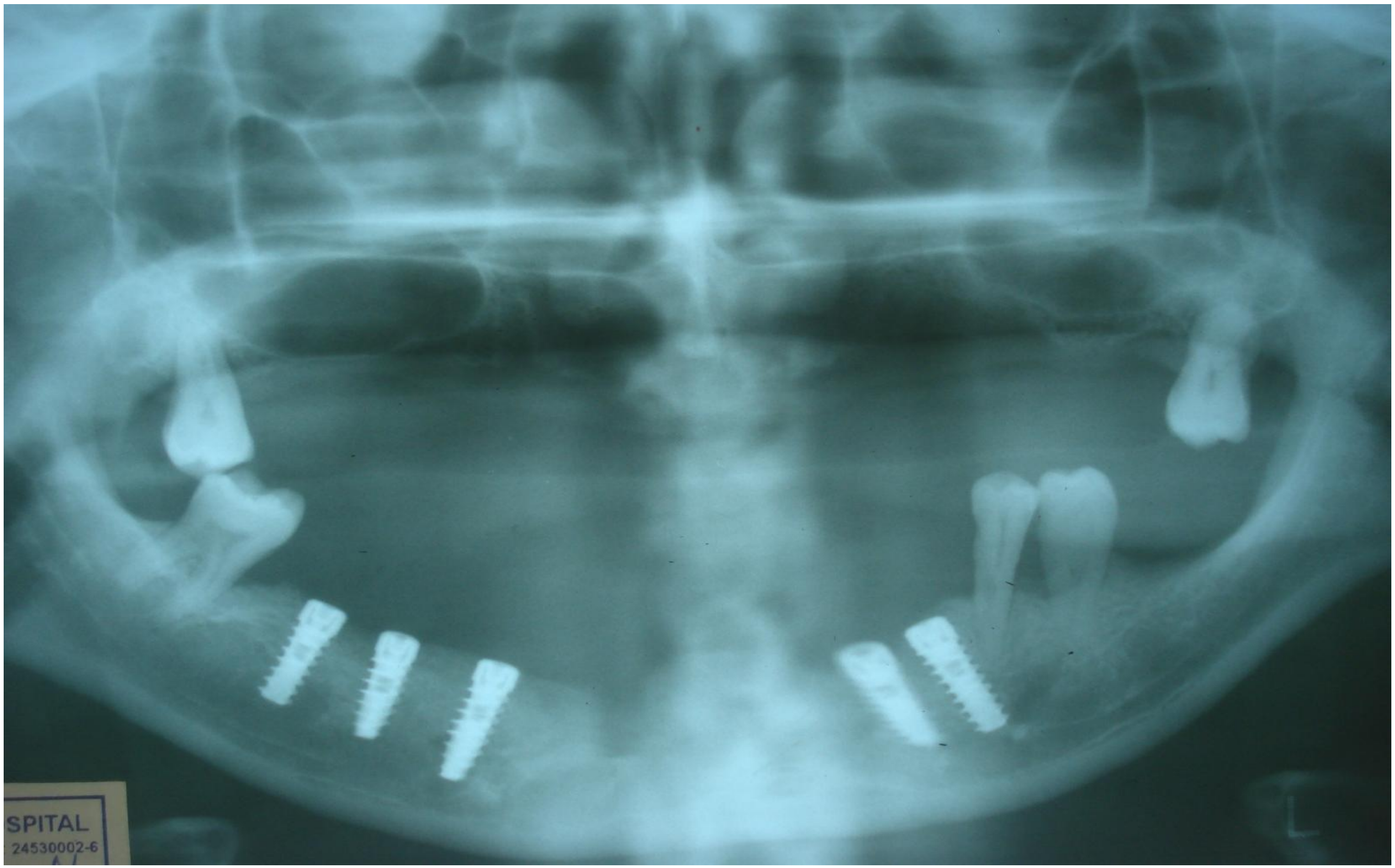
a)



b)

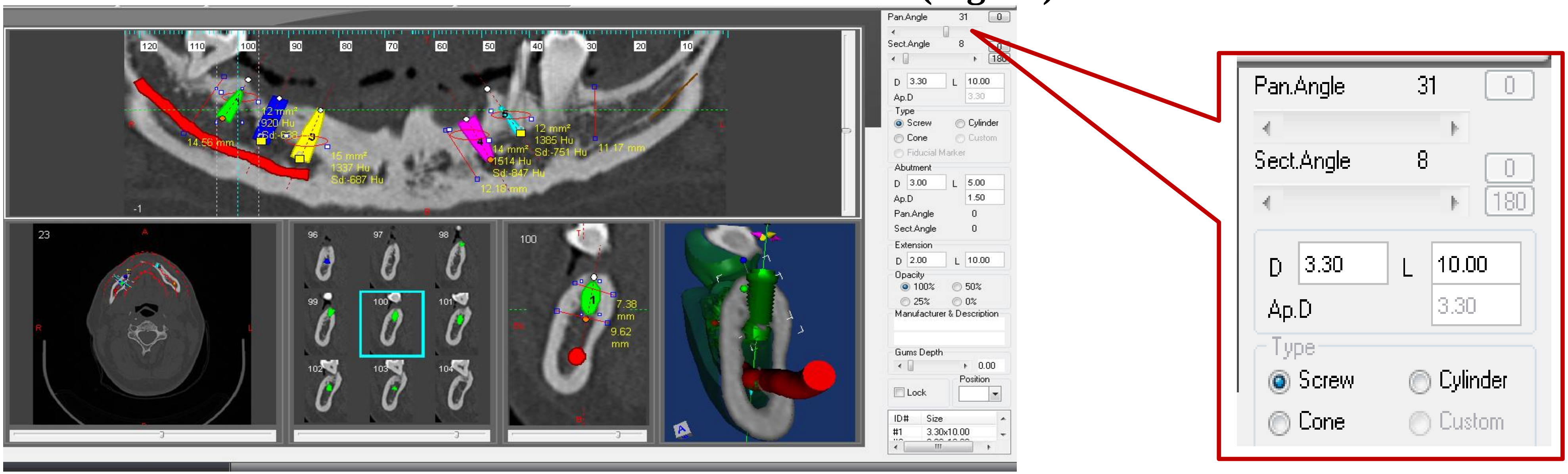
c)

POST OPERATIVE ORTHOPANTOMOGRAPH (Fig. 42)

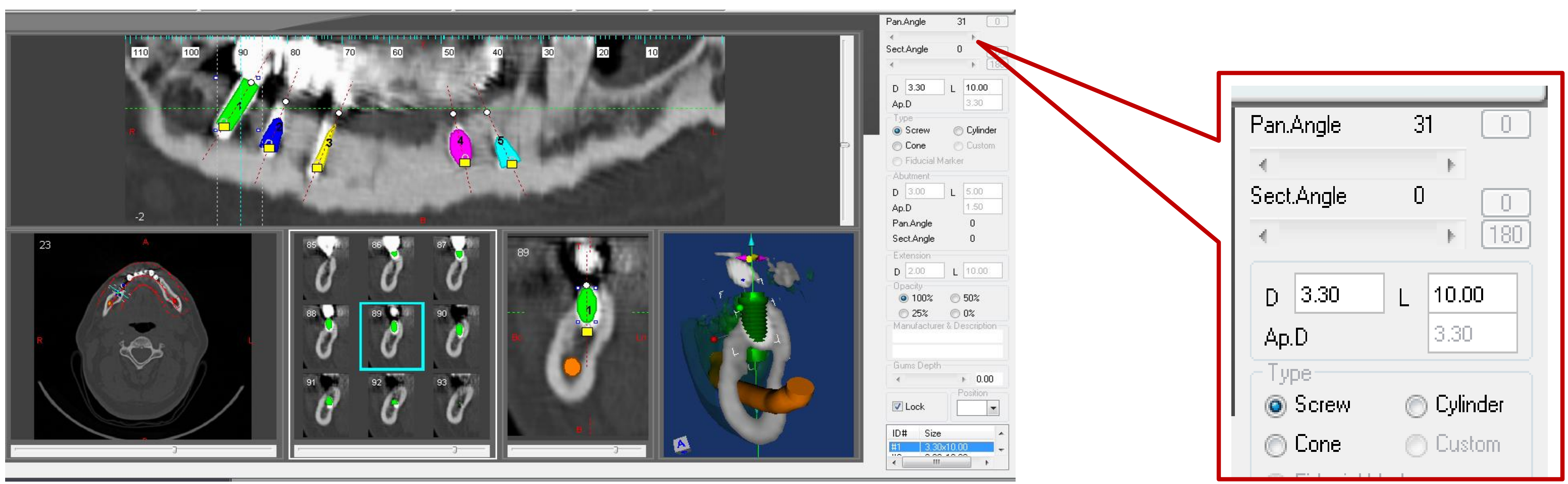


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 1(Fig. 43)

a)

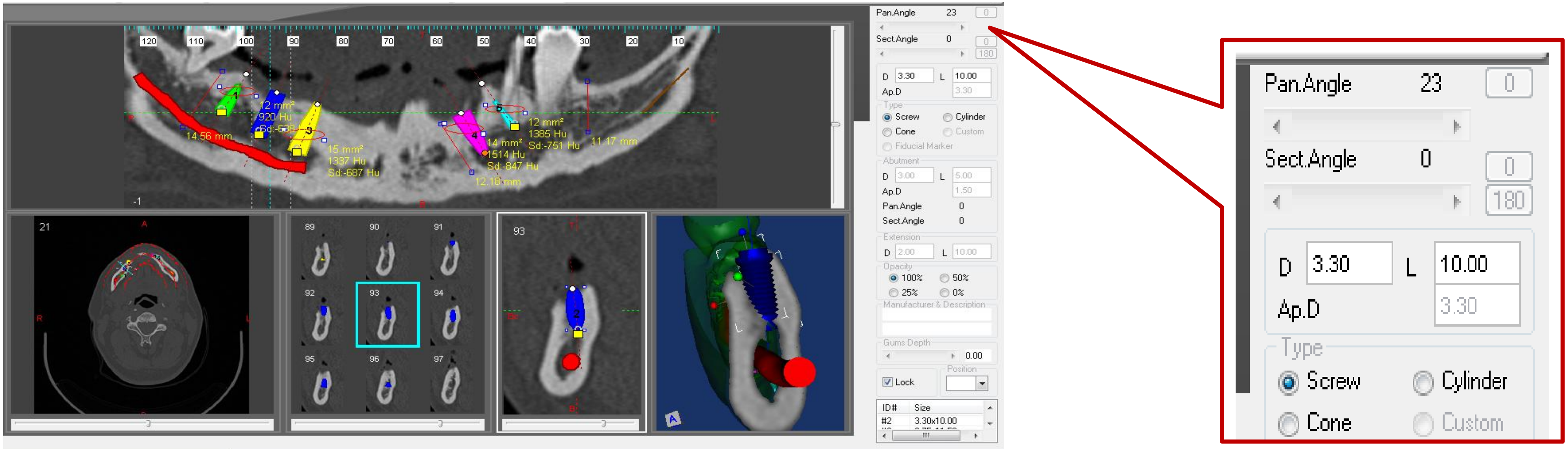


b)

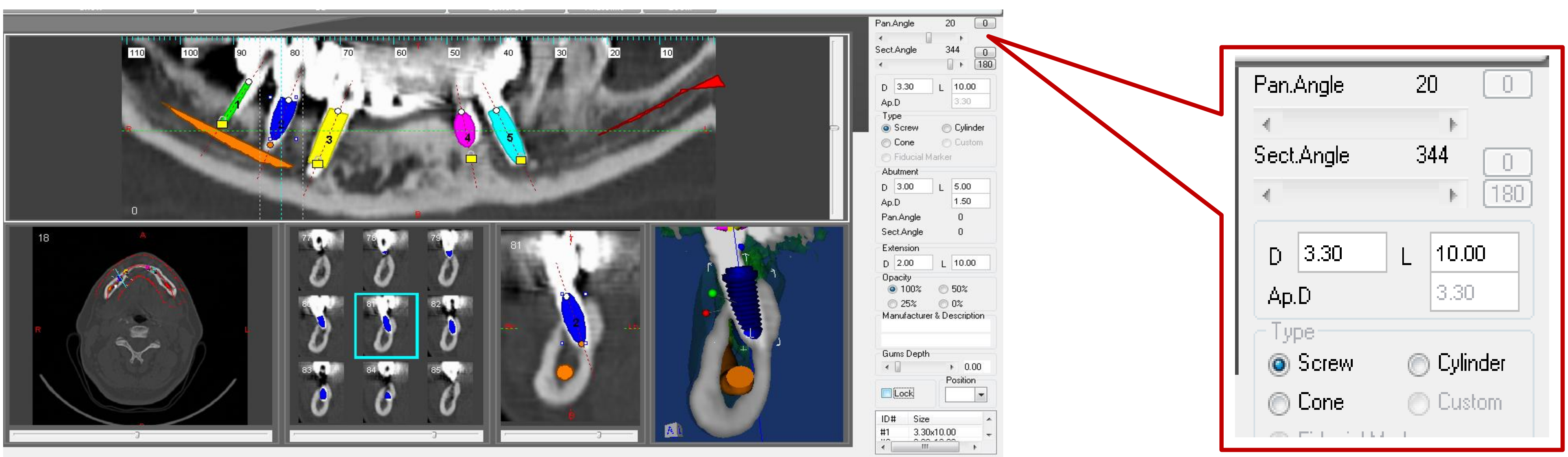


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 2 (Fig. 44)

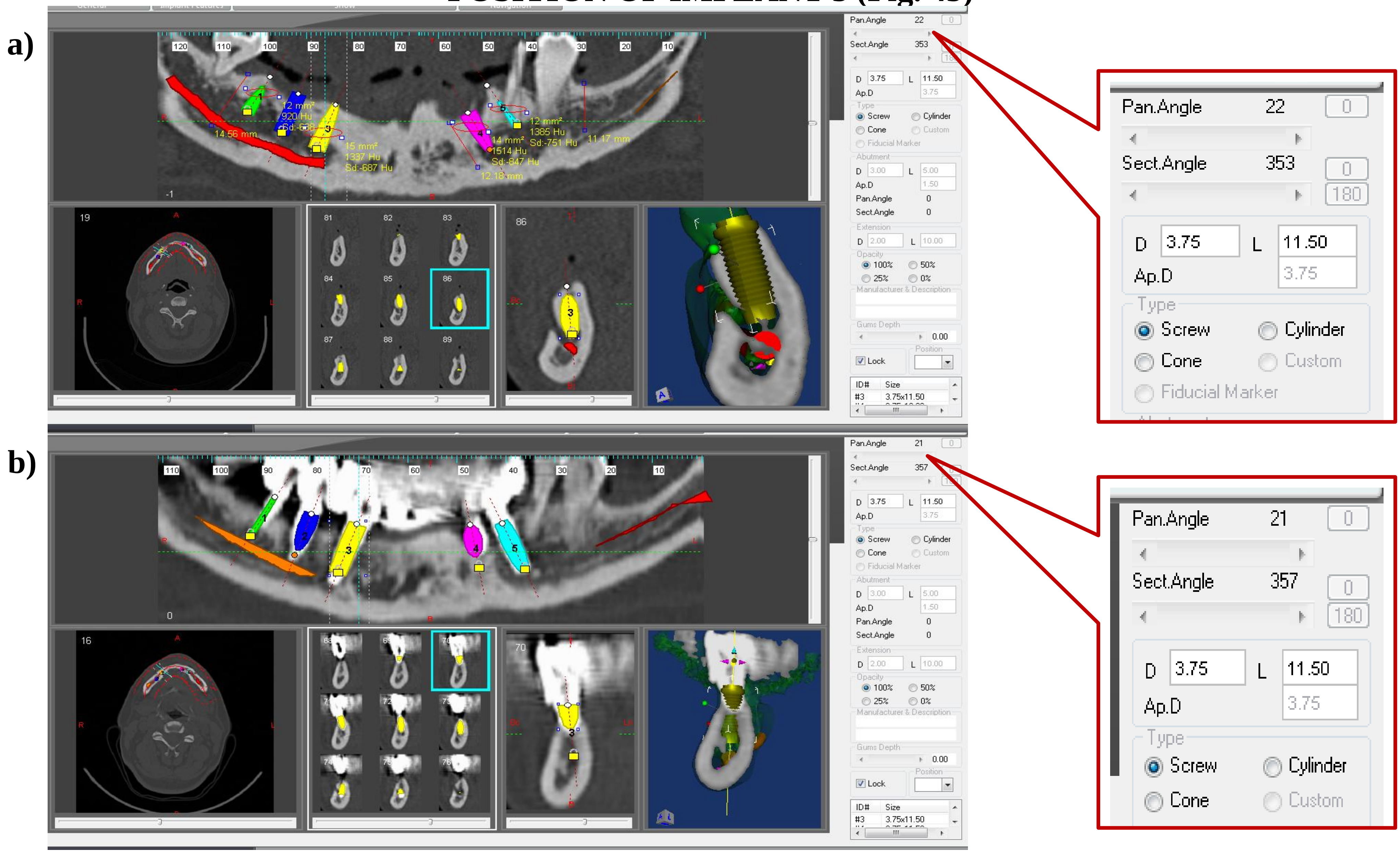
a)



b)

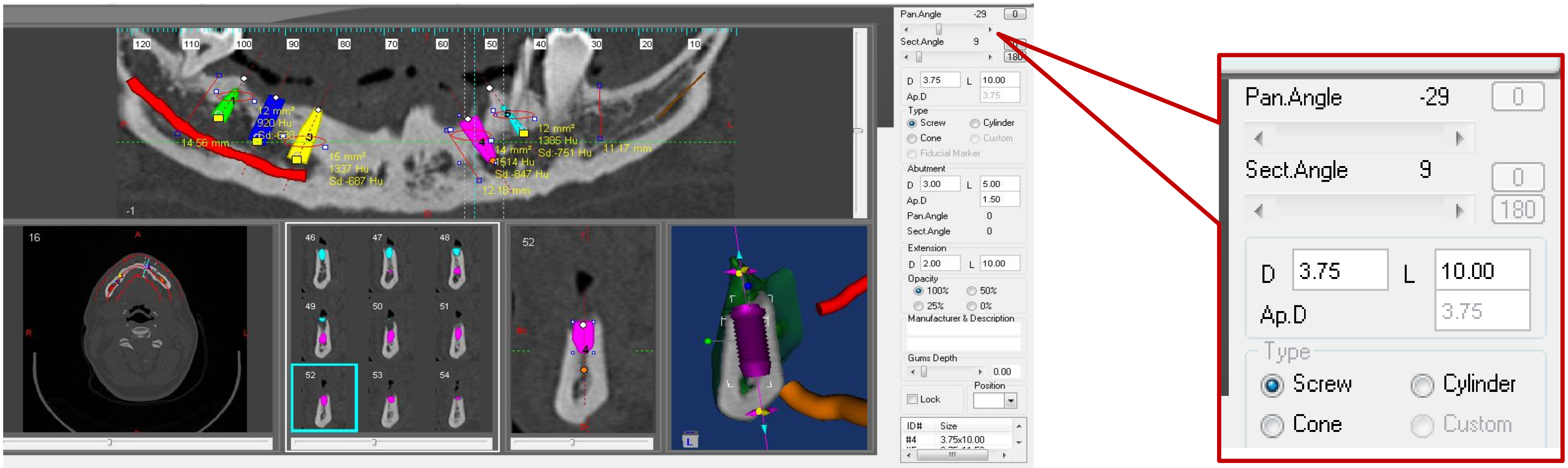


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 3 (Fig. 45)

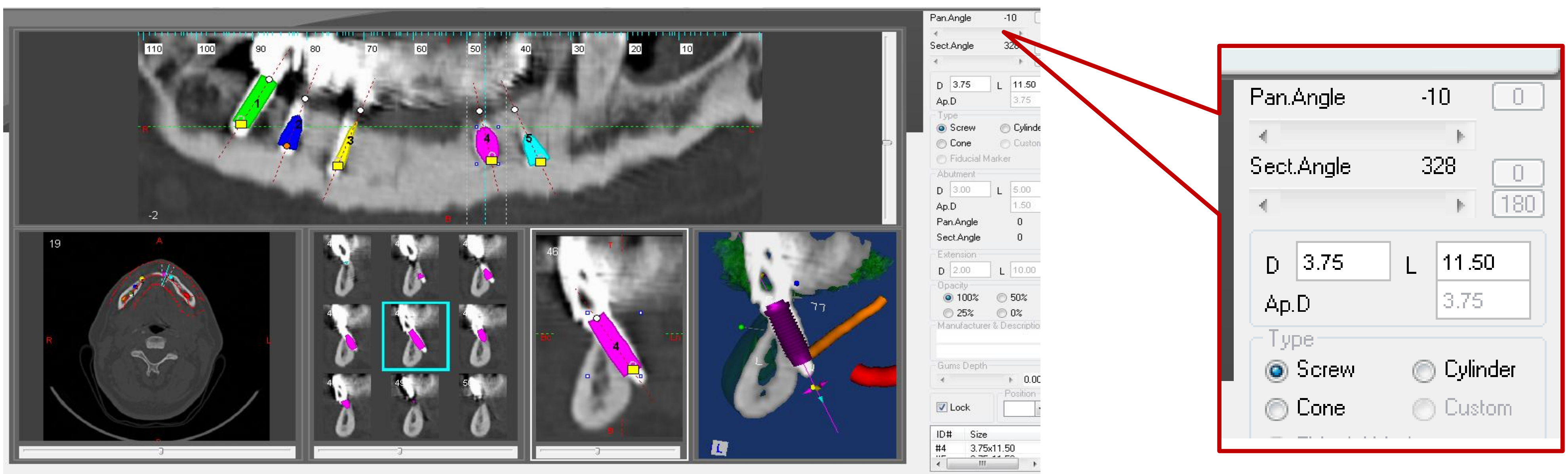


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 4 (Fig. 46)

a)

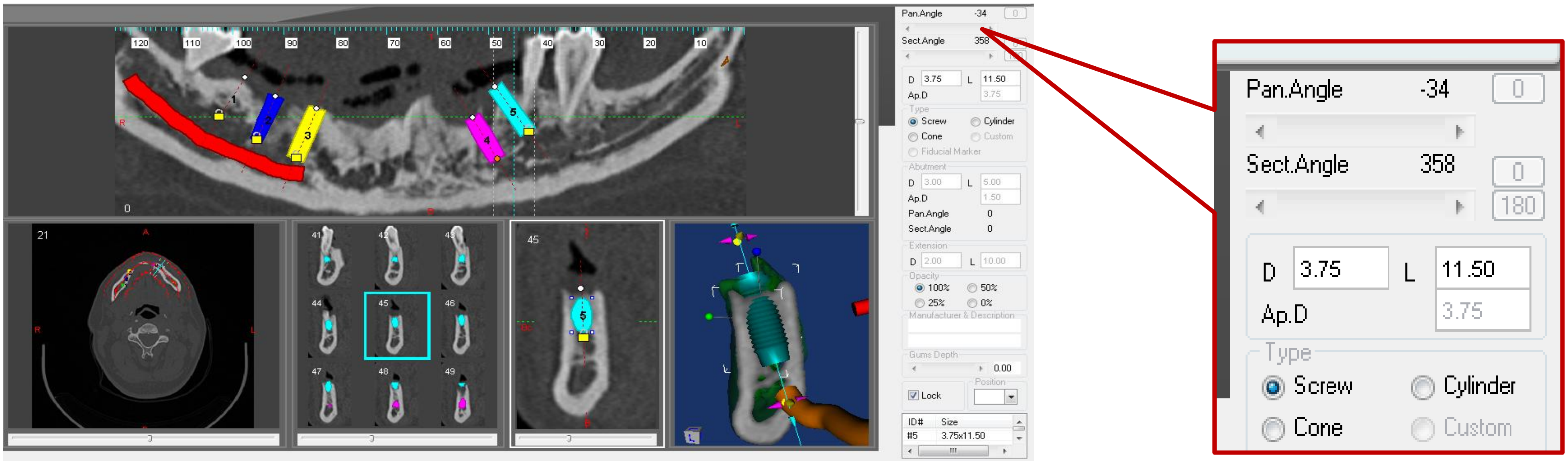


b)

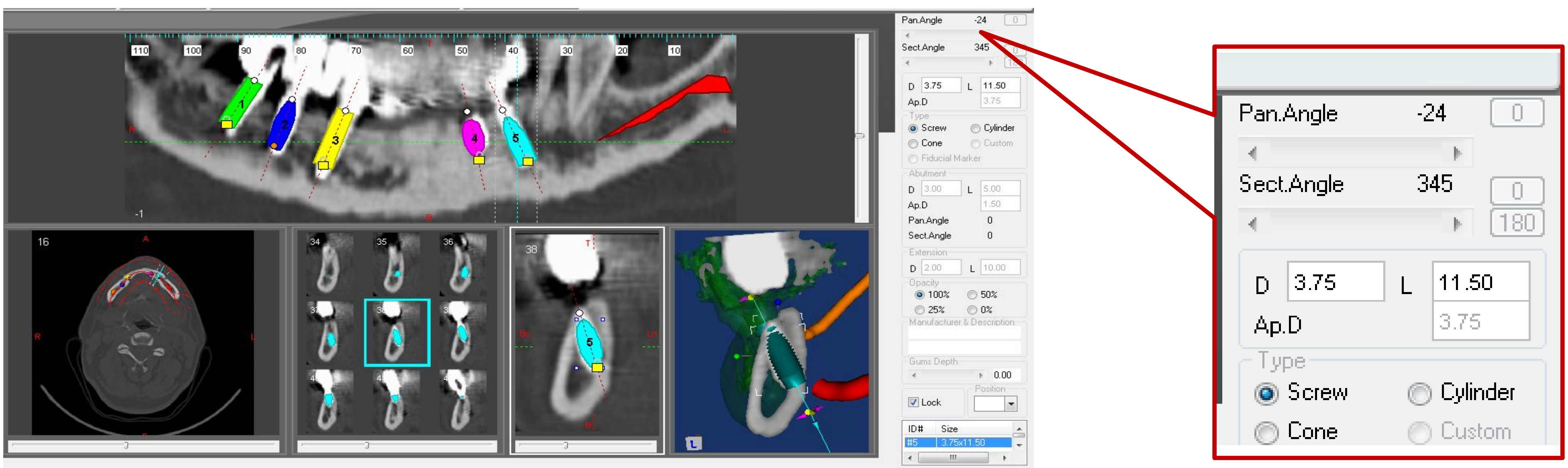


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 5 (Fig. 47)

a)



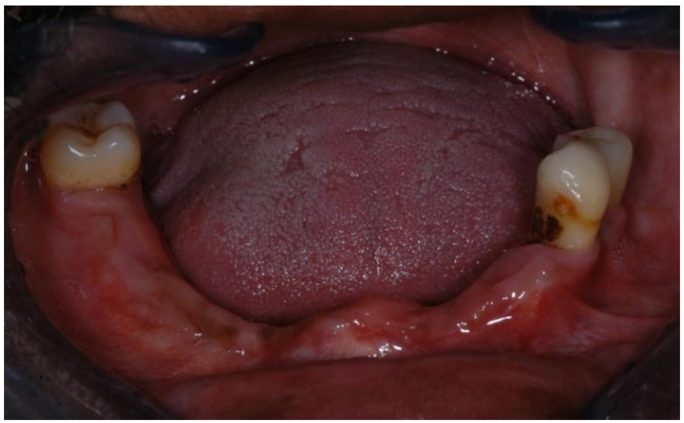
b)



COMPARISION OF PRE TREATMENT AND AFTER PROSTHETIC REHABILITATION (Fig. 48)

PRE TREATMENT

a)



b)

PROSTHETIC REHABILITATION

c)

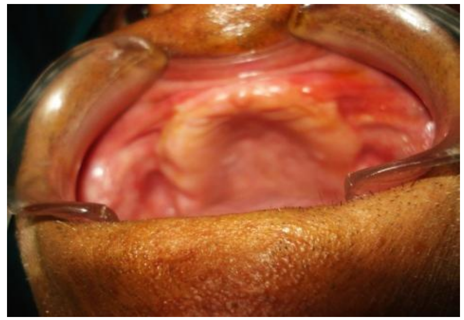
PRE TREATMENT (Fig. 49)

AFTER TREATMENT (Fig. 50)

CASE 4

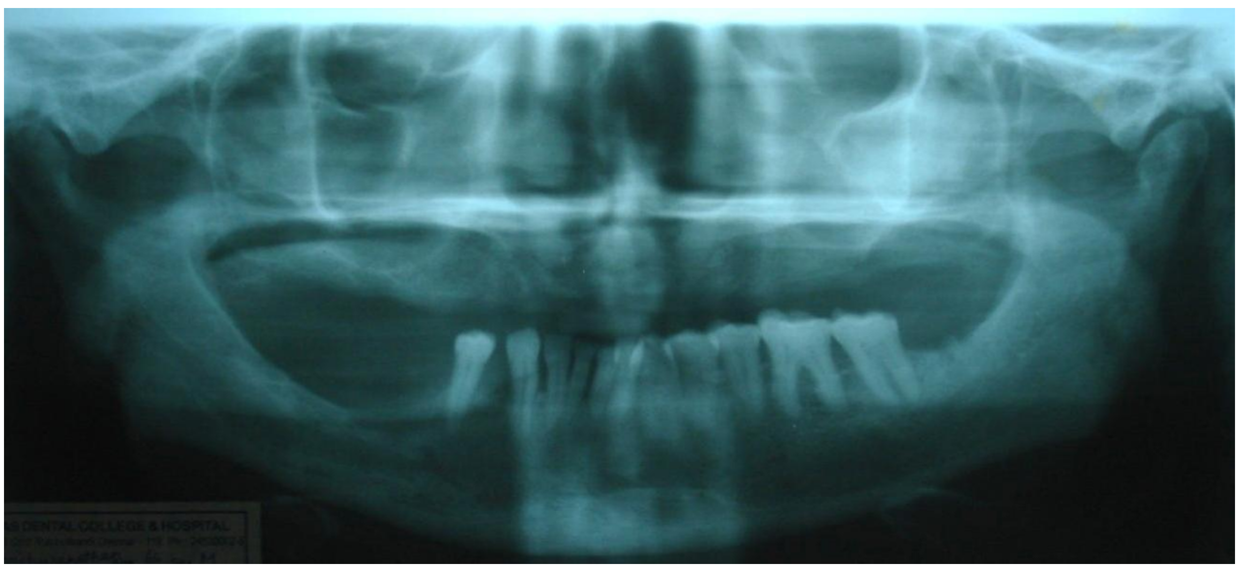
PRE OPERATIVE STATUS (Fig. 51)

a)



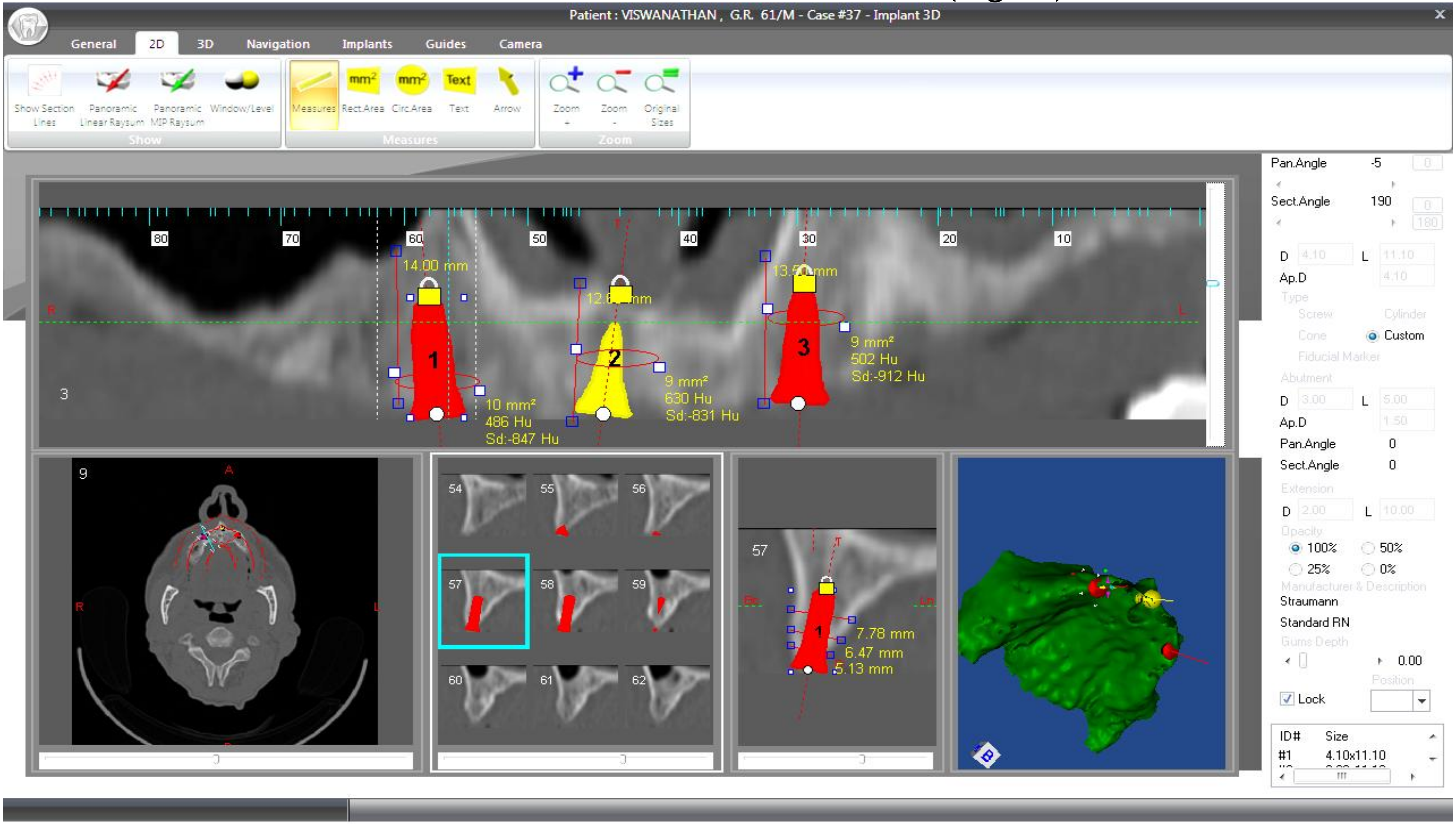
b)

c)



d)

PRE OPERATIVE PLANNED POSITION OF VIRTUAL IMPLANTS WITH BONE DENSITY AND MEASUREMENTS (Fig. 52)



STEREOLITHOGRAPHIC MODEL

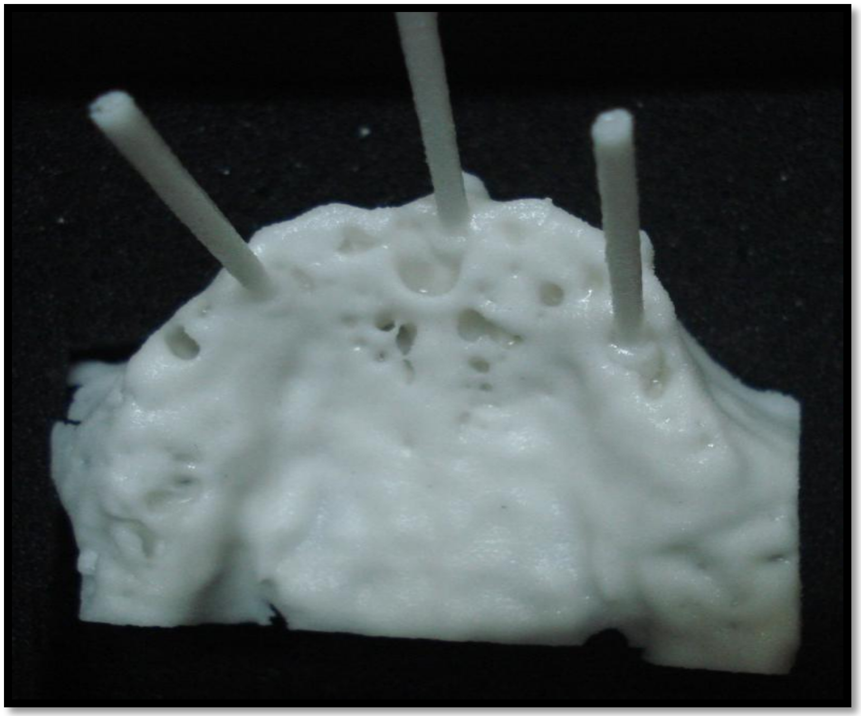
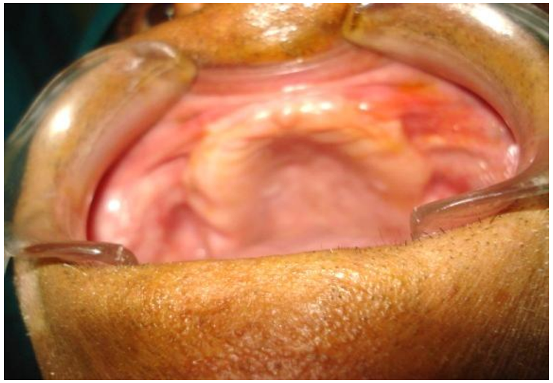


Fig. 53

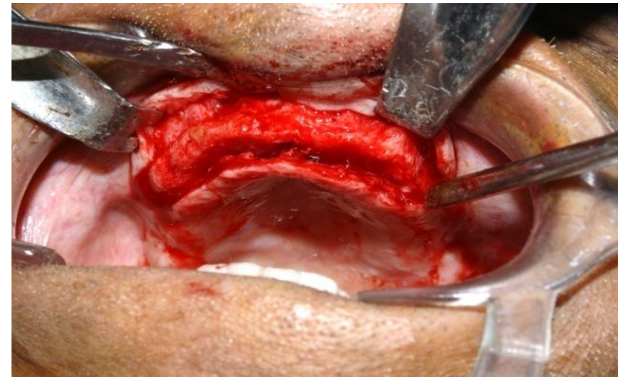
PREPARATION OF SURGICAL GUIDE

Fig. 54

INTRA OPERATIVE PICTURES (Fig. 55)



a)

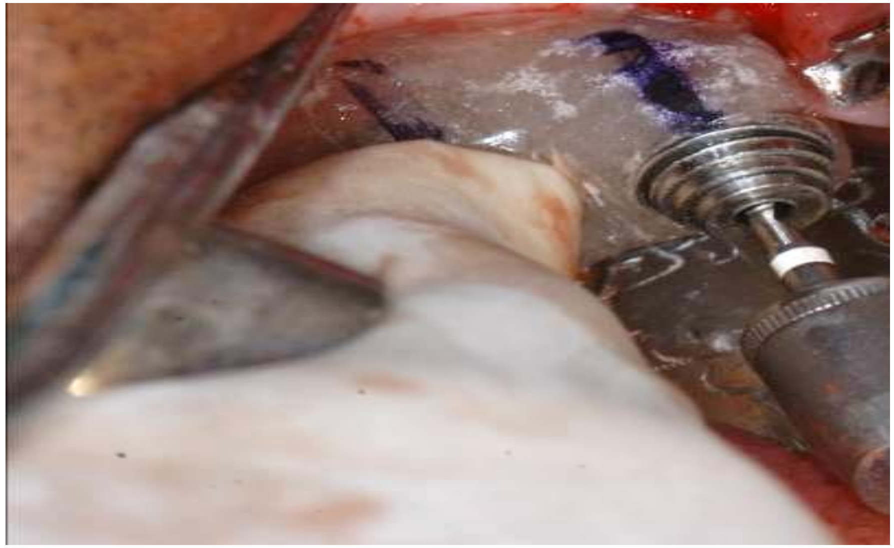


b)

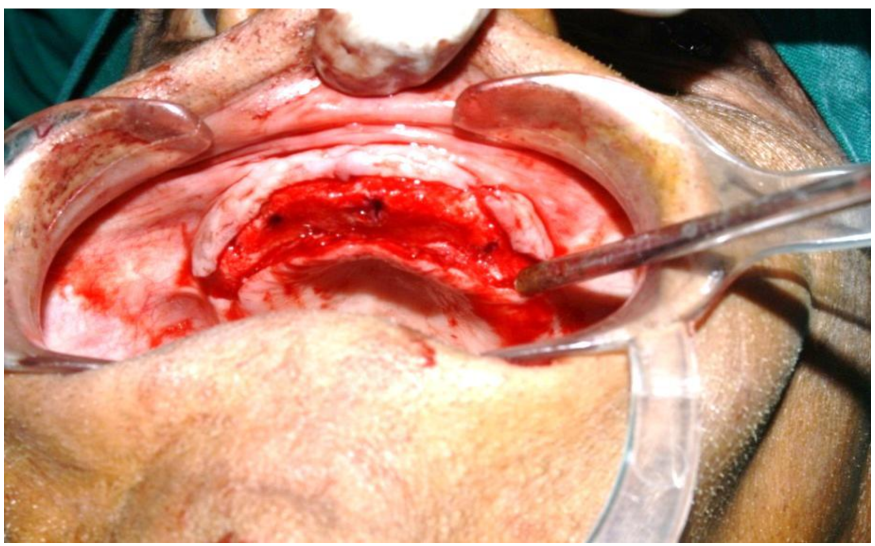
SURGICAL GUIDE IN POSITION

c)

DRILLING THROUGH SURGICAL GUIDE (Fig. 56)



a)



b)

c)

IMPLANTS IN THE PLANNED POSITION

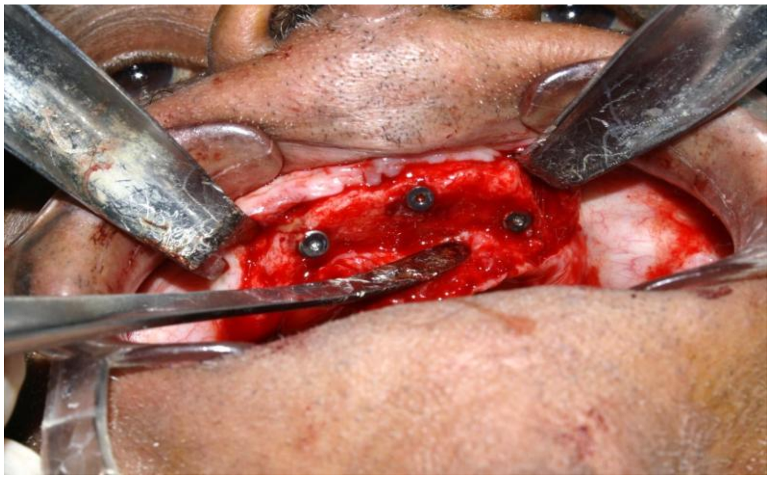
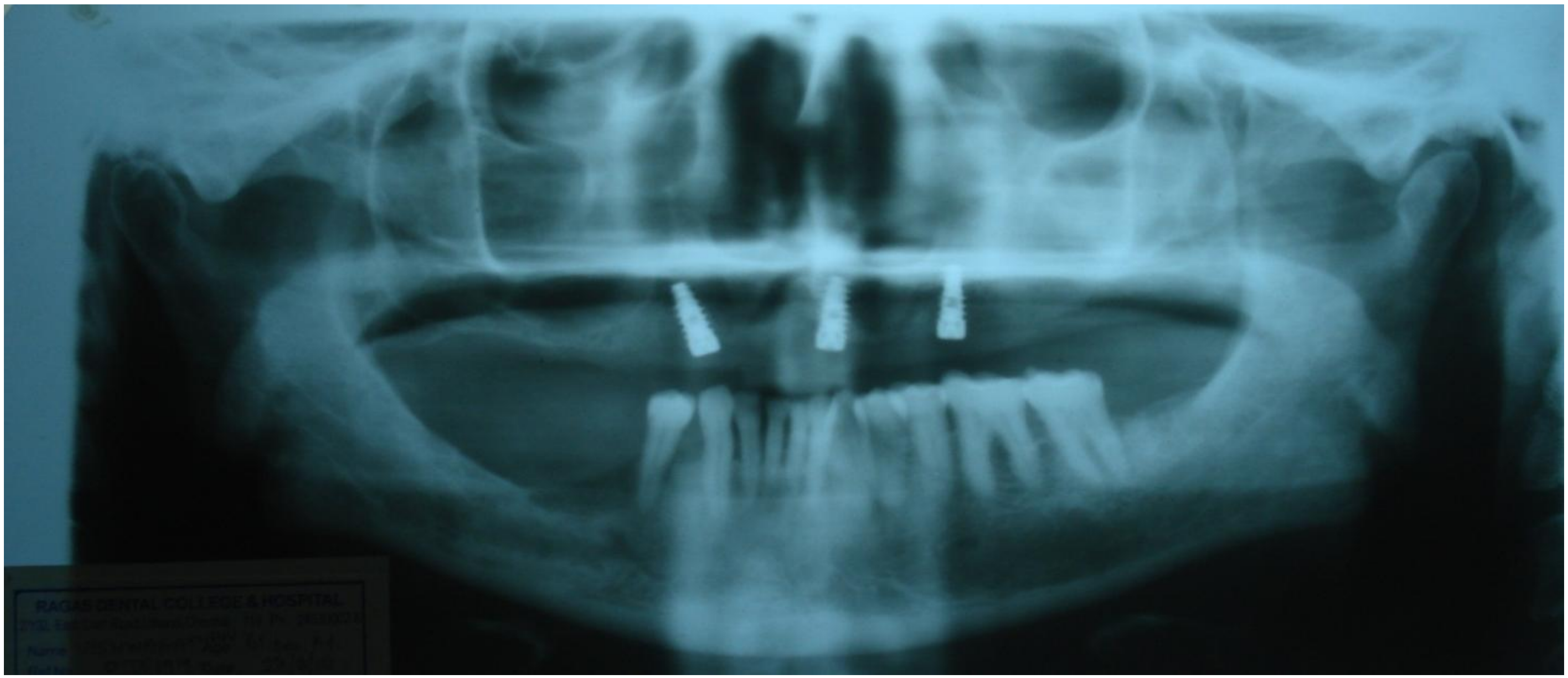


Fig. 57

APPROXIMATION OF FLAP & PRIMARY CLOSURE

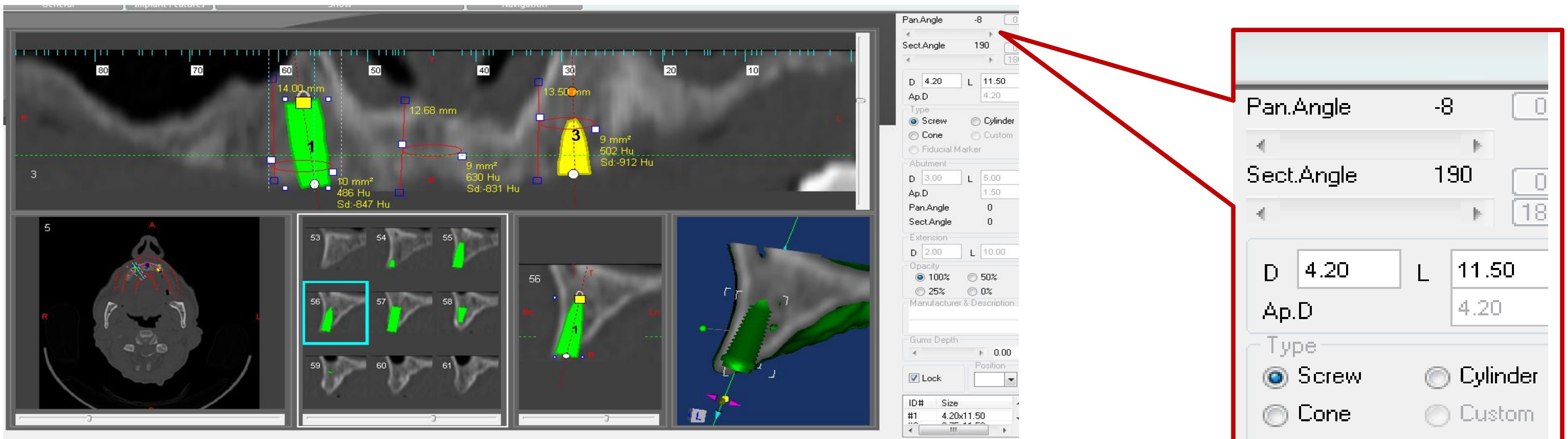
Fig. 58

POST OPERATIVE ORTHOPANTOMOGRAPH (Fig. 59)

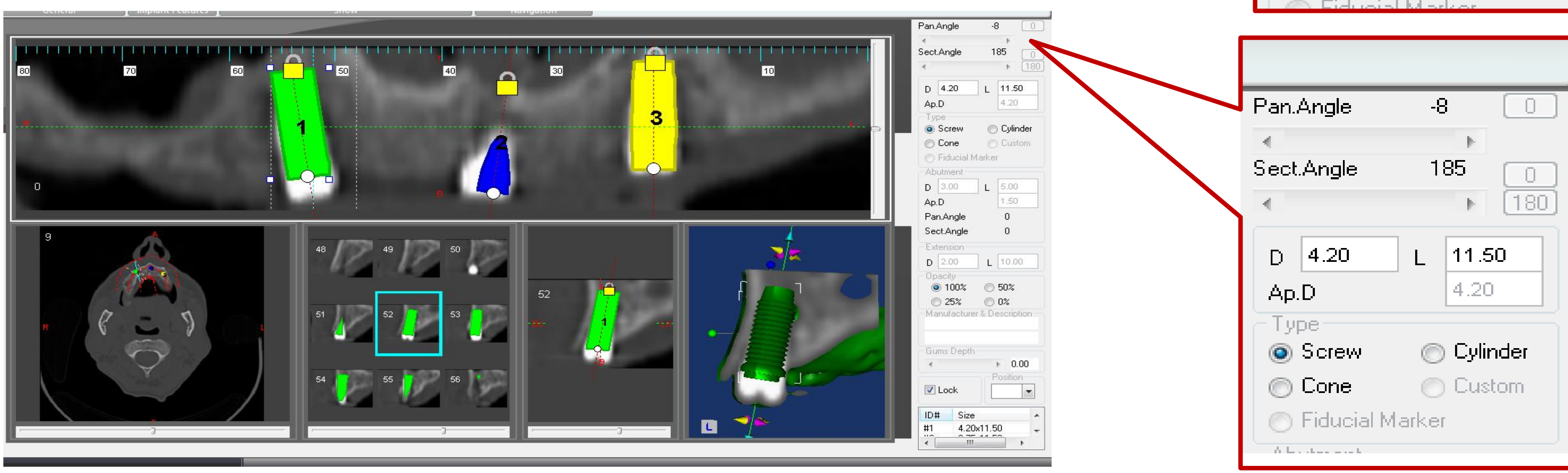


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 1 (Fig. 60)

a)

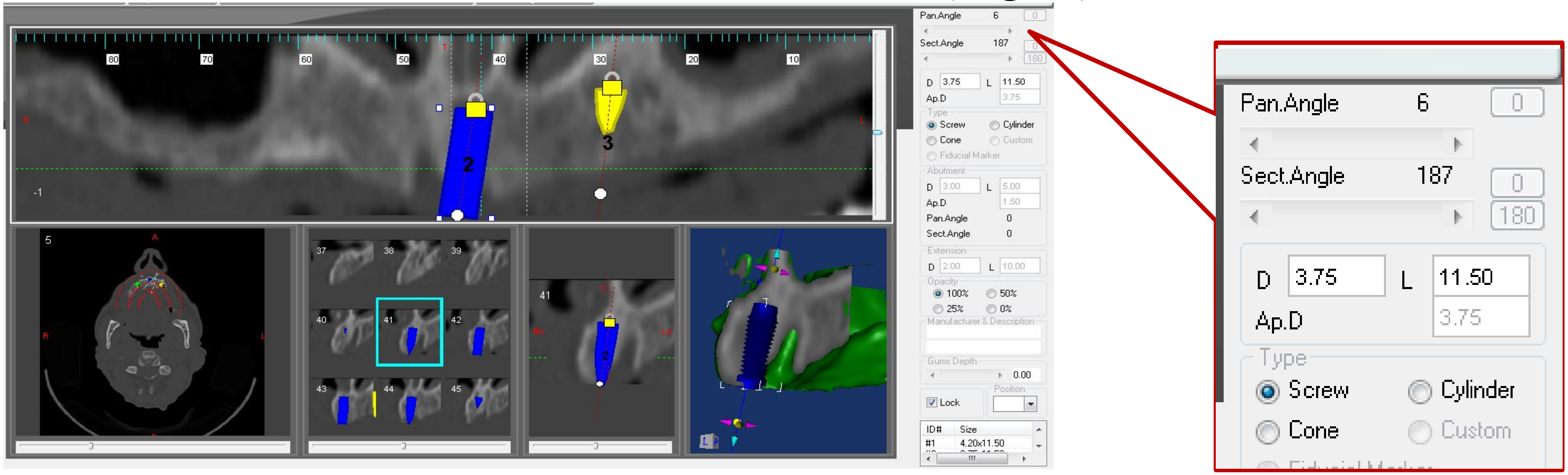


b)

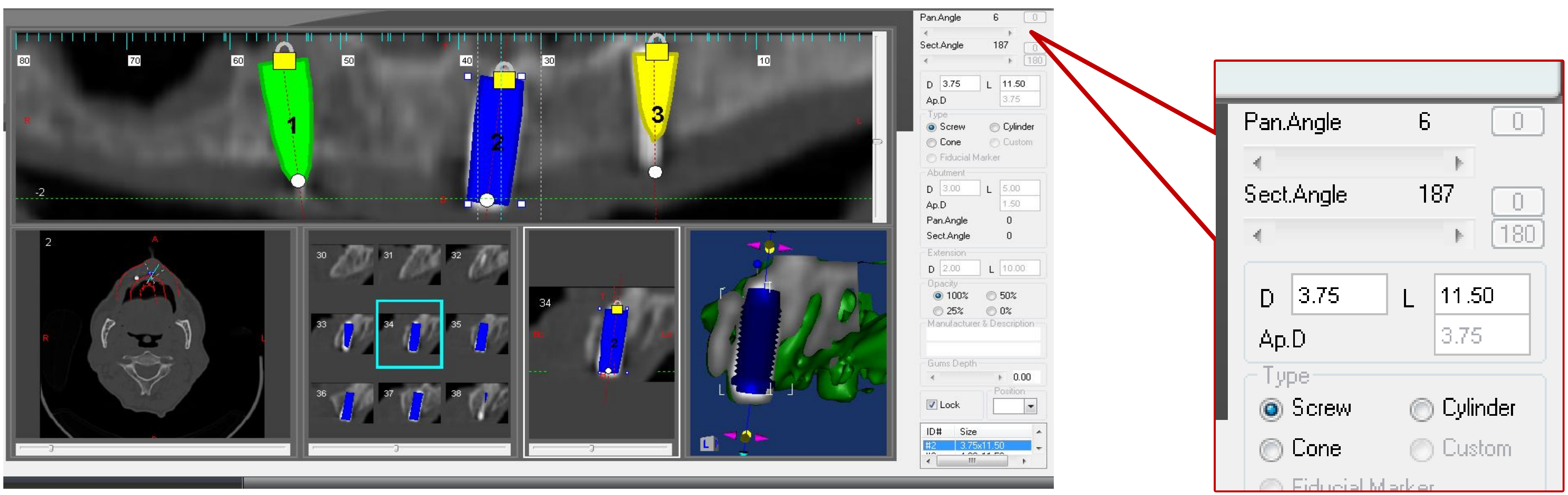


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 2 (Fig. 61)

a)

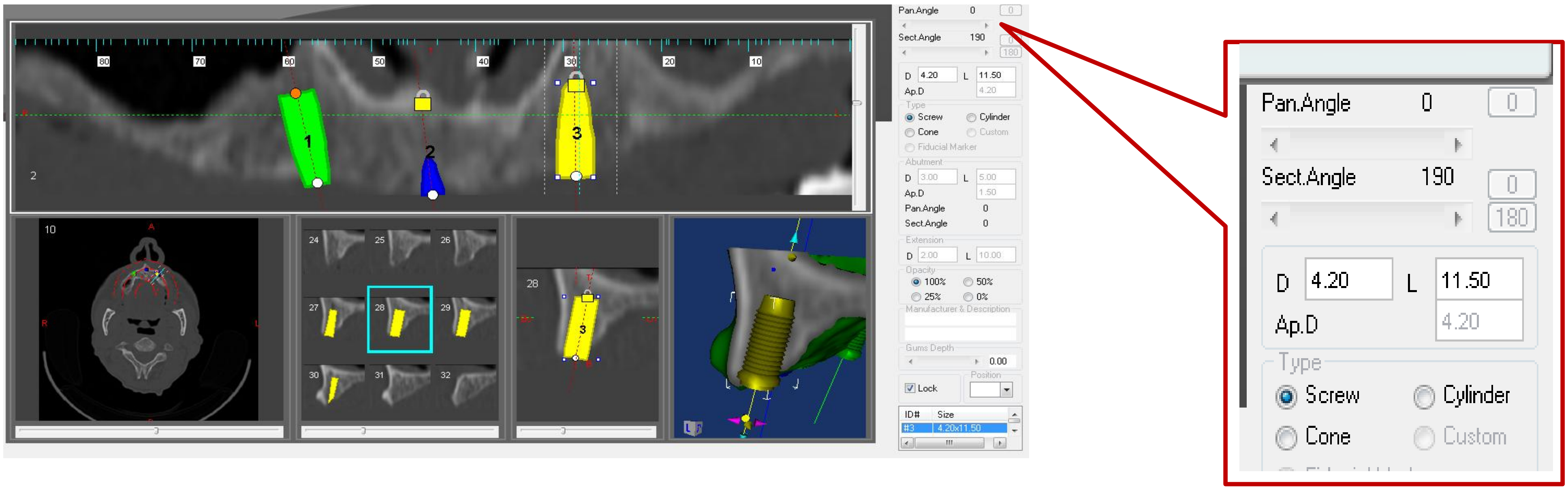


b)

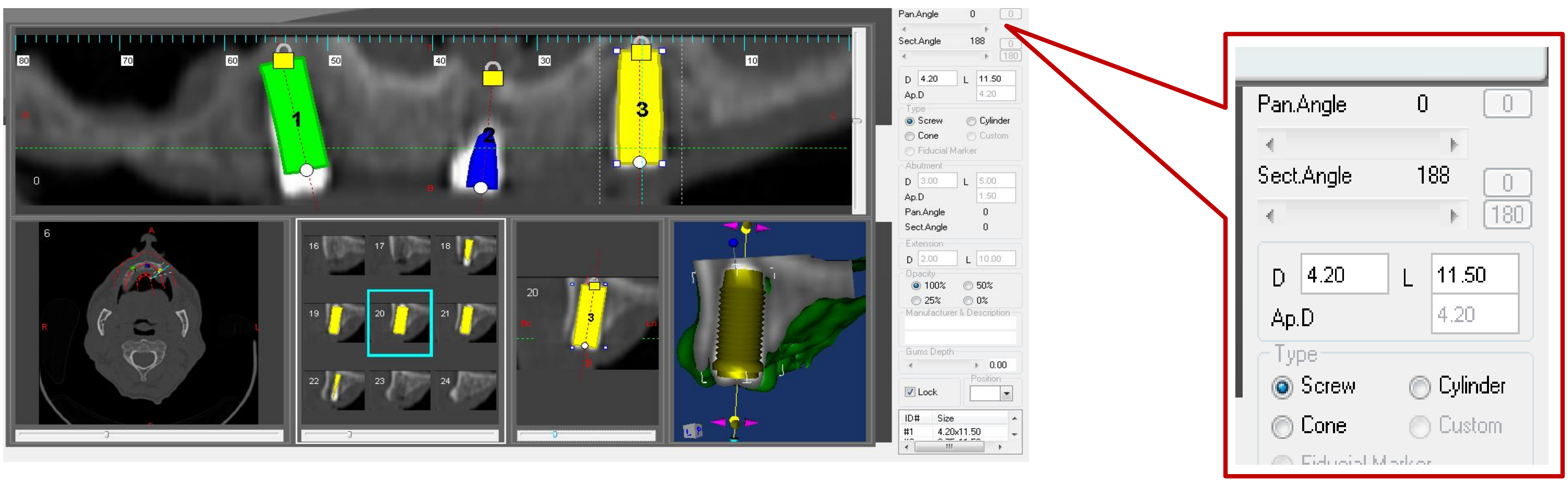


COMPARISON OF PRE-OP PLANNED VIRTUAL POSITION AND POST-OP ACTUAL POSITION OF IMPLANT 3 (Fig. 62)

a)

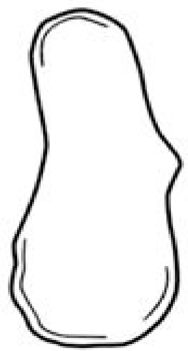


b)



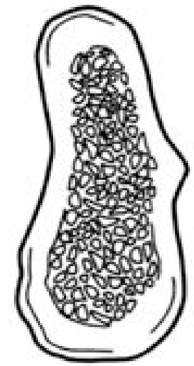
BONE DENSITY GROUPS (Fig. 63)

a)



D1

b)

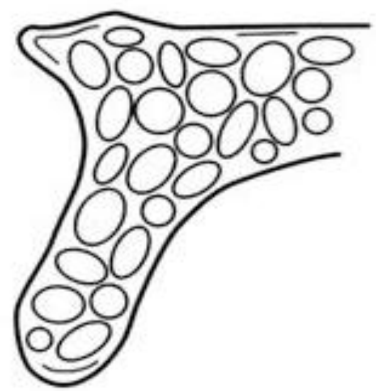


D2

c)

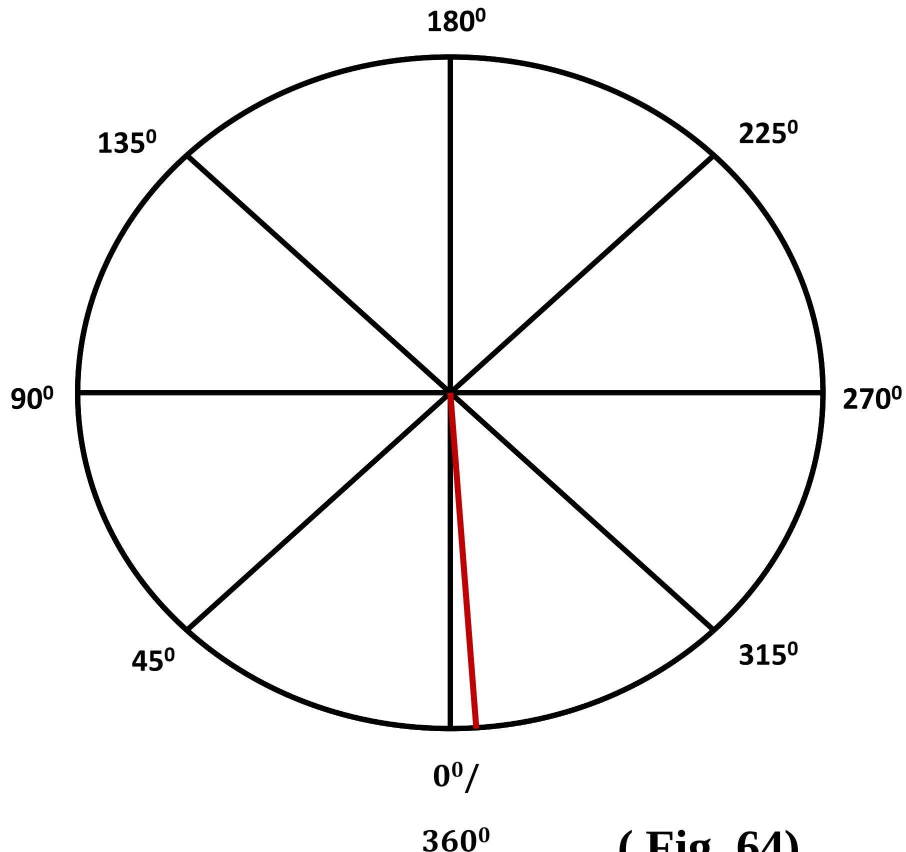
D3

d)



D4

CALCULATING SECTIONAL ANGLE ‘0^o -360^o’



(Fig. 64)