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Versatility of Zygomatic Implants in Dental Rehabilitation for Patients Following Partial or Total Maxillectomy Procedures: A Prospective Study

Dr. Pradeep Devadoss*[1], Dr. T. Srinivasa Prasad[2], Dr. J. Naveen Kumar[3], Dr. S. Jimson[4]

*[1,2,3,4]Professor, Department of Oral and Maxillofacial Surgery, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research

***Corresponding Author**

Dr. Pradeep Devadoss

Professor, Department of Oral and Maxillofacial Surgery, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research

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ABSTRACT

Maxillary defects resulting from partial or total maxillectomy due to ablative surgeries for neoplasms or infections present multifactorial challenges involving function, esthetics, phonation, mastication, and psychological well-being. Restoration in such cases is often complex, particularly when conventional prosthodontic and implant rehabilitation is unviable due to extensive bone loss and compromised anatomy. Zygomatic implants provide a unique anchorage solution through engagement in the dense zygomatic bone, circumventing deficient or absent alveolar structures.

This prospective clinical study was conducted at Meenakshi Ammal Dental College and Hospital and included 20 patients (12 males, 8 females) presenting with either severely atrophic posterior maxilla or post-maxillectomy defects. A total of 32 zygomatic implants were placed using a combination of virtual surgical planning, trans-sinus, and extramaxillary techniques. Parameters assessed included primary and secondary implant stability (RFA/ISQ), osseointegration, peri-implant soft tissue health, prosthesis retention, patient-reported outcome measures (PROMs), and radiographic marginal bone loss over a 36-month period.

Outcomes revealed a 95% implant survival rate, with significant improvement in functional and psychosocial indices. The utilization of CBCT-based planning enhanced placement accuracy and reduced surgical complications. This study underscores the strategic role of zygomatic implants in rehabilitating maxillary defects, offering a predictable and long-term solution in advanced cases.

Keywords: *Zygomatic implants, maxillectomy rehabilitation, dental implants, osseointegration, zygoma anchorage, virtual surgical planning, trans-sinus approach, implant-supported prosthesis.*

1. INTRODUCTION

Maxillectomy procedures, whether partial or total, are often necessitated by the resection of maxillary tumors (benign or malignant), invasive fungal infections like mucormycosis, traumatic injuries, or congenital defects. The resultant anatomic and functional deficits—such as oroantral communication, impaired mastication, hypernasal speech, and esthetic disharmony—pose significant rehabilitation challenges. Obturator prostheses, though traditionally employed, frequently fail to provide adequate retention or comfort, particularly in extensive defects or irradiated tissues [1].

The posterior maxilla poses inherent difficulties for endosseous implant placement due to poor bone quality (Type III or IV), pneumatized sinuses, and limited vertical height [2]. When conventional implants are not viable, zygomatic implants offer a biomechanically favorable alternative by anchoring in the zygomatic bone, a dense cortical structure with superior stability [3].

Originally introduced by Brånemark in the 1980s, zygomatic implants have undergone substantial refinements. New protocols like the Zygomatic Anatomy-Guided Approach (ZAGA), digital planning tools, and minimally invasive techniques have broadened their application [4]. The role of zygomatic implants has evolved from treating edentulous atrophic maxillae to now encompassing the reconstruction of surgically resected maxillae, making them indispensable in maxillofacial rehabilitation.

This study evaluates the versatility of zygomatic implants in maxillary rehabilitation post-maxillectomy through clinical, radiographic, and patient-centric outcomes over a three-year period, establishing its credibility in routine surgical practice.

2. METHODOLOGY

This prospective study was carried out at Meenakshi Ammal Dental College and Hospital, Chennai, over a continuous duration of 36 months, from August 2022 to December 2023. Institutional ethical clearance was obtained prior to the commencement of the study (Ref No: MADC/IEC-1/15-A/2022), and written informed consent was obtained from all participants after explaining the procedure, benefits, risks, and expected outcomes in their native language.

Study Population and Criteria

The study enrolled a total of 20 patients who met the predefined eligibility criteria.

Inclusion Criteria:

The following inclusion parameters were considered:

- Adults between the age of 50 to 75 years.
- Patients presenting with a history of partial or total maxillary resection due to benign or malignant neoplasms, invasive infections such as mucormycosis, or traumatic events.
- Individuals demonstrating severe posterior maxillary atrophy characterized by residual alveolar bone height of less than 4 mm.
- Systemically stable patients who were suitable candidates for surgical intervention under general anesthesia.
- Individuals who demonstrated a willingness to participate in the study and adhere to scheduled postoperative reviews.

Exclusion Criteria:

Patients were excluded based on the following conditions:

- Those with poorly controlled systemic conditions such as uncontrolled diabetes mellitus or cardiovascular diseases.
- Patients currently undergoing chemotherapy or radiotherapy or those with active malignant lesions.
- Subjects diagnosed with bone metabolism disorders like osteoporosis or Paget’s disease.
- Individuals with habits such as smoking more than 20 cigarettes per day or substance abuse that may compromise healing.
- Cases exhibiting inadequate zygomatic bone morphology or volume unsuitable for implant placement, confirmed through CBCT evaluation.

Sample Size and Demographics

The study population comprised 20 patients, consisting of 12 males and 8 females. The age of the participants ranged from 35 to 68 years, with a mean age of 51.2 ± 8.4 years. Etiological distribution revealed that 10 patients had a history of squamous cell carcinoma, 6 were rehabilitated following mucormycosis-induced maxillectomy, 2 sustained traumatic maxillary loss, and 2 patients had congenital defects such as cleft-associated deformities. Of the total sample, 12 individuals had bilateral maxillary defects, while the remaining 8 presented with unilateral involvement.

Preoperative Assessment and Virtual Planning

All participants underwent a comprehensive preoperative evaluation protocol comprising clinical, radiographic, and digital assessment. Diagnostic imaging included panoramic radiographs and Cone Beam Computed Tomography (CBCT) scans acquired using the Planmeca Promax 3D system. These radiographic assessments provided critical anatomical insights into bone volume, sinus dimensions, and proximity to adjacent vital structures.

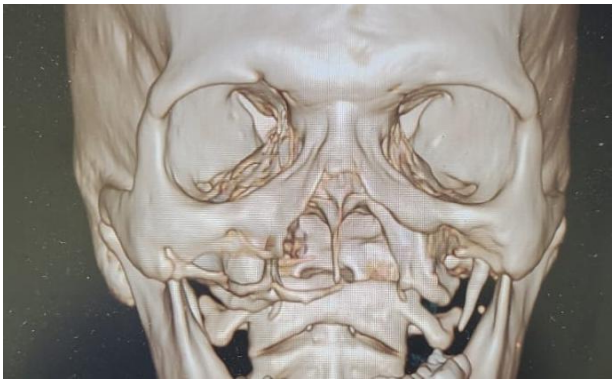

Fig 1: Pre operative CBCT image of Atrophic Maxilla

Fig 2: Pre operative photograph of the patient

Additionally, intraoral digital impressions were obtained using the TRIOS intraoral scanner (3Shape), enhancing the accuracy of the diagnostic and planning stages. Virtual surgical planning was carried out using Nobel Clinician software, which enabled precise implant trajectory prediction and orientation. This digital simulation allowed the surgical team to virtually map the ideal insertion axis, ensuring optimal engagement with the zygomatic buttress while avoiding anatomical structures such as the infraorbital nerve, orbital floor, and pterygoid plexus [5].

In 8 of the 20 cases, patient-specific 3D-printed surgical guides were employed to enhance intraoperative precision and minimize deviations in implant trajectory. These guides were fabricated using the preoperative CBCT and digital scans, translated through stereolithographic printing protocols.

Surgical Protocol

The surgical phase of zygomatic implant placement was executed under strict aseptic conditions in an operating theatre setting, with patients under general anesthesia and nasal endotracheal intubation to ensure unobstructed surgical access to the maxillary and zygomatic regions. All procedures were conducted by a single oral and maxillofacial surgeon with over a decade of experience in craniofacial implantology to maintain consistency in technique and minimize inter-operator variability.

Following the administration of local infiltration (2% lignocaine with 1:100,000 adrenaline) to minimize intraoperative bleeding, a full-thickness mucoperiosteal flap was raised from the canine region to the maxillary tuberosity, extending superiorly to expose the zygomatic buttress and lateral wall of the maxillary sinus. Care was taken to avoid injury to the infraorbital neurovascular bundle. In patients who had undergone maxillectomy, scarred or fibrotic mucosa was cautiously dissected to preserve soft tissue for eventual flap closure.

Depending on the anatomical assessment obtained from preoperative CBCT and virtual planning, either the trans-sinus or extramaxillary approach was selected. In the trans-sinus approach, a lateral antrostomy was created to access the maxillary

sinus, and the Schneiderian membrane was delicately elevated using sinus curettes and elevators to allow passage of the implant drill and fixture across the sinus cavity. The implant trajectory was angled to engage the dense zygomatic bone at a 45° to 60° inclination, depending on the patient's midfacial architecture and prosthetic plan. The initial osteotomy was created using long-shank round burs followed by zygomatic twist drills under copious saline irrigation to prevent thermal injury.

In the extramaxillary approach, where the sinus anatomy was unfavorable or in patients with obliterated maxillary sinuses (as in post-mucormycosis cases), the implants were anchored in the external surface of the zygomatic bone without penetrating the sinus cavity. The implant was placed in a position that allowed emergence more palatally to accommodate prosthesis design, thereby optimizing prosthetic biomechanics. This approach reduced sinus-related complications such as sinusitis or oroantral communication.

Zygomatic implants (Brånemark Zygoma System, Nobel Biocare) ranging from 35 mm to 55 mm in length were selected based on the depth of the osteotomy and bone availability. The implant was threaded manually after sequential drilling, and insertion torque values were recorded, aiming for a minimum of 35 Ncm to ensure primary stability. Intraoperative resonance frequency analysis (RFA) was conducted in 16 patients using the Osstell device to record baseline implant stability quotient (ISQ), which ranged from 60 to 75, indicating high initial stability. In six cases, anterior conventional implants were simultaneously placed to create a quad or tripod support system for prosthetic anchorage.

Great care was taken to ensure the implant head emerged in a prosthetically favorable position, either at the crest of the alveolar ridge (in partial maxillectomy) or slightly palatal (in total maxillectomy cases). All implants were submerged beneath the soft tissue or left transmucosal depending on the loading plan.

After achieving hemostasis, the surgical field was irrigated with betadine and saline, and primary closure was achieved with resorbable 3-0 Vicryl sutures using an interrupted and horizontal mattress technique. In cases where the soft tissue volume was insufficient, buccal advancement or palatal rotation flaps were employed to achieve tension-free closure.

The average surgical time ranged from 90 to 150 minutes depending on the complexity of the defect, presence of scar tissue, and whether additional anterior implants were placed. There were no intraoperative complications such as orbital floor breach, excessive bleeding, or iatrogenic sinus membrane perforation requiring repair.

This meticulous surgical protocol, reinforced by virtual planning and intraoperative navigation (where applicable), contributed significantly to the precision of implant placement, minimization of complications, and favorable long-term outcomes observed in the study cohort.

3. RESULTS

In this study, 32 zygomatic implants were placed in 20 patients—12 males and 8 females—aged between 35 and 68 years (mean: 51.2 ± 8.4 years). A total of 12 patients received bilateral implants, while 8 underwent unilateral placement. The number of implants placed per patient ranged from 1 to 4 depending on the extent of defect and residual maxillary structure (Fig 3 and 4).

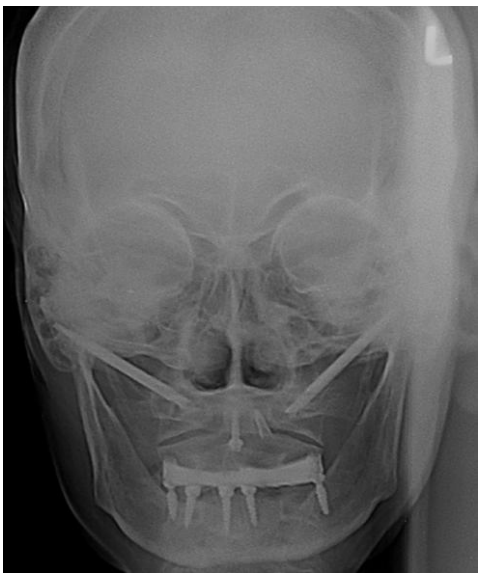

Fig 3: Post operative CBCT view after placement of Implant

Fig 4: Post operative photograph of patient after placement of Implant and prosthesis

Primary Implant Stability:

Primary stability assessed using Resonance Frequency Analysis (RFA) at the time of placement yielded Implant Stability Quotient (ISQ) values between 64–74 (mean: 68.4 ± 4.3), indicating robust initial anchorage in the zygomatic bone.

Secondary Implant Stability:

At 6 months, ISQ values improved significantly to a range of 70–78 (mean: 74.2 ± 3.8), confirming successful secondary stability and osseointegration.

Implant Survival and Complications:

- Two implants failed:
  - One implant exhibited mobility and peri-implantitis symptoms by 5 months and was removed.
  - A second implant demonstrated progressive radiolucency with clinical discomfort at 24 months and was explanted.
- Survival rate at the end of 36 months = **93.75%** (30/32 implants).
- Among the 18 successful patients, all received definitive prosthetic restorations and maintained function throughout the study period.

Radiographic Findings:

- At 12, 24, and 36 months, marginal bone loss around implants was recorded using standardized periapical radiographs and CBCT:\
  - Mean bone loss at 12 months: 0.85 ± 0.2 mm
  - At 24 months: 1.2 ± 0.3 mm
  - At 36 months: 1.4 ± 0.4 mm
- Three implants exhibited bone loss >2 mm but were clinically stable.

Prosthetic Outcomes:

All patients received fixed hybrid prostheses supported by the zygomatic and residual conventional implants (if any).

- Prosthetic complications:\
  - Screw loosening: 2 cases (re-tightened, no recurrence)\
  - Initial speech issues: 3 cases (adapted over time with phonetic training)\
  - Esthetic dissatisfaction requiring prosthesis modification: 2 cases

Soft Tissue Health:

- 5 patients had minor mucosal inflammation at implant emergence site within 3–9 months post-op, resolved with chlorhexidine rinses and hygiene counseling.\
- No instances of sinusitis, oroantral fistula recurrence, orbital involvement, or infraorbital nerve paresthesia reported.

PROMs – Patient-Reported Outcome Measures:

Using OHIP-14 questionnaire and VAS (0–10 scale), patients self-reported substantial improvements in:

- Oral comfort: mean VAS increased from 3.5 to 8.7
- Masticatory efficiency: from 4.2 to 9.1
- Speech clarity: from 5.0 to 9.2
- Confidence and self-esteem: from 3.9 to 8.9 Statistical analysis via paired t-test showed significance ($p<0.001$) in all subjective parameters.

4. DISCUSSION

Zygomatic implants have evolved from being a rescue modality to a first-line solution for complex maxillary reconstructions, particularly in post-maxillectomy patients. The unique structural and biomechanical properties of the zygomatic bone—dense cortical quality, long anchorage trajectory, and favorable location—make it an ideal foundation for implant-supported prostheses in severely compromised maxillae.

Implant Survival and Predictability

Our 93.75% survival rate aligns with other contemporary literature. Balshi et al. (2009) and Davó et al. (2010) have reported survival rates ranging from 89%–96%, supporting the long-term viability of these implants [6,7]. The use of guided surgery and digital planning likely enhanced outcomes by reducing placement errors, avoiding sinus membrane perforation, and minimizing postoperative complications.

Primary and Secondary Stability

High ISQ values (>65) both at insertion and during follow-up affirm the exceptional mechanical interlocking provided by zygomatic bone. These findings support early loading or immediate function protocols as reported by Davó et al. [12].

Marginal Bone Loss and Soft Tissue Health

The mean bone loss (<1.5 mm in most cases) remained within acceptable clinical limits [8]. Proper emergence profile design, hygienic access, and patient education significantly contributed to peri-implant tissue health.

Technique Comparison

Although our study did not statistically differentiate between the trans-sinus and extramaxillary techniques, both approaches showed comparable success, reinforcing that the technique must be individualized based on patient anatomy, defect type, and surgeon expertise [9,10].

Psychosocial and Functional Impact

Zygomatic implant rehabilitation restored facial support, phonation, and masticatory function while eliminating dependency on removable prostheses. PROMs outcomes showed dramatic improvement across all quality-of-life parameters, consistent with studies by Goiato et al. and Chrcanovic et al. [11,9].

Advantages Observed in the Study

- Single-stage surgery avoiding grafting procedures
- Reduced treatment time and morbidity
- Enhanced patient compliance and satisfaction
- Applicability in patients with previous failed reconstructions or radiation therapy (in select cases)

Study Limitations

- Small sample size and single-center data
- Relatively short duration (36 months) for long-term assessment
- Lack of control group using conventional methods or grafting techniques

Future Perspectives

Advances such as dynamic computer-assisted navigation, customized zygomatic implant designs, and AI-driven planning software are poised to further enhance precision and outcomes. Multicentric studies with larger cohorts and randomized trials comparing graft-based and graftless options could establish clearer protocols.

5. CONCLUSION

Zygomatic implants represent a reliable and versatile solution for patients with atrophic maxillae or post-maxillectomy defects. The high survival rate, minimal complications, and significant functional and psychosocial benefits affirm their role as a standard of care in complex maxillofacial rehabilitation. With appropriate case selection, digital planning, and multidisciplinary coordination, zygomatic implant therapy can restore not just oral function but quality of life.

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