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Angulated implants: a novel concept for the rehabilitation of severe atrophic maxilla with 3 years follow up supported by Finite Element Analysis

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ABSTRACT

Aim Rehabilitation of maxillary edentulous arches is a challenging task for the Dentists. Angulated implants used for implant placement which utilizes bicortical engagement of implants at the nasal cortex and pterygoid region in a flapless manner. The aim of this study was to evaluate the clinical outcome when 6 tall angulated implants were placed in a maxilla and restored with screw-retained fixed prosthesis after 3 years follow up.

Methods Total of 40 patients were considered for implant placement in the maxilla, 20 patients who underwent implant placement followed by delayed loading and 20 patients who underwent the same surgical procedure followed by immediate loading. Angulated implants were supported by Finite element analysis (FEA) comparing stress distribution on cortical, cancellous and basal bone on mesial and distal side of each implant with All-on-6 concept for maxillary arch.

Results Angulated implant shows 100% survival rate in implants and prosthesis, in both delayed and immediate loading protocols of maxillary rehabilitation. The FEA based on von Misses stress, shows little higher values for All-on-6 for cortical, cancellous and basal bone when compared with Angulated 6 implants design.

Conclusions Angulated implants a novel concept shows a good survival rate. Due to the bicortical engagement of implant the chances of marginal bone resorption around the implant, implant and prosthesis failure is minimal.

KEYWORD Angulated implants, Finite element analysis, Bicortical engagement, All-on-6.

INTRODUCTION

In the literature, healing periods of approximately 3-6 months with two-stage implant surgery bound to be essential for osseointegration of dental implants. However, over a years the evolution of implant surface and designs (diameter and length) (Pessoa et al., 2011), modified surgical and loading protocols have demonstrated similar outcomes (Weber HP et al., 2009). Regarding one versus two stage implant surgery, Esposito et al. (2009) states that the one-stage approach is more suitable, it avoids few surgical intervention and cuts treatment times. Still, the question remains unresolved when less bone quality and quantity is available, the anatomic localization of the implant is not favorable, implant failure rates appears to be higher.

Numerous approaches (bone augmentation, sinus lift) have been tried to overcome the challenge of rehabilitation of atrophic maxilla affected by low-density bone, poor bone quantity. However, the result does not entirely support these therapeutic options which is mostly used among dentists (Malo et al., 2013). The 'All-on-6' implant concept (Gastaldi et al., 2017) involves less stress when compared to the All-on-4 implant concept. In All-on-6 concxept (6 straight axial implants), two additional implants were placed in the second molar region. This two additional implants will avoid the distal cantilever and allows fixed screw retained prosthesis. This implant concept require ridge augmentations or sinus direct or indirect lifts for placement of implant in the compromised conditions of posterior maxilla. Since bone in this region shows poor density, additional factors like sinus pneumitization and residual ridge resorption is very common which lead to implant failure due to poor osseointegration (Gargari et al., 2013).

In the literature, evolution of angulated implants has occurred as a graftless solution avoiding major anatomic structures while achieving bicortical stabilization. Numerous studies have evaluated angulated implant-prosthetic framework with decent follow up years showing success rates of 95-100%. The use of angulated implants to avoid the maxillary sinus has been proposed (Calandriello et al., 2005). In this study, long angulated

implants were placed subcrestally (length of 16-25mm; 30°-45° angulation) in anterior and posterior regions of maxilla with nasal cortex engagement and pterygoid pillar engagement respectively (Nag et al., 2019; Nag, Dhara et al., 2019; Venkat Ratna Nag, 2019). Tall implants have more bone to implant contact, thus improving osseointegration and by using angulated implants concept, stabilization and elimination of cantilever is possible. By engaging the implants in alveolar and nasal cortex, hard tissue augmentation procedures and vital structures in the premaxilla are avoided (Aparicio et al., 2001; Yvan et al., 2010; Kim et al., 2011).
Rosen and Gynther performed a retrospective study on the surgical outcome of angulated implants in severely resorbed edentulous maxilla as an alternative to bone grafting. They demonstrated that in patients the success rate of 97% in 103 implants of 19 patients along with long term follow up of approximately 10 year (Rosen and Gynther, 2007). The implants were placed flapless to maintain the soft tissue profile not compromising mucointegration (Chrcanovic et al., 2014).
Implants were immediately loaded within 48 hours in most of the cases where good primary stability was achieved (Georgios et al., 2010; Nag et al., 2018; Venkat Nag et al., 2017, 2018 a, 2018 b). The delayed protocol was followed (3 months) for remodeling of bone around implant and better osseointegration. The Finite element analysis (FEA) was applied to analyze the stress and strain in the field of implant dentistry for alveolar structures. Finite Element Model represents a finite number of elements and nodes. The system of elements is formed when these nodes are connected (Cobo et al., 1993).
FEA allows the prediction of the stress distribution of the implants in cortical bone, and around the apex of the implants in the cancellous and basal bone (Geng et al., 2001). This study aimed to compare the clinical outcome of angulated implants between two groups: delayed (Group A) and immediate (Group B) loading. The null hypothesis of this study was that there is no difference in the outcome between the two protocols using angulated technique. This study was also supported by a Finite element analysis for better understanding the stress on cortical, cancellous and basal bone on mesial and distal side of each implant in Angulated implant design concept when compared to All-on-6 concept for severe atrophic maxilla.

MATERIALS AND METHODS

Presurgical protocol

For this study, patients selected between age group of 30-85 years, with good general health and no contraindication to any surgical procedure. These patients underwent 6 tall angulated implants placement for atrophic partial/complete edentulous maxilla performed at Institute for Dental Implantology, Hyderabad, India, from January 2014 to March 2019. The only exclusion criteria for this study were patients unable to commit for 3 years follow up. Informed consent was taken from all the patients who were willing to go ahead for the treatment and agreed for follow up protocol. The implants placed in these patients were Bioline-i Implants (Bioline Dental GmbH &Co.KG, Germany). All the patients were subjected to standard presurgical protocol of panoramic radiograph and computed tomography for the assessment of vital structure and bone density. Patients were then divided into two groups, Group A and Group B for better indulgent. Group A includes patients in whom primary stability of 40Ncm was achieved on implant placement and Group B, primary stability of 65Ncm as per the respective delayed and immediate protocol (Fig. 1).

Surgical protocol

Under aseptic precautions, local anesthesia is given at the planned surgical sites and atraumatic extractions was done for immediate implant placement. Metal surgical guide (flapless approach) was used to shows the angulation of drills required for delayed implant placement (canine, second premolar, first molar/second molar). To visualize the direction of the drill into the bone and relation with the vital structure radiographic assessment was carried out. A depth gauge was then used to assess and finalize the length of the implant by nasal cortical proprioception confirmed with RadioVisioGraphy. The selected Bioline-i-implant was placed and torque ratchet was used for final placement and the resistance of the implant was checked. To determine the loading protocol the primary stability of the implant was then checked using torque test. Thus, two tall angulated implants were placed in the premaxilla engaging the alveolar and nasal cortex and one pterygoid implant in the posterior maxilla (bicortical engagement). The same procedure was followed for the placement of three implants were done on the other side. All the six angulated implants were placed subcrestally in a flapless manner (Sotto-Maior et al., 2014). Implants were torqued and the values were recorded to categorize the patients for loading protocol.

FIG. 1 Presurgical orthopantomograph of the case.

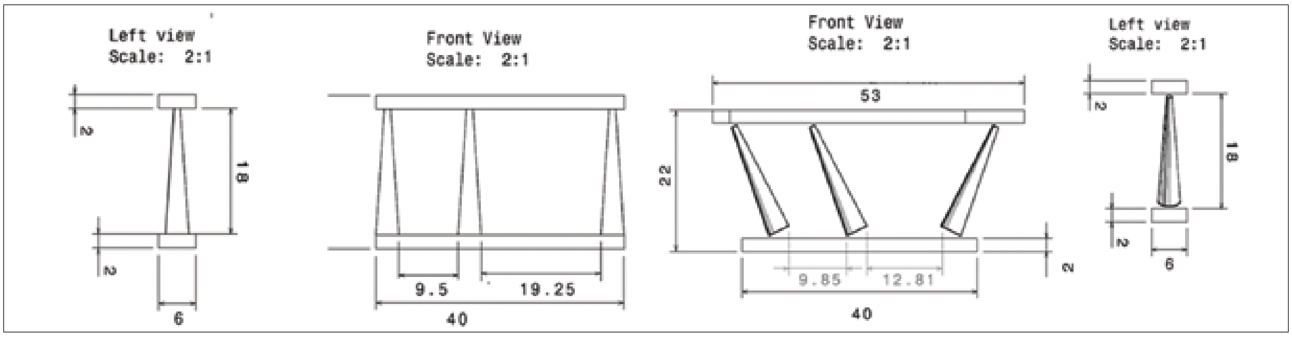

FIG. 2A, 2B Model showing All-on-6 and angulated implant concept.

The patients were advised to adhere to strict soft diet regimen for few days with regular oral hygiene maintenance. Group A patients was asked to report for follow up after a week's time.

Prosthetic protocol

After surgical intervention, same day of surgery, multi-units abutments were placed (30-50°) to compensate the angulation of implants.

1. For patients under Group A, Immediate provisionalization was done using self-cure acrylic resin and cemented with provisional cement (IRM). A definitive prosthesis was planned after few months.
2. For the group B patients, final prosthetic procedures were started immediately after implant placement followed by placement of screw retained permanent prosthesis using CAD/CAM technology for design and fabrication was done within 2-5 days.

The patients were recalled after 1 year for clinical and radiographic assessment. All patients were checked for implant stability and occlusion.

Finite element analysis

Three dimensional (3D) finite element model of maxilla with angulated implants were used to inspect the distribution of stress in maxillary arch on cortical, cancellous and basal bone on mesial and distal side of each implant. Three dimensional finite element models were constructed using finite element software (ANSYS Workbenchversion 9 package; ANSYS, Inc, Canonsburg, Pa) from the computerized tomography (CT) data considering left side of the patient. CAD images of implants were supplied by the manufacturer (Bioline dental GmbH & Co. KG, Germany). In the maxillary model three implants with diameter of 3.75 mm and 18 mm length were placed with one angulated implants being modelled at the canine, one at the second premolar position and one implant at the first/second molar position i.e. pterygoid implant (Fig. 2b). Another pair of maxillary models were made with three straight implants in the similar location to simulate the All-on-6 concept of implant placement (Fig. 2a). Boundary conditions were fixed, by constraining the movement of the peripheral nodes and the properties were given to the designed models to simulate the clinical situation (Fig. 3a, 3b).

Implant and prosthesis survival

In this study, no implant failure was noted during the follow up period. The survival of the implant was highly based on the marginal bone loss, absence of pain and infection by using radiographic analysis for the first year and third year follow up.

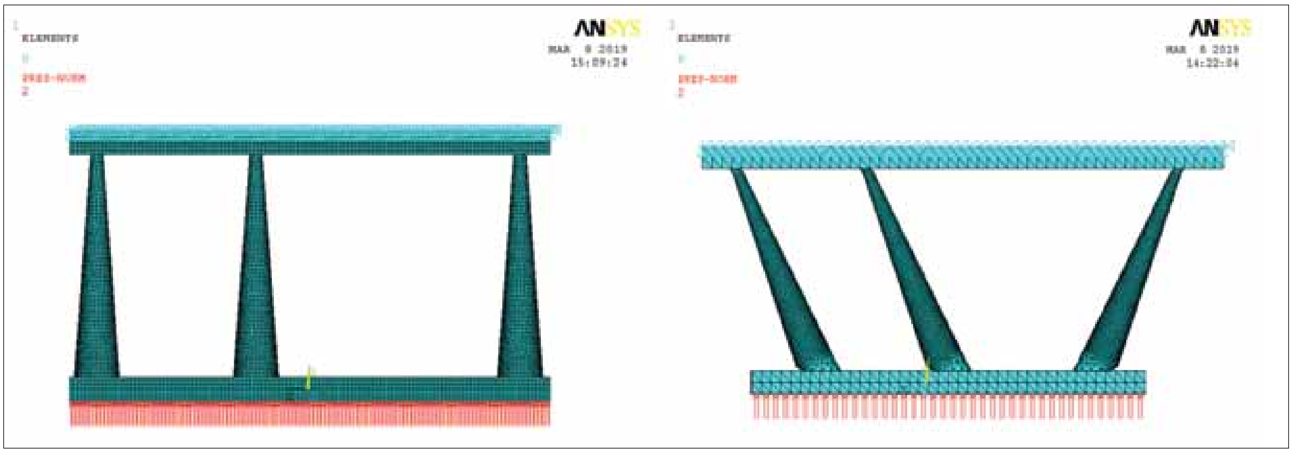

FIG. 3A/B Model showing all-on-6 and angulated implant concept.

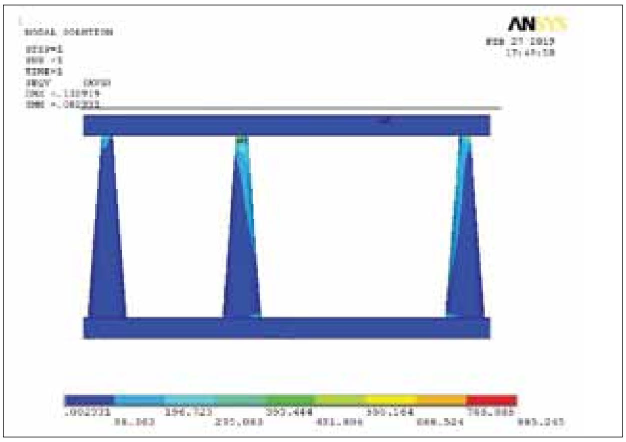

FIG. 4 All-on-6 in crestal, cancellous and basal bone.

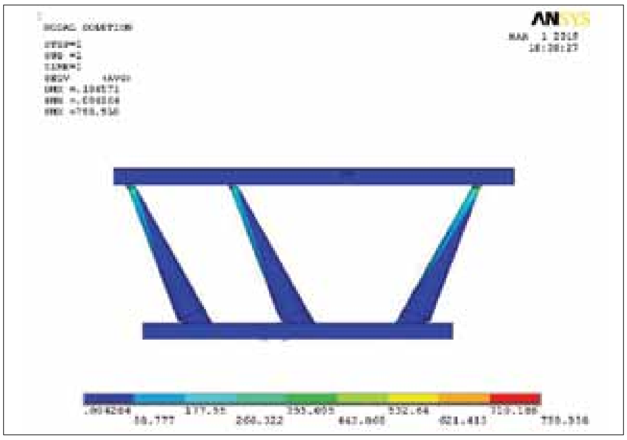

FIG. 5 Angulated implant in crestal, cancellous and basal bone.

Location	Lateral incisor	
Bone	Mesial	Distal
Crestal	98.363	98.363
Cancellous	98.363	98.363
Basal	393.444	196.723

TABLE 1 A Stress distribution on lateral incisor (mesial and distal) due implant on peri-implant bone for All-on-6 concepts.

Location	Second premolar	
Bone	Mesial	Distal
Crestal	196.723	393.444
Cancellous	98.363	196.723
Basal	885.245	295.083

TABLE 1 B Stress distribution on second premolar (mesial and distal) due implant on peri-implant bone for All-on-6 concepts.

Location	Second molar	
Bone	Mesial	Distal
Crestal	393.444	98.363
Cancellous	196.723	98.363
Basal	196.723	786.885

TABLE 1 C Stress distribution on second molar (mesial and distal) due implant on peri-implant bone for All-on-6 concepts.

Location	Canine	
Bone	Distal	Mesial
Crestal	88.777	88.777
Cancellous	88.777	177.55
Basal	621.413	355.095

TABLE 2 A Stress distribution on canine (mesial and distal) due implant on peri-implant for angulated implant concepts.

Location	Second premolar	
Bone	Distal	Mesial
Crestal	88.777	177.55
Cancellous	88.777	177.55
Basal	621.413	88.777

TABLE 2 B Stress distribution on second premolar (mesial and distal) due implant on peri-implant bone for angulated implant concepts.

Location	Second molar	
Bone	Distal	Mesial
Crestal	88.777	177.55
Cancellous	88.777	177.55
Basal	798.958	443.868

TABLE 2 C Stress distribution on second molar (mesial and distal) due implant on peri-implant bone for Angulated implant concepts.

RESULTS

Finite element numerical analysis

The results of the this study were as follows: the maximum von Mises stress recorded in the All-on-6 implant model for canine/lateral incisor were 98.363 Mpa, 98.363 Mpa and 393.444 Mpa for mesial and for distal side 98.363 Mpa, 98.363Mpa and 196.723 Mpa, second premolars were 196.723 Mpa, 98.363Mpa and 885.245 Mpa for mesial and for distal side 393.444 Mpa, 196.723Mpa and 295.083 Mpa, second molar were 393.444 Mpa, 196.723Mpa and 196.723 Mpa for mesial and for distal side 98.363 Mpa, 98.363Mpa and 786.885 Mpa on crestal, cancellous and basal bone respectively (Fig. 4; Table 1), whereas the maximum stress recorded in the angulated implants model for

FIG. 6 Preoperatiive (A) and postoperatiive (B) pictures of the patient with 6 angulated implants concept.

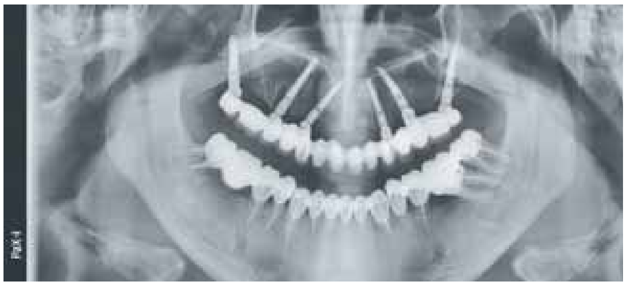

FIG. 7 Orthopantomographs of a patient with angulated implants taken immediately after surgery (A), 1 year postoperatiively (B) and at the3-year follow up (C).

canine was 88.777 Mpa, 177.55 Mpa and 355.095 Mpa for mesial and for distal side 88.777 Mpa, 88.777 Mpa and 621.413 Mpa, second premolar were 177.55 Mpa, 177.55 Mpa and 88.777 Mpa for mesial and for distal side 88.777 Mpa, 88.777 Mpa and 621.413 Mpa, second molar were 177.55 Mpa, 177.55 Mpa and 443.868 Mpa for mesial and for distal side 88.777 Mpa, 88.777 Mpa and 798.953 Mpa for crestal, cancellous and basal bone respectively (Fig. 5; Table 2).

Clinical Follow up

In this study, all the 40 patients have been followed up every 1st and 3rd year for routine checkup and evaluation of bone loss. Few patients showed screw loosening and mucositis which was treated. Few patients noticed chipping of the ceramic layer exposed metal, which occurred in 3rd year of follow up. In such cases the prostheses were removed and a new fixed prosthesis was given (Fig. 6, 7).

DISCUSSION

In the angulated implants concept, 6 tall angulated implants were placed with bicortical engagement. Screw retained prosthetic solutions with cross arch stabilization suggested to be the most predictable restorative option for immediate loading (Malo et al., 2015; Cavalli et al., 2012). Curi et al. performed a retrospective study for implant and prosthesis survival rates of pterygoid implants with delayed loading and found overall pterygoid survival rate is 99 % and prosthesis survival rate was 97.7% (Curi et al., 2015). Immediate loading requires minimal torque values of 35–40 Ncm, when combined with cross-arch-stabilized interim hybrid prosthesis with minimal cantilevers will provide the greater chance for survival of angulated implants (Grusovin et al., 2007; Ottoni et al., 2005; Ghoul et al., 2012).
Bhering et al. performed a study on two treatment

concepts (All-on-4 and All-on-6) and there effect of framework material due to stress. And the study revealed that All-on-6 showed less stress values on cortical bone, implant, and cancellous bone when compared to All-on-4 (Bhering et al., 2016).

Almeida et al performed study to compare the biomechanical behavior of tilted long implant and vertical short implants to support fixed prosthesis in an atrophic maxillary arch using FEA model and concluded that the presence of distal tilted (all-on-four) and distal short implants (all-on-six) resulted in higher stresses in both situations in comparison to the presence of vertical implants (all-on-four) (Almeida et al., 2013).

Limitations of the present study is that the number of patients is less and follow up period of 3 years could be a shorter time. More long term studies needs to be performed and proposed by dentists to evaluate and improvise the reliability of angulated implant concept.

CONCLUSION

Angulated implant concept for maxillary arch rehabilitation in both delayed and immediate loading showed 100% survival rate. The finite element analysis concluded that the stress dissipated on crestal, cancellous and basal bone on mesial and distal side of each implant was comparatively less than All-on-6 suggestive of no bone loss. Angulated implants thus is proven to be an effective clinical treatment option as it bypasses vital structures, minimizes need for grafting procedures, maintains marginal bone levels, and also eliminates distal cantilevers.

Conflicts of interest

None.

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