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# Evaluation of the Accuracy of Zygomatic Implant Placement Using CAD/CAM Guides in Patients with Post Maxillectomy Defects

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**Aim:** This prospective clinical study aimed to assess the accuracy of computer-guided preoperative planning for zygomatic implant positioning in post-maxillary resection patients.
**Materials and Methods:** Patients who had undergone partial or total maxillectomy and needed to rehabilitate their maxilla were enrolled based on eligibility criteria. Those patients underwent thorough full-skull multislice computed tomography (MSCT) scans to assess the condition of their maxilla and zygoma before undergoing zygomatic implant placement. Based on these scans, an individualized surgical plan was developed for each patient. The patients were undergoing zygomatic implant placement. The patients underwent another post-operative MSCT scan compared to the preoperative scan to assess the study outcomes.
**Results:** Four patients (one female and three male) aged 30 to 50 and in good physical health were seeking oral rehabilitation following maxillary resections. This study involved placing ten zygomatic implants in four patients; all patients received two zygomatic implants, except one patient, who only had four implants. The surgical procedures were completed without any significant issues. No significant differences existed between the virtual-planned and real-placed implants in all planes ($p \geq 0.05$). The average direct linear deviation was 6.88 ±4.45mm at the entry point and 4.27 ±2.45mm at the exit point, indicating no significant differences between the two points. The average angular deviation was 10.01° ±7.59 for anterior implants and 9.57° ±6.44 for posterior implants.
**Conclusion:** With the study's limitations, virtual surgical planning and computer-guided templates consistently led to reliable and predictable outcomes for zygomatic implant placements while avoiding risks of negative consequences.

**Keywords:** zygomatic implants; oral rehabilitation; maxillectomy; computer-aided planning; computer-assisted surgery

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## Introduction

Malignant disorders affecting the maxilla and midface are not very common, but when they do occur, they often necessitate aggressive and sometimes a combination of treatments to achieve a cure for the patient. The extent of the resection and the expected functional and aesthetic results for the patient depend on the primary tumor's location, type, and size.[1] Given that the maxilla and midface are centrally located in the skull, patients undergoing oncologic bone excision for neoplastic lesions in this area are posing significant negative consequences. These consequences include disruptions to speech, swallowing, chewing, and the appearance of the face and teeth. As a result, severe oral dysfunction can occur following this procedure.[2] The literature contains a wide range of documented treatment modalities, but utilizing classifications such as the one developed by Brown[1] and Okay[2] proves valuable in aiding surgical planning and decision-making for surgical reconstruction, prosthetic obturation, and oral rehabilitation in the intricate field of maxillofacial surgery.[2] Since the Ohngren research[3] was published, numerous categorization methods have emerged to delineate the anatomic borders of maxillectomy deficiencies.[2-4] For instance, after a complete resection of the maxilla, patients often experience complex deficiencies involving the orbital floor, paranasal sinuses, palate, and alveolar bone.[5] The loss of these anatomical components can have significant practical and aesthetic implications. Therefore, reconstruction in this area should aim to achieve three primary goals: a) restoration of the palatal surface; b) prevention of any communication between the oral cavity and the nasopharynx; and c) provision of satisfactory facial morphology and symmetry.[6]

There is a wide array of alternatives to surgical reconstruction, such as local flaps, nonvascularized grafts, and microsurgical reconstruction involving bone or soft tissues.[7] However, it is essential to note that dental implants have increasingly played a significant role in restoring function by providing mechanical support for dental prostheses in numerous cases.[8] The placement of dental implants and subsequent prosthetic rehabilitation is often challenging after undergoing maxillectomy, which is primarily due to insufficient bone alveolar tissue and gingiva.[8] As a result, dental implants can only serve as an effective restorative treatment option when the basal maxillary bone remains intact.[9, 10] Patients with insufficient bone volume for conventional dental implants may benefit from zygomatic implants[11], which can be placed in the zygomatic bone when the alveolar bone is lacking following a maxillectomy.[12] However, using zygomatic implants in reconstructive surgeries is frequently associated with several challenges, namely the need for a soft tissue flap for reconstruction and defects in bone tissues.[8]

The use of zygomatic implants for rehabilitation has become increasingly popular as a cutting-edge treatment option for achieving faster restoration with fewer surgical procedures, complications, and costs in patients with maxillary atrophy and in those who have undergone cancer surgical treatment.[13] However, due to the angled trajectory and length of the implants, inserting zygomatic implants is considered challenging.[14] Limited visibility and nearby anatomical structures during surgery can make accessing the deeper areas of the malar bone difficult.[14] To address this issue and ensure the safe and clinically sound placement of implants, some experts suggest using computer-assisted planning and placement techniques. These advanced technologies could potentially improve the accuracy and safety of zygomatic implant procedures.[15] Therefore, this research aimed to evaluate the accuracy and effectiveness of using the computer-guided approach for the preoperative planning of zygomatic implant positioning in patients who have undergone maxillary resection.

## Material and Methods

### Ethical Approval

Patients with partial or complete deformities in their maxilla due to tumor resections were recruited from the Department of Oral and Maxillofacial Surgery at the Faculty of Dentistry at Ain Shams University and Nasser Institute Hospital. The study protocol had been approved by the Research Ethical Committee of the Faculty of Dentistry at Ain Shams University (ID: OMS-2022-74M). Each patient gave written informed consent, and the research methodology adhered to the World Medical Association's Declaration of Helsinki for experiments involving human subjects.

### Sample Size Calculation

The sample size was calculated using G*Power version 3.1.9.4, based on previous research by Gao et al.[16] They reported that the mean angular deviation was 6.114 degrees, and the standard deviation was 4.28 for zygomatic implants placed in post-maxillary resection patients using CT-based planning. The sample was estimated to represent a study power of 80%, a two-tailed significance level of 5%, and an effect size of 0.82, based on the study by Gao et al.[16] Therefore, a minimum sample size of 10 implants was required to ensure that the 95% confidence interval of the mean angular deviation of zygomatic implants implanted using virtual planning and surgical guides is within three degrees of the true mean.

### Eligibility Criteria

The following eligibility criteria were used to identify suitable patients for participation.

**Inclusion Criteria**

- Patients who are 18 years or older and mentally capable of understanding and providing written informed consent.
- Patients with partially or totally maxillectomy require dental implants to rehabilitate their maxilla.
- Patients who demonstrate adequate oral hygiene and are compliant with treatment recommendations.

**Exclusion Criteria**

- Patients with significant medical conditions such as cardiovascular or pulmonary diseases or any condition that makes general anesthesia unsafe.
- Patients with contraindications to implant placement, such as a history of head and neck radiation, intravenous bisphosphonate use, or uncontrolled diabetes mellitus.
- Heavy smokers, defined as those who smoke two or more packs of cigarettes per day.
- Patients with limited mouth opening, specifically those with a three-centimeter interincisal distance.

### Pre-surgical assessment

All participants in this research underwent comprehensive health assessments and clinical examinations of their maxillary bone defects to confirm their eligibility. They also underwent complete anesthetic laboratory investigations, and a specialist in anesthesiology approved the patient for general anesthesia surgery. Before the surgery, the patients included in the study underwent comprehensive full-skull multislice computed tomography (MSCT) scans. These scans evaluated the condition of the maxilla and zygoma before the placement of zygomatic implants.

### Virtual Planning

Utilizing the BlueSkyPlan software (Blue Sky Bio®, Libertyville, IL, United States), an individualized surgical plan was established for each patient based on their MSCT scans. Following the zygoma anatomy-guided approach (ZAGA) guidelines and considering the residual anatomy after maxillectomy[1, 17], we employ an anatomically and prosthetically driven approach to achieve optimal surgical and prosthetic outcomes for post-maxillectomy patients. To achieve the best placement, we strategically plan the implant location beneath the resected site's mucosa. This positioning allows the implant to be covered by the mucosa, facilitating an optimal placement conducive to the successful fitting of the prosthesis. As such, the implant threads were wholly covered by sufficient bone for each proposed zygomatic implant, with at least 3mm of zygomatic bone surrounding the virtual implants. It was also essential to ensure a minimum distance of 2mm between the implants and the orbital and infraorbital nerves. (Fig. 1)

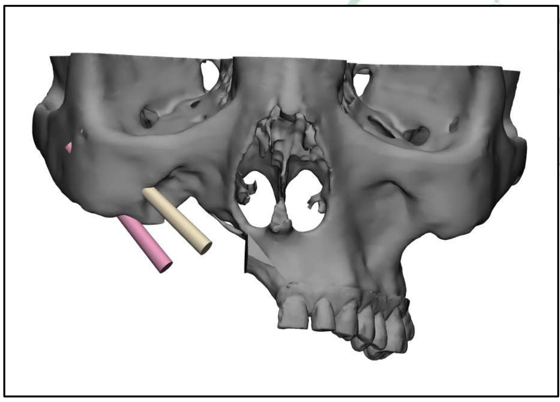

**Figure 1: Virtual plan model**

Once the virtual plan was approved, the surgical guide was designed to follow the zygomatico-maxillary buttress. This allowed for adequate coverage of most of the zygomatic bone surfaces during surgery. The surgical guide was then modified to include a cut-off window slightly wider than the zygomatic implant route. Additionally, this study utilized a modified acrylic guide, along with computer-guided surgical templates known as "zygoma drill guides." These guides were made of clear photopolymeric resin and were created using CAD software with minimal adjustments to the initial design by Chow et al.[18]

Finally, the surgical guides and mid-face 3D models were exported in STL format and then printed using the MSLA Anycubic Photon Mono X 6Ks (ANYCUBIC, Shenzhen, Guangdong, China) 3D printer with transparent photopolymer resin. Before the actual surgery, practice mock operations were conducted on these 3D models for every case, following the exact procedure and steps of the actual operation. (Fig. 2)

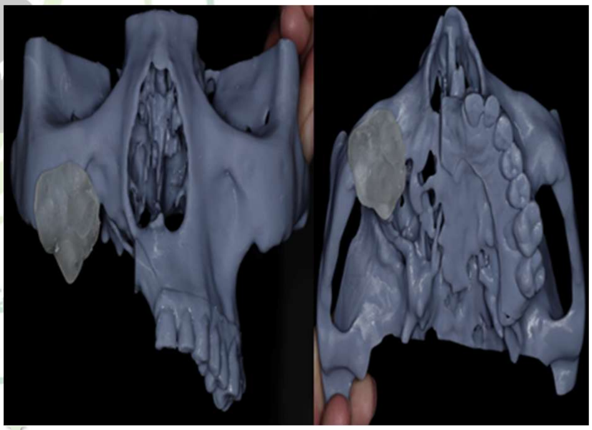

**Figure 2: A 3D-printed model representing the patient's mid-face, with a surgical template accurately positioned on the mid-face model. Right; frontal view, Left; inferior view.**

## Surgical Procedure

After administering general anesthesia to ensure unconsciousness and para-periosteal injection of articaine with a vasoconstrictor (Epinephrine 1:100,000) to provide pain relief and promote hemostasis, precise incisions were carefully made along the mucosa at the inferior border of the remaining zygomatic bone after maxilla resection. It was essential to identify two key landmarks: the lateral orbital boundary and the anterior border of the zygomatic arch.

When performing the dissection, special attention was paid to locating, identifying, and safeguarding the nerves and blood vessels beneath the eye socket. A Langenbeck retractor was placed at the fronto-zygomatic notch to ensure clear visibility during the surgical process. After carefully lifting the mucoperiosteal flaps and precisely exposing all the critical anatomical landmarks, the surgical template was meticulously positioned and firmly secured on the zygomatic buttress. This was achieved using three to four 2.0 screws, which varied in length from 10 to 14mm. (Fig. 3)

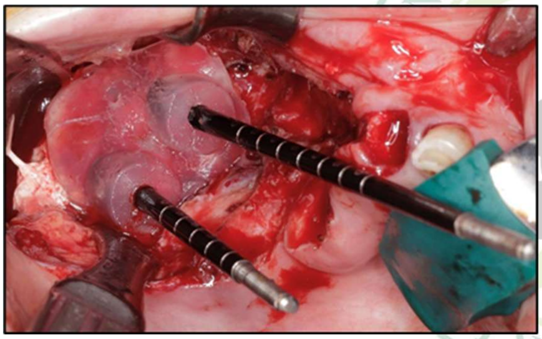

**Figure 3: Intra-operative image shows the surgical template's precise placement within the patient's mouth, with the initial drills accurately inserted into the surgical template for the zygomatic implant osteotomy.**

The osteotomy drilling process began with meticulous execution of the zygomatic osteotomy using specialized key-less guided surgical drilling tools provided by the manufacturer. These tools were carefully inserted into the zygoma from the palatal side to ensure precision and accuracy during the procedure. Subsequently, the zygoma's initial entrance head was positioned into the slots of the surgical template before three zygoma-specific drills were utilized. The lengthy drill tips were accurately directed to their respective second entrance positions in the zygomatic bone, as the heads of the drills are co-axial and aligned based on the initial head position. Throughout each step, continuous in-and-out drilling motions were employed, with the drills being visible through the window created in the surgical templates until they reached the zygomatic bone.

After performing osteotomies and removing surgical guides, the length of the zygomatic implant was confirmed using a depth gauge, which assessed the osteotomy's depth and direction. Subsequently, the zygomatic implants (JDZygoma; JDentalCare®, Madona, Italy) were carefully inserted with a maximum insertion torque of 80 N/cm starting from the inferior edge of the zygomatic osteotomy. Healing caps were then utilized to cover the multi-unit abutments installed over the implants if there was adequate primary implant stability. In cases where primary stability was insufficient, the implants were covered with screws and left to heal for three months before the abutments were placed. (Fig. 4)

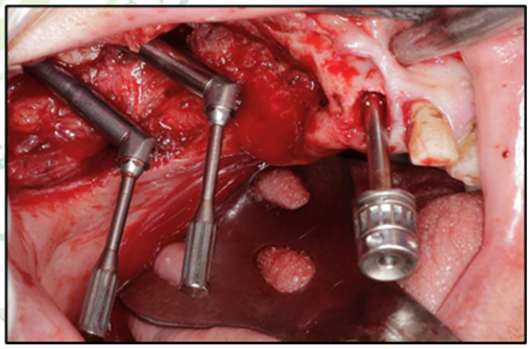

**Figure 4: Intra-operative image shows two zygomatic implants accurately placed, with the multi-unit abutments attached over the implants` platforms**

After thoroughly irrigating the surgical incision with sterile saline, buccal fat pads (if available) were applied to enhance the soft tissue quality around the implant's protruding bony shafts and provide coverage. The flaps were then repositioned, and we used 4-0 polyglycolic acid sutures (Assucryl®, Assut sutures, Switzerland) in a continuous, simple, interrupted technique to close the wound securely.

Post-operative care was administered, which focused on relieving pain with nonsteroidal anti-inflammatory medications and swelling by applying ice, evaluating the head, administering corticosteroids, and maintaining an appropriate hydration intake. The prescribed post-operative medications included Amoxicillin/Clavulanic acid (875 mg/125 mg tablet twice daily for one week; Augmentin®, Glaxosmithkline, England), Ibuprofen (600 mg tablet twice to thrice daily during meals for five days, then once if needed; Brufen®, Abbott, Laboratories, Egypt), and Prednisolone (5 mg one tablet twice daily for one week; Epicopred®, EIPICO, Egypt). Furthermore, 0.1% xylometazoline hydrochloride nasal drops (Otrivine®, Glaxosmithkline, England) were recommended thrice daily for three days, followed by standard saline nasal drops for an additional four days. Patients were given specific instructions to ensure their recovery, including avoiding brushing or causing damage to the surgical areas, consuming a soft diet for the first two weeks, and using 0.12% chlorhexidine mouthwash (Antiseptol®, Kahira Pharmaceuticals, Egypt) for one minute twice daily.

**Prosthetic Procedure**

Patients were scheduled for a follow-up appointment four to five days after surgery to evaluate the healing process and check for any wound infections. Ten days later, the sutures were removed after the incision had healed entirely, and a second post-operative whole skull MSCT was performed.

Three months later, patients were called for a follow-up appointment to digitally scan their maxillary and mandibular arches using the PANDA P2 intraoral scanner (Panda scanner, Jiangsu Province, China). Scan bodies were then placed over the implants to help the scanner identify implant locations. For partially rehabilitated patients, the maxillary arch was scanned again with the scan bodies, and the bite was recorded. For completely rehabilitated patients, the initial scans were used to create a special tray, including an occlusion block, to record their bite. These records were sent to the dental lab to fabricate the final restoration. After several try-in appointments, the dental lab delivered the final restorations, and the patients were called back to receive them. All of the provided restorations were screw-retained on multi-unit abutment prostheses, and the prosthetic phase was supervised by a prosthodontics team for each patient.

**Outcome assessment**

Each patient was required to undergo a 2-week post-operative facial bones MSCT scan to assess the implants placed during the operation radiographically. These scans had to be conducted at the same radiology center and meet the exact specifications as the pre-operative CT scan. The 3D models of the planned implants before the surgery and the actual implants placed after the surgery were created using Materialise Mimics and 3-Matic Medical software from Materialise in Leuven, Belgium. These models were then overlapped using the “N-Point” registration tool. This process involved identifying unaltered anatomical landmarks on the skull (e.g., the infraorbital foramina, posterior and anterior nasal spine, and base of the skull) and making additional adjustments using “Global” registration. Afterward, the fixed landmarks in the virtual-planned implants were identified, focusing on comparing these with the actual implant locations. These landmarks were designated at the end of both implants and identified as entry sites at the implant platforms and exit sites at the implant apex. This study involved identifying the three reference planes in space, which are the Frankfort Horizontal Plane (FHP), Coronal Plane (CP), and Mid-Sagittal Plane (MSP) on the skull. Then, the lengths between each implant's entrance and exit points and these three planes and the direct length between the two points were measured for both implants. We aimed to assess the precision of the intra-operative 3D virtual surgical plan and the accuracy of computer-guided surgical templates in executing the plan during the surgery, which directly influenced the final implant positions.

**Statistical Analysis**

Categorical data was presented as frequency and percentage, and continuous data were presented as mean and standard deviation (SD). The normality distribution of data was determined by the Kolmogorov-Smirnov and Shapiro-Wilk tests. Since data were normally distributed (i.e., parametric), the paired t-test was used to analyze the comparison between virtual-planned and real-placed implants. However, the independent t-test was used to compare the coronal and apical regions for both plan and actual measurements, whereas the Mann-Whitney U test was utilized to compare the delta values due to the non-parametric distribution of these data. For every test, the significance level was set at $p \leq 0.05$. All statistical tests were conducted using SPSS 26 software (IBM. Armonk, USA).

**Results**

This research involved the placement of ten zygomatic implants for four patients seeking oral rehabilitation following maxillary resections. Those patients were one female and three male patients aged 30 to 50 years and in good physical health (ASA I or II). All patients in this study received a total of two zygomatic implants, except one patient who only had four implants. The surgical procedures were completed without any significant issues or complications. The immediate post-operative phase was uneventful for every patient, without significant complications. However, the patients experienced post-operative tension, pain, and varying degrees of facial swelling, as anticipated.

*1. Comparison between virtual-planned and real-placed implants:*

Overall, there were no significant differences between the virtual-planned and real-placed implants within all planes ($p \geq 0.05$). (Table 1)

In anterior implants, the differences between virtual-planned and real-placed implant measurements at the entry points were 3.84 ± 7.59 mm in the FHP, 2.13 ± 1.94 mm in the CP, and 0.64 ± 4.97 mm in the MSP. The measurement differences at the exit points were -2.47 ± 4.63 mm in the FHP, -1.57 ± 3.17 mm in the CP, and 1.62 ± 1.62 mm in the MSP.

In posterior implants, the differences between virtual-planned and real-placed implant measurements at the entry points were 3.15 ± 3.75 mm in the FHP, -1.16 ± 4.48 mm in the CP, and -1.48 ± 2.85 mm in the MSP. The measurement differences between them at the exit points were -1.19 ± 1.83 mm in the FHP, 0.47 ± 2.56 mm in the CP, and -0.21 ± 1.15 mm in the MSP.

*2. Comparison between the entry and exit points at both virtual-planned and real-placed implants:*

At the MSP and FHP, the measurements at the exit point were significantly higher than at the entry point in both virtual-planned and real-placed implants (p= 0.000). However, there were statistically significant differences in the change (delta) (p= 0.028 at the MSP and p= 0.028 at the FHP). In contrast, the measurements at the entry point in the CP were significantly higher than at the exit point (p= 0.023) in real-placed implants, with no statistically significant differences in terms of the change (delta) (p= 0.382). (Table 2)

*3. Direct linear distance:*

The mean of direct linear deviation was 6.88 ± 4.45 mm at the entry point and 4.27 ± 2.45 mm at the exit point, showing no significant differences between the two points. (Table 2)

*4. Angular deviation:*

After measuring the angle created by the two lines connecting the virtual-planned and real-placed implants' entry and exit points, the data were collected and examined. The descriptive statistics for angular deviation showed that the mean angular deviation was 10.01° ± 7.59 (median 7.63°) in anterior implants and 9.57° ± 6.44 (median 10.69°) in posterior implants.

**Discussion**

In certain situations, bone grafting may not be advisable due to underlying health conditions or previous unsuccessful grafting attempts. Reconstructive surgeries often require prolonged recovery periods and ongoing medical attention, which is crucial for the success of the procedure. Despite the widespread use of biomaterials, harvesting bone from donor sites within or outside the mouth is often necessary to address severe maxillary bone atrophy. This additional procedure can lead to increased patient discomfort and contribute to the overall financial burden of treatment.[19, 20] As a result, zygomatic implant-supported rehabilitation has emerged as a promising alternative for addressing deficits resulting from maxillectomy and atrophic edentulous maxillae. This approach has shown potential as an effective substitute for reconstructive surgeries in addressing these complex issues.[21-24] The development of zygomatic implants was primarily driven by the need to enhance the stability of prostheses and reduce both the duration and invasiveness of surgical procedures.[24]

However, it has been recognized that the planning and placement of zygomatic implants can be challenging; thus, there is a proposal to utilize computer-assisted planning and placement techniques to overcome these challenges since these advanced techniques are expected to address the complexities involved in zygomatic implants procedures and improve the overall success and safety of the placement process.[25] Our study's findings indicated no statistically significant variations between the implants planned virtually and the ones actually placed across all planes at the entry and exit points. Furthermore, no noteworthy challenges or complications hindered the completion of the surgical procedures. Additionally, the immediate post-operative phase was uneventful for all patients, with no significant complications reported.

Several research studies have shown that zygomatic implants, either used alone or combined with conventional dental implants, have demonstrated high survival rates comparable to traditional implants in severely atrophic maxillae.[26-28] This approach has been particularly encouraged for rehabilitating patients who have undergone maxillary resection due to oncologic disorders, as it has shown high success rates in this patient population.[29] However, rehabilitating these patients presents significant challenges and necessitates a high level of surgical expertise. Various categories have been proposed to aid in decision-making for prosthetic solutions, oral rehabilitation, and surgical planning.[1, 30] Despite these advancements, the anatomical defect following cancer removal remains distinct and requires careful consideration.

**Table 1: Differences between virtual-planned and real-placed implants measurements**

| Implants | Plane | Point | Virtual-planned | | Real-placed | | Paired difference | | | | t | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Mean* | *SD* | *Mean* | *SD* | *Mean* | *SD* | *C.I. lower* | *C.I. upper* | | |
| Anterior | Mid-Sagittal Plane (MSP) | *Entry* | 11.63 | 4.80 | 11.00 | 4.26 | 0.64 | 4.97 | -7.28 | 8.55 | 0.26 | 0.815 ns |
| | | *Exit* | 53.22 | 1.56 | 51.60 | 1.49 | 1.62 | 1.62 | -0.96 | 4.20 | 2.00 | 0.139 ns |
| | Frankfort Horizontal Plane (FHP) | *Entry* | 28.22 | 3.49 | 24.39 | 4.14 | 3.84 | 7.59 | -8.25 | 15.92 | 1.01 | 0.387 ns |
| | | *Exit* | -0.92 | 0.92 | 1.55 | 4.05 | -2.47 | 4.63 | -9.84 | 4.90 | -1.07 | 0.364 ns |
| | Coronal Plane (CP) | *Entry* | 81.62 | 2.42 | 79.49 | 4.21 | 2.13 | 1.94 | -.96 | 5.21 | 2.20 | 0.116 ns |
| | | *Exit* | 66.78 | 4.35 | 68.34 | 3.18 | -1.57 | 3.17 | -6.60 | 3.47 | -0.99 | 0.396 ns |
| Posterior | Mid-Sagittal Plane (MSP) | *Entry* | 21.40 | 4.76 | 22.88 | 3.11 | -1.48 | 2.85 | -6.01 | 3.05 | -1.04 | 0.375 ns |
| | | *Exit* | 54.10 | 1.18 | 54.31 | 1.20 | -0.21 | 1.15 | -2.04 | 1.61 | -0.37 | 0.736 ns |
| | Frankfort Horizontal Plane (FHP) | *Entry* | 32.15 | 2.90 | 29.01 | 1.65 | 3.15 | 3.75 | -2.82 | 9.11 | 1.68 | 0.192 ns |
| | | *Exit* | 6.36 | 1.52 | 7.55 | 3.05 | -1.19 | 1.83 | -4.10 | 1.72 | -1.30 | 0.285 ns |
| | Coronal Plane (CP) | *Entry* | 67.35 | 7.94 | 68.50 | 3.50 | -1.16 | 4.48 | -8.29 | 5.98 | -0.52 | 0.642 ns |
| | | *Exit* | 66.67 | 1.94 | 66.21 | 2.42 | 0.47 | 2.56 | -3.61 | 4.54 | 0.36 | 0.740 ns |

**Table 2: Differences between the entry and exit points at both virtual-planned and real-placed implants**

| Plane | Implant | Entry point | | | Exit point | | | Paired difference | | | | Test value | p-value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Mean* | *SD* | *Median* | *Mean* | *SD* | *Median* | *Mean* | *SD* | *C.I. lower* | *C.I. upper* | | |
| **Mid-Sagittal Plane** | *Virtual-planned* | 16.52 | 6.84 | 17.68 | 53.66 | 1.36 | 54.01 | -37.14 | 2.47 | -42.89 | -31.39 | t= 15.05 | 0.000* |
| | *Real-placed* | 16.94 | 7.23 | 17.65 | 52.95 | 1.92 | 53.23 | -36.01 | 2.64 | -42.11 | -29.91 | t= 13.62 | 0.000* |
| | *Delta* | -0.42 | 3.92 | 0.56 | 0.71 | 1.63 | 0.52 | -1.13 | 1.50 | -4.35 | 2.09 | Z= 0.631 | 0.574 |
| **Frankfort Horizontal Plane** | *Virtual-planned* | 30.19 | 3.64 | 29.86 | 2.72 | 4.06 | 2.02 | 27.47 | 1.93 | 23.33 | 31.61 | t= 14.24 | 0.000* |
| | *Real-placed* | 26.70 | 3.82 | 27.61 | 4.55 | 4.61 | 5.08 | 22.15 | 2.12 | 17.61 | 26.69 | t= 10.46 | 0.000* |
| | *Delta* | 3.49 | 5.56 | 1.48 | -1.83 | 3.33 | -1.40 | 5.32 | 2.29 | 0.41 | 10.23 | Z= 2.15 | 0.028* |
| **Coronal Plane** | *Virtual-planned* | 74.48 | 9.37 | 77.52 | 66.72 | 3.12 | 67.24 | 7.76 | 3.49 | -0.20 | 15.72 | t= 2.22 | 0.055 |
| | *Real-placed* | 74.00 | 6.88 | 74.00 | 67.27 | 2.85 | 67.70 | 6.72 | 2.63 | 1.08 | 12.37 | t= 2.55 | 0.023* |
| | *Delta* | 0.49 | 3.65 | 1.22 | -0.55 | 2.88 | -1.13 | 1.04 | 1.64 | -2.49 | 4.56 | Z= 0.945 | 0.382 |
| **Direct linear distance** | | 6.88 | 4.45 | 6.39 | 4.27 | 2.45 | 4.08 | 2.61 | 1.79 | -1.24 | 6.46 | t= 1.46 | 0.167 |

The available literature provides more extensive information on using zygomatic implants in individuals with atrophic maxillae compared to oncologic patients.[13] Research indicates that the success rate of zygomatic implants in patients who have undergone maxillary resection due to cancer is notably lower than in those with atrophic maxillae. A study by Chrcanovic et al.[23], which was notably comprehensive, examined the outcomes and implications of zygomatic implants in both atrophic maxillae and cancer patients. Over a 12-year period, 96.7% of these patients demonstrated cumulative survival. Specifically, patients with atrophic maxillae exhibited a zygomatic implant survival rate ranging from 95.8% to 100%, while those with cancer showed a lower range of 78.6% to 91.7%.[23]

The use of three-dimensional technology has dramatically simplified the zygomatic implant rehabilitation process. With virtual planning, the surgeon can clearly visualize the anatomical components and accurately determine the implant length before the actual surgery. This eliminates the need to create a stereolithographic model for pre-surgical practice.[31] Real-time surgical navigation allows the surgeon to replicate the planned implant trajectories precisely.[32] Clinical investigations have shown that dynamic navigation accuracy in routine implant placement is consistently high, making it a reliable tool for this procedure.[33-35]

The use of dynamic navigation for placing zygomatic implants has been the focus of only a limited number of studies.[36] However, the results have been highly promising, with a maximum variation of 1.35 mm at the entry point and 2.15 mm at the apex.[36] These findings instill hope for the future of zygomatic implant placement. The process of preparing the zygomatic implant site involves the use of a lengthy drill, which presents a significant challenge. Various strategies have been proposed to tackle this issue, including the utilization of ultrasonic equipment either in combination with or as an alternative to real-time tip tracking.[37-39] In the existing literature, a few static guiding approaches have been documented; however, these approaches involve additional clinical stages and costs for fabricating and preparing surgical stents. It is important to note that due to their unique engagement at the bone crest level and distinct aesthetic criteria, the success rates of zygomatic implants cannot be directly compared to those of traditional dental implants.[40] This complexity underscores the need for further research and understanding in this field.

## Conclusion

With the study's limitations, the implementation of virtual surgical planning and computer-guided surgical templates led to consistently reliable and predictable surgical outcomes for zygomatic implant placements, while also avoiding the risk of negative consequences.

## Funding

This study is self-funded, as no grants were received from funding agencies in the public, commercial, or not-for-profit sectors.

## Data Availability

Complete data is available for anyone. It may be acquired by requesting it by email.

## Ethics Approval and Consent to Participate

The Research Ethical Committee of the Faculty of Dentistry, Ain Shams University, examined and approved the protocol before conducting the study during meeting number 222 on September 7, 2021 (ID: OMS-2022-74M). All patients signed informed consent forms after being explained the whole procedure.

## Competing Interests

The authors have no conflicts of interest to declare.

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