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The role of cone-beam computed tomography in all-n-four dental implant placement: A case report of imaging-guided implant placement in maxilla

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Abstract

Digital technology is becoming an indispensible tool in dental practice now a days. Cone-Beam Computed Tomography (CBCT) – guided dental implant placement has been gaining stronghold as a concept over the past decade, and the techniques have become interestingly refined. There is a growing acceptance for the adoption and implementation of these techniques in routine practice. All-n-Four technique for dental implant placement with prosthetic considerations has generated an increased interest as a highly functional, esthetic, cost effective replacement of missing teeth in completely edentulous patients, where two straight and two angulated implants can take care of the entire arch with prosthetic replacement as an alternative to the cement retained or screw retained rehabilitation.

Keywords: cone beam CT, implant, surgical template, all-n-four

Introduction

Three-dimensional imaging, particularly cone-beam computed tomography (CBCT), has made significant contributions to the planning and placement of implants to replace missing teeth. The accuracy of CBCT data can be used to fabricate a surgical guide that transfers the implant planning information to the surgical site, and facilitates implant placement. Virtual implant planning using CBCT data allows the clinician to create and visualize the end result before actually initiating treatment. It also allows the clinician to consider and investigate multiple treatment scenarios until the optimum treatment plan is attained [1]. The optimized virtual plan may then be converted through modelling to create a "surgical guide" for clinical implementation.

The actual standards of care for replacement of missing teeth by means of dental implants demand not only the replacement of missing teeth in terms of function, but also the achievement of satisfactory aesthetics [1]. Optimal positioning of the dental implant through prosthetically driven decision-making is mandatory to achieve these goals [2, 3]. Computer-aided treatment planning may offer significant advantages in this regard.

The imaging-guided prosthetic replacement procedures benefit the patient greatly in terms of immediate and pain-free replacement of the missing teeth [4] However, precise and meticulous planning of the implant-based replacement in advance of the procedure to be performed, is mandatory for the success outcome [5]. The conventional free-hand dental implant placement is challenged by many factors that jeopardize the desirable beneficial outcomes, such as movement of the patient during drilling, and a limited arial vision of the operative field. Moreover, the accurate diagnosis of the surgical site surface on a 2-dimensional radiograph, its interpretation, and transfer of the acquired 2-dimensional data into the actual 3-dimensional surgical environment, pose a great challenge for achieving the integration of aesthetic, biomechanical and functional aspects, these being the principle pre-requisites for long-term success of the implant. Thus the maxillofacial radiologist is faced with numerous dilemmas ranging from the surgical perspective to the implant positioning, all in a critical time period. A thorough preoperative planning done by the oral radiologist with the view point of accurate placement of dental implant will thereby ensure uneventful placement procedures.

The growing interest in flapless minimally invasive implant placement procedures followed by immediate replacement with pre-fabricated temporary prosthesis to restore function and aesthetics, have led to the development of numerous three-dimensional (3D) visual software programmes. 3D visualization of the site characteristics, neighbouring anatomy, and proximity of vital structures, provides the clinicians with a thorough vision of the surgical, prosthetic and aesthetic requirements of the ideal treatment plan [4-6] This enhances the decision-making, thereby increasing the overall reliability and success outcome of the dental implant treatment.

All n four treatment concept is rehabilitation concept that maximise the use of available bone. With the use of this Nobel technology the use of straight and angled multiunit abutments were used to edentulous and soon to be edentulous patients with an immediately loaded full arch restoration on only four implants, two placed vertically in antrerior region and two placed posteriorly angled up to 45^0 just anterior to the maxillary sinus wall. By tilting the two posterior implants the bone to implant contact is enhanced, providing optimised bone support even with minimum bone volume. Additionally tilting of implants in the maxilla allows for improved anchorage in better quality anterior bone and bicortical anchorage in the cortical bone of the sinus wall and nasal fossa. Tilting of the posterior implants also helps avoid vital structures, such as the mandibular nerve or the maxillary sinus Computerised imaging-guided dental implant placement calls for 3-dimensional imaging of both the jaw bones and virtual planning of the prosthesis. Such integration of the planned prosthesis within the intra-oral dental implant is achieved through a double-scan technique with fluducial marker-based matching; means the use of gutta-percha incorporated in the temporary prosthesis during the second scan [6]. The first scan is obtained with the temporary prosthesis stabilised in position in the patient's mouth with an occlusal silicone index. The same planned prosthesis is than scanned separately with different exposure parameters as suggested by the specific guide designing software, in order to allow its 3D visualization. As the markers are visible in both sets of scans, they can be fused, and the prosthesis properly positioned, within the maxillofacial structures. A recently introduced 3D implant planning software (Nobel Clinician, Nobel Bio- care,) automatically combines the Digital Imaging and Communication in Medicine (DICOM) data belonging to the CT/CBCT examination of the patient with the STL data derived from the optical digital high-resolution scan of the preoperative patient master cast [7].

An additional benefit of this streamlined workflow is that multiple planning options can be visualized and considered well before the surgery is done, and the treatment plan which best fulfills the functional and esthetic demands of the surgical site can be opted for. Once the planning is completed and approved by the clinician, the digital information is used to produce the surgical stent or template that will be tooth supported with CAM rapid prototype (milling or 3D printing.) [8, 9]

Implant placements in the aesthetic zone continue to present a major challenge for the surgical as well as prosthetic phase [8]. Potential advantage of computer-guided implant placement in the aesthetic zone includes a decreased mucosal recession and maximum preservation of the peri-implant papillae when the implant is positioned properly [10].

Case Report

A 62 year old female patient with edentulous upper jaw reported with difficulty in mastication with an ill-fitting upper denture, and wanted a fixed restoration. Her medical and systemic history was non-contributory. After recording the case history, a routine OPG (orthopantomogram) was taken for an overview of the jaw bone, and the case was selected for minimum of four implant placement in the upper arch without any bone grafting in the available height in upper posterior region, which was relatively poor. A new finished complete maxillary denture was fabricated by the dental laboratory for later modification as a provisional fixed restoration. A Multiple–piece scanning prosthesis with gutta percha radiopaque fiducious marker and an occlusal registration was fabricated by the dental lab as per the Guided surgery protocol.

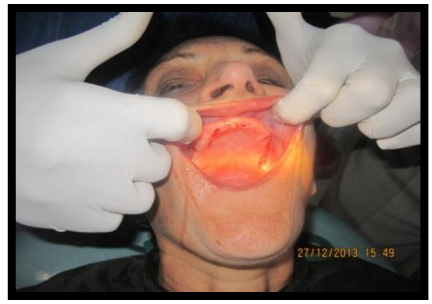


Fig 1: Intraoral View

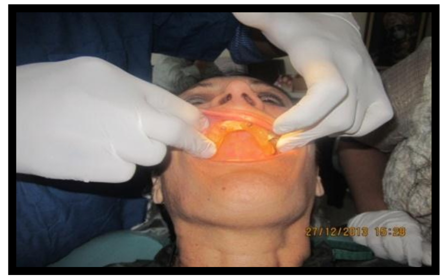


Fig 2: Guide positioned intraotally

Fig 3: Surgical Template

Fig 4: Overview of Virtual plan

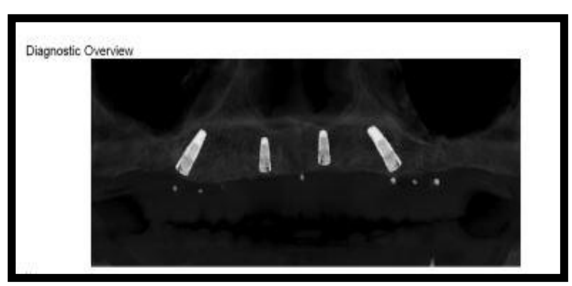


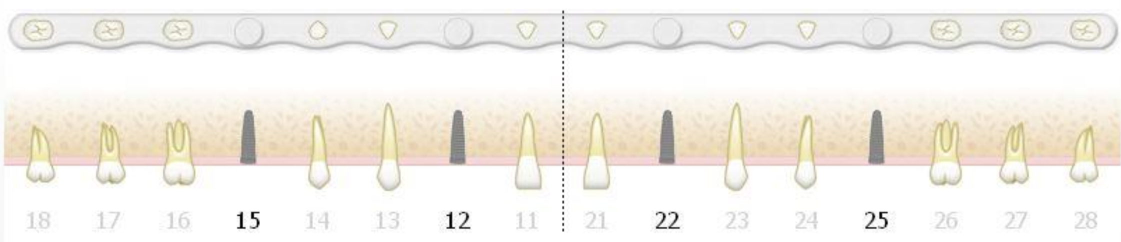
Fig 5: Virtual implant placed in Nobel clinician

Position	Product name	Platform	Diameter	Length	Surgery Type	Sleeve Offset
13	NobelReplace Tapered Groovy	RP	4.3 mm	11.5 mm	-	-
11	NobelReplace Tapered Groovy	NP	3.5 mm	8 mm	-	-
21	NobelReplace Tapered Groovy	RP	4.3 mm	8 mm	-	-
24	NobelReplace Tapered Groovy	RP	4.3 mm	11.5 mm	-	-

Abutment products

Position	Product name	Height
13	30° Multi-unit Abutment Non-Engaging	4 mm
11	Multi-unit Abutment	2 mm
21	Multi-unit Abutment	3 mm
24	30° Multi-unit Abutment Non-Engaging	4 mm

Fig 6: Measurment of Proposed Implants



Warning overview

Clinical Warnings (count: 1)

Radiographic guide was not calibrated

The 3D model of the radiographic guide was created with a grey value (isovalue) as treshold, which is not calibrated for your scanner. To produce an accurately fitting surgical template it is important to follow the NobelGuide Calibration Procedure, which is described in the NobelGuide Procedures Manual.

Fig 7: Implant placement site finalised.

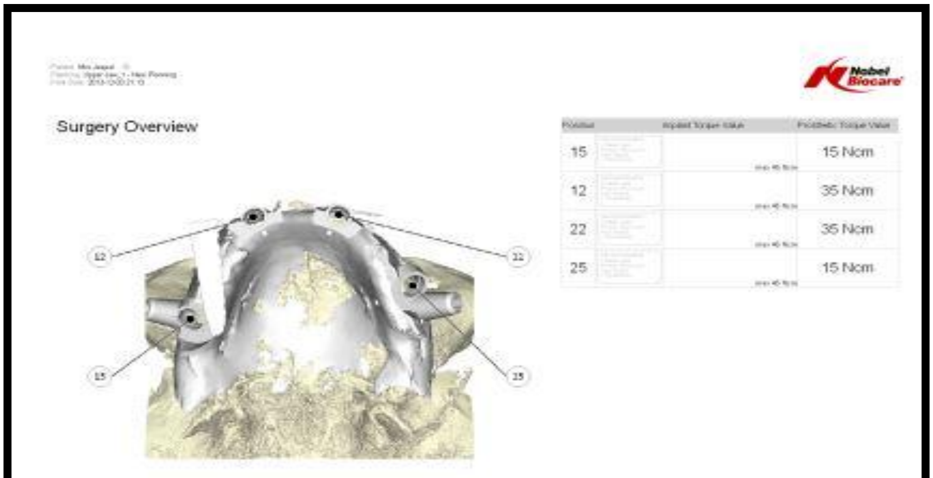


Fig 8: Surgical guidelines.

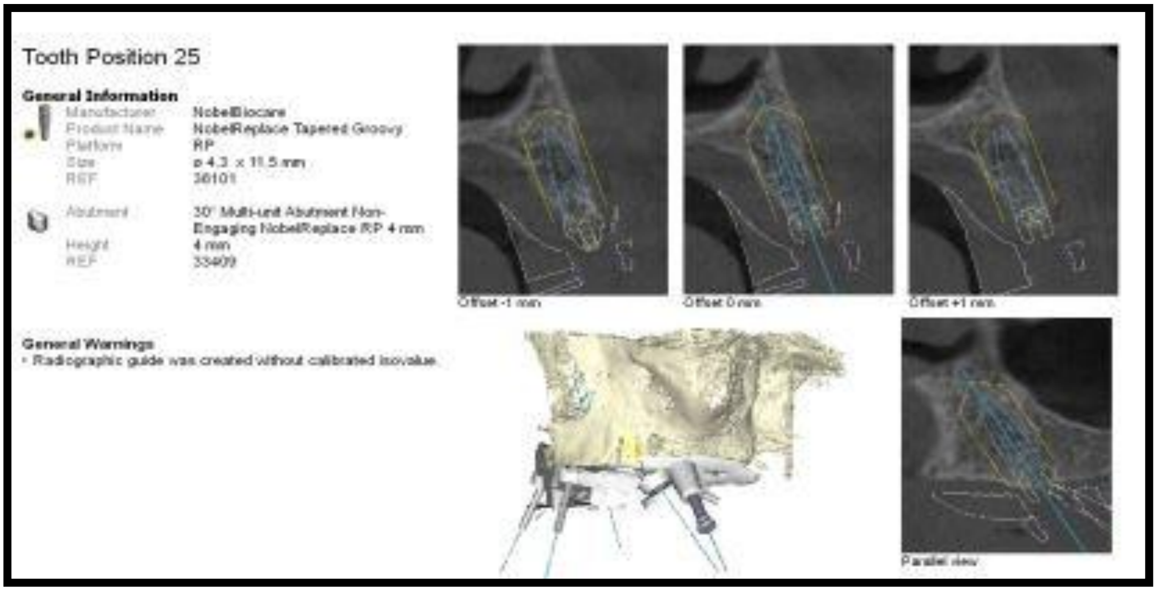


Fig 9: Positioning of upper right first Premolar region Implant

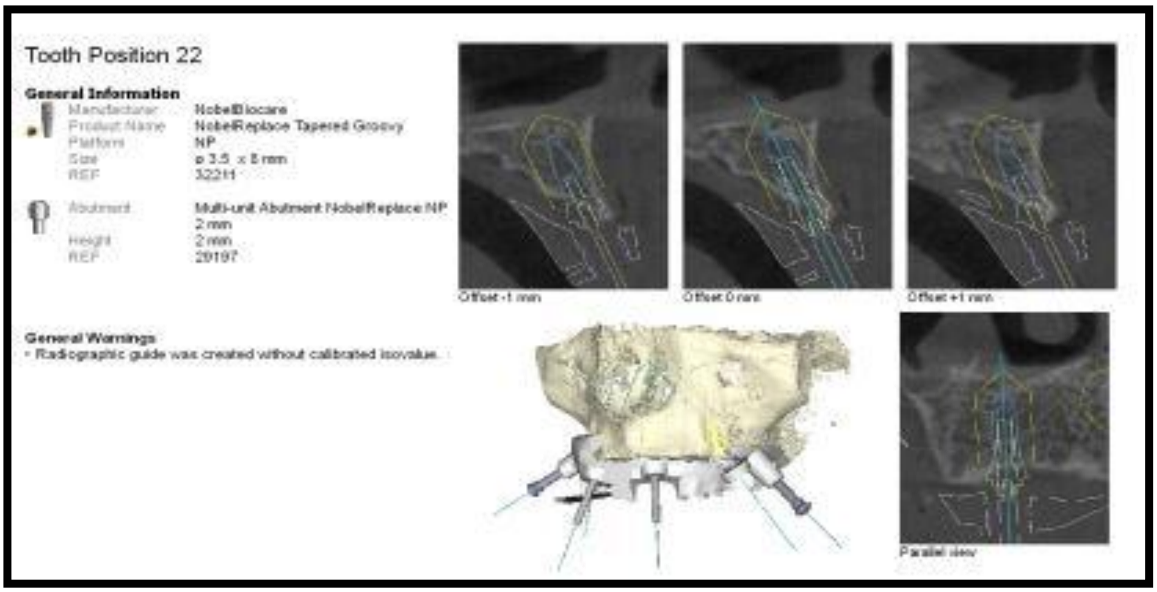


Fig 10: Positioning of upper left Lateral incisor region Implant

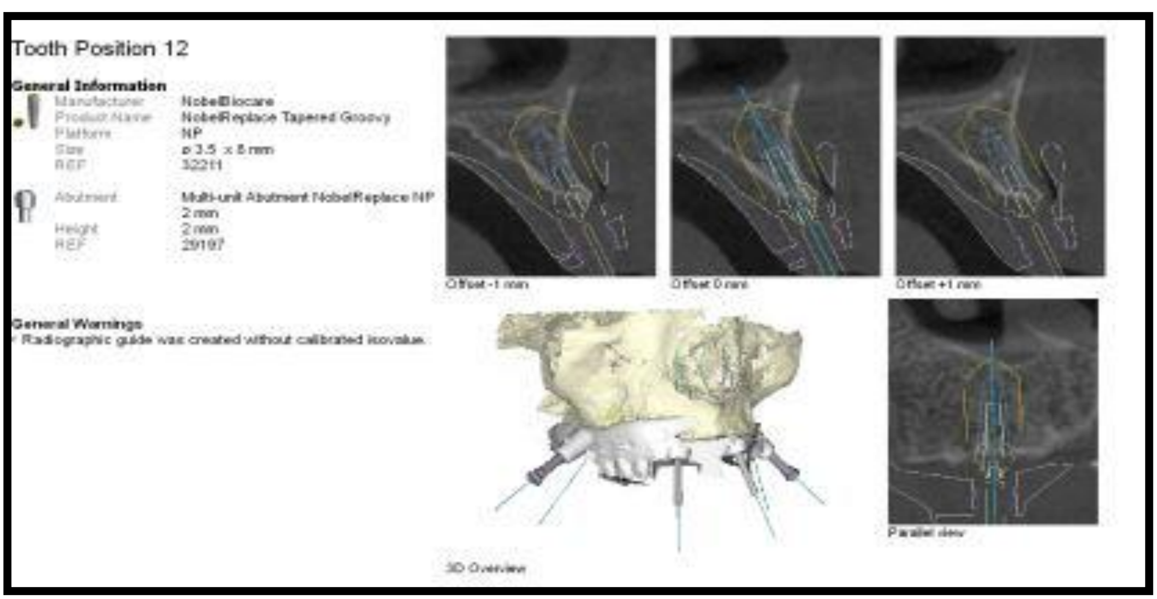


Fig 11: Positioning of upper right Lateral incisor region Implant

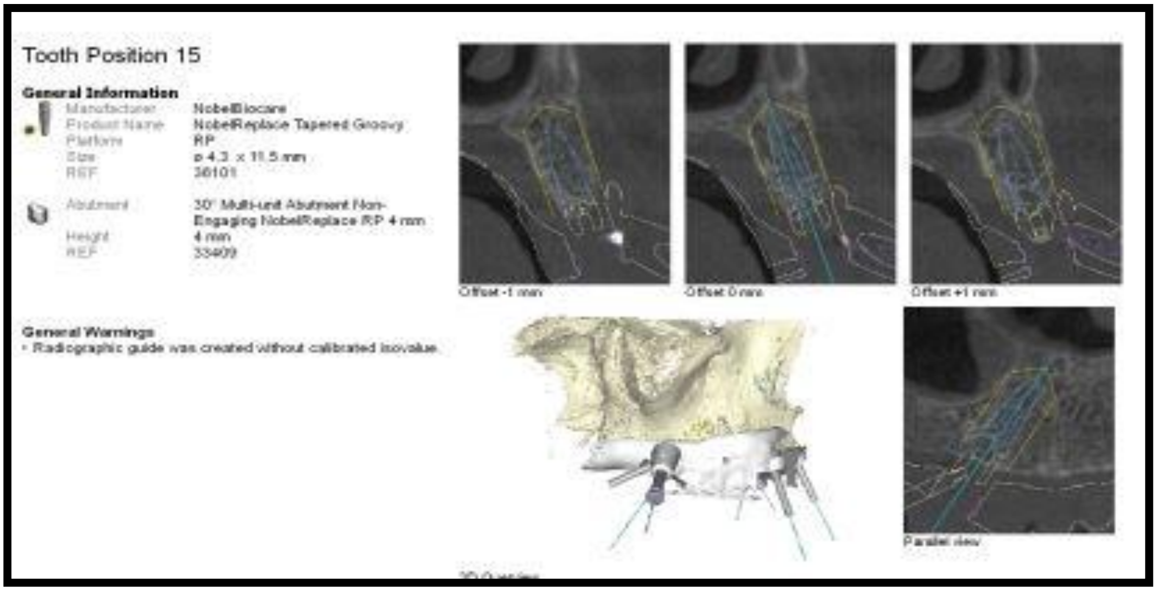


Fig 12: Positioning of upper left Lateral incisor region Implant

Fig 11: Post implant placement immediate denture

CBCT scan (Sirona XG3D) was taken with the patient wearing the radiographic guide and stabilizing arch with occlusal registration, using the double – scan technique. The CBCT data was then converted into third party DICOM images of proper valuation, and imported into the Nobel Clinician software for imaging-guided implant placement and designing a surgical guide. One implant angulated at 35 degrees was considered for each posterior side, just anterior to the anterior wall of the maxillary sinus. The remaining two impants were planned to be placed in the lateral incisor and canine region of each side. The complete implant placement plan was studied virtually to verify the accuracy of implant placement, and its extensions and were digitally conveyed to the manufacturer for fabrication of the surgical guide.

After one week, the patient was appointed for actual procedure of Imaging-guided flapless surgery. The stability of the surgical guide was confirmed in the patients oral cavity with the help of bite registration. Stabilization pins were then placed to secure the surgical template in position in the oral cavity. Implant-specific armamentarium was used to prepare the appropriate osteotomies and place the four Implants, fully guided, using implant mounts through the surgical guide, to the desired planned depth and angulation.

Thirty five degree angulated abutments were placed on two posterior implants and zero degree abutments were placed on the two anterior implants. At the time of surgery, open –tray impression was placed on the abutments, and an abutment level impression was made of the post-implant surgery positions. The impression and occlusal registration along with the immediate upper denture were sent to the dental lab. The following morning, a provisional upper denture was fixed with a prosthetic screw and with minimal occlusal adjacement. The patient was discharged with appropriate instructions regarding immediate loading dental implants.

Discussion

Initially, no computer-guided drill guides which provided absolute precision of dental implant placement were available [13]. Sterlithographic guides were tried initially, but these showed certain discrepancy in the virtual plan and the final implant in all dimensions. Various modifications in preparing the surgical guide were provided by DICOM image integration in the digital world, which minimized theses deviations. Better advancements like metal guide sleeves, drilling protocol, stabilizing screws and minimally invasive procedures further helped in decreasing the discrepancies in dimensions of the virtual and actual plan.

The goal of computer-guided implant planning should be the achievement of maximal surgical safety on the basis of a 3-dimensional diagnosis, virtual planning and high accuracy for the surgical transfer. The use of surgical template allows for flapless insertion, while minimizing potential soft tissue elevation complications such as infection, dehiscence, and soft and hard tissue necrosis [14-18] Predetermined drill depth and correct occlusion-bearing angulation minimizes potential injury to underlying anatomical structure, which plays a crucial role in the success outcome of the implant.

Accuracy of the transfer procedure is defined as the deviation between the position of the implant postoperatively and the position of the implant in the planning. Deviations between the planned and the actual implant position can occur at each step of the computer-guided implant placement, right from the planning stage to the operative stage (Vercruyssen *et al*. 2008; Jung *et al*. 2009; Schneider *et al*. 2009; D'haese *et al*. 2010).

Errors at the planning stage can be generated from errors in acquisition of the CBCT data set (image quality, reliability, motion or metal artefacts). The accuracy of CBCT has been reported previously to be between 0.5 and 0.7mm (Loubele *et al*. 2007; Behneke *et al*. 2009). Software planning and examiner errors (conversion, volume rendering, visualization detail accuracy, referential marker registration) are the other possible factors influencing precision at the planning stage. Therefore, in the surgical guiding systems, the most important goal is to achieve a stable and reproducible fitting position of the template during the radiological investigation and the implant placement.

Limited data regarding the accuracy of conventional implant placement is available in literature. In an *in vitro* study, Sarment *et al*. (2003) established a mean deviation of 1.5mm with a maximum deviation of 1.8mm at the entrance, and a mean deviation of 2.1mm with a maximum deviation of 3.7mm at the apex, for conventional templates with occlusal drilling channels. In another *in vitro* study, the accuracy of freehand dental implant placement in single tooth gaps was evaluated (Brief *et al*. 2005), and the average distance between the planned and actual osteotomy was found to be 1.35 with a maximum of 2.16mm at the entrance, and 1.62 with a maximum of 2.68mm at the apex, when a manual implant placement procedure was performed.

The accuracy of surgical transfer for stereolithographically fabricated guides is based on image data acquired using CT or CBCT units, and is assessed by pre-clinical and clinical models. In an *in vitro* study with cadavers treated according to the NobelGuide technique, van Assche *et al*. (2007) established an acceptable variation.

The present technique of template supported, CBCT-based implant planning with mechanical transfer illustrates a procedure that provides a range of advantages. At the virtual planning stage the implant can be positioned more favourably in relation to the super structure, and the effect on the restoration of any necessary deviations from the prosthetic ideal alignment can be analysed. There is increased safety with regard to protecting the anatomical structures, as the 3D image provides more information about nerve paths, root curvature of adjacent teeth and other important anatomical structures.

The minimally invasive nature of the procedure is a considerable advantage for the patient, as, even with compromised bone anatomy, the existing hard tissue can be ideally analysed and utilized, consequently reducing the amount of augmentation measures. More implants can be placed without flap mobilization, so that not only the amount of pain and swelling can be reduced (Arisan *et al*. 2010b), but the bone resorption associated with detachment of the periosteum can also be minimised (Arau ́jo *et al*. 2005).

The concept of All-on-4 reported by Mathews and eventually popularized by Malo[4,7].

typically involves the placement of a minimum number of implants in full edentulous arch, with maximum occlusal force distribution in the area. Two implants are placed in the maxillary or mandibular anterior lateral incisor / canine region in a conventional vertical fashion.[8] Two additional anterior – posterior angled implants are placed in the posterior region, usually in the premolar regions, at a 30-35 degree angulation. The posterior angled implants are placed in order to avoid the maxillary sinus and mental foramina, while enlarging the anterior-posterior spread of the implant platform in order to maximize the number of teeth fabricated in the final restoration.[9] This technique lessens the number of implants needed for a complete arch restoration and minimizes the need for preparatory bone–grafting procedures. Multi-angled abutment is another step for this technique to be successfully adapt with the success rates. The final restoration is commonly a complete arch, which is usually limited to the second premolar or first molar teeth..

Immediate loading of dental implants has a positive effect on the tissue differentiation and bone formation around titanium implants[10]. Imaging on 3D Cone beam CT allows the pre-fabrication and designing of such prosthesis and reduces the time interval required to deliver the functional teeth to patients. Hence, proper case selection and patient awareness, education, and compliance are all critical factors for success.

Conclusion

The use of Cone-Beam CT-guided Implant placement to perform the all-on –four is a great example of the recent multi-beneficial digital technologies being implemented in common practice. Early experience shows great integration of the prosthetically driven plan, where the conventional concept of placing implant and then reviewing the prosthetic application is totally changed. This actually benefits the patient largely as regards greater accuracy and exact location of the implant placement at the most reliable implant site for perfect outcomes, even in atrophic jaw bones.

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