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A Review on Zygomatic Implants-Historical Perspectives, Challenges, and Recent Developments

Zygomatic Implants: Evolution, Challenges, and Innovations

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Abstract: Maxillary edentulism is increasingly common, often resulting from conditions such as advanced dental caries, periodontal disease, trauma, or infection. This condition can have significant psychological, social, and functional consequences, leading to nutritional changes and various health conditions. The resorption of alveolar bone, particularly in the posterior maxilla, complicates the placement of conventional implants, necessitating bone grafting and sinus augmentation. With their excellent success rates and ability to eliminate the need for bone grafting, zygomatic implants offer an efficient alternative. Zygomatic implants, which were first introduced by Branemark in 1988, use the zygoma bone for posterior support, doing away with the requirement for directed bone regeneration or sinus elevation. Over time, surgical techniques and implant designs have evolved, with modifications such as the Zygoma Anatomy Guided Approach (ZAGA) for better implant placement. Indications include moderate to severe maxillary atrophy, cleft palate, and congenital or acquired defects. Zygomatic implants are particularly beneficial for patients requiring immediate loading and those unable to undergo multiple procedures. The procedure can be performed in an office setting with reduced operating time. The development of dynamic navigation systems has further improved the accuracy and safety of zygomatic implant placement, offering flapless techniques that minimize morbidity. Zygomatic implants are cost-effective compared to traditional grafting procedures, providing stable, aesthetically pleasing prostheses.

Keywords: *Zygomatic Implants, Zygoma Anatomy Guided Approach, Extrasinus, Intrasinus.*

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I. INTRODUCTION

Maxillary edentulism is a prevalent condition worldwide. According to the World Health Organization (WHO), tooth loss is often the outcome of a lifelong history of oral diseases, primarily advanced dental caries and severe periodontal disease. However, it can also result from trauma, pathology, infection, and other factors. Losing teeth can have significant psychological, social, and functional consequences.[1]

Adverse consequences of edentulism include limited food consumption due to the inability to chew properly, which can lead to significant nutritional changes. This may contribute to conditions such as obesity, diabetes, coronary artery disease, and certain types of cancer.[2]

Alveolar bone resorption in the maxilla occurs posterior-superior and lateral-to-medial after tooth removal. Both vertical and horizontal bone volume can be decreased in the posterior region as a result of sinus pneumatization and alveolar bone resorption. Insufficient anterior alveolar bone resorption may further limit the feasibility of conventional implants. Additionally, prolonged use of complete dentures can increase the severity of maxillary atrophy. [3,4]

Severe maxillary atrophy and post-maxillary resection present a significant challenge for dental rehabilitation.

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Zygomatic implants provide a dependable and efficient alternative to traditional implant-supported rehabilitation in these situations, obviating the requirement for bone augmentation techniques such sinus augmentation or guided bone regeneration. They have shown a 95% 12-year survival rate.[5] In 1988, PI Branemark suggested the use of the zygoma bone to provide posterior support for patients who lacked maxillary bone volume. The use of the zygoma bone, to establish posterior support for patients lacking maxillary bone volume was introduced by PI Branemark in 1988.[6] In the initial zygomatic Branemark protocol, one implant was inserted into each zygoma, passed into the sinus, and fastened to two to four standard implants in the anterior area.[6] Numerous changes to loading protocols, surgical methods, and zygomatic implant designs have been reported in the literature over time.

➢ *Evolution of Zygomatic Implants*

Implant dentistry entered a new era with the development of zygomatic implants for patients undergoing rehabilitation whose maxillary bone structure was impaired. Branemark's original technique involved a vestibular incision, resembling a LeFort I approach, followed by periosteal elevation and anthrotomy.[6] However, the implant's palatal drift frequently resulted in an unfavorable location, which affected patient comfort, hygiene, and phonetics. Stella and Warner addressed this by modifying Branemark's procedure to place the implant within the maxillary sinus. They created slots on the external surface of the sinus, effectively improving the positioning of the implant head.[7]

➢ *Indications and Contraindications*

Zygomatic implants are typically preferred for patients with moderate to severe maxillary atrophy, and post-maxillary resection rehabilitation; however, they can also be a valuable option for individuals with or without significant atrophy and who have undergone complete or partial maxillary resection. Additionally, they are indicated in syndromic patients, such as those with ectodermal dysplasia presenting with partial anodontia. They can be used for acquired and congenital defects, including cleft palate or rhinectomy following malignant nasal tumors.[8] Other indications include partial edentulism and cases requiring immediate loading. (Figure 1).

Absolute contraindications include limited mouth opening that makes instrumentation impossible, an intolerance for anaesthesia, and the existence of zygomatic or maxillary pathological diseases. Relative contraindications include active maxillary sinus pathology, with chronic sinusitis being acceptable, as well as the use of bisphosphonates and radiation exposure.

➢ *Conventional Zygomatic Implant*

The original Branemark bespoke zygoma fixture was made to be inserted from the palatal aspect of the resorbed maxilla, close to the second premolar region. It was then supposed to travel through the maxillary sinus and anchor itself into the thick zygoma bone.

Zygomatic implants (Figure 2) are self-tapping screws with a carefully machined surface composed of commercially pure titanium. Eight distinct lengths, ranging from 30 to 52.5 mm, are offered. In order to fit the anatomical angulation between the maxilla and zygoma, these implants have a specially constructed 45° angulated head. The diameters of the sections that engage the zygoma and the residual maxillary alveolar process are 4.0 and 4.5 mm, respectively. Several abutments from the Branemark System can be attached to the angulated implant platform at the maxillary level. However, for traditional screw-retained prosthesis fabrication, a somewhat shorter abutment screw is needed for the most recent generation of abutments.[9]

With a smooth mid-implant body, a broader neck at the alveolar crest, a 55° angulation of the implant head, and an oxidized rough surface, zygomatic implants are currently offered by at least three distinct firms.[10]

➢ *Zygoma Anatomic Classification*

The Zygoma Anatomy Guided Approach (ZAGA) classification describes the remaining maxillary ridge's palatal resorption as well as the degree of concavity in the lateral maxillary sinus walls. ZAGA classifications range from 0 to 4. (Figure 3.)

According to Aparicio, 93.8% of the patients evaluated had anatomical presentations ranging from ZAGA 0 to ZAGA 3, with only 6.5% exhibiting topography compatible with ZAGA 4. Thus, quad-cortical stabilisation should be possible in the majority of cases. The primary determinants are the concavity of the lateral maxillary sinus wall and the degree of palatal resorption in the maxillary alveolus. The resorption pattern seen in ZAGA 4 patients impairs the implant platform's capacity to stabilise in bone.[11]

➢ *Presurgical Evaluation*

To determine a patient's suitability for zygomatic implants, a thorough history and physical examination should be part of the evaluation process. Patients with significant maxillary atrophy, those who are unable or unwilling to endure several treatments, and those who want an immediately loaded fixed prosthesis are all examples of patients who should be carefully chosen. Effective planning requires interdisciplinary interaction between a prosthodontist or general dentist and an oral and maxillofacial surgeon.[12] Cone-beam computed tomography (CBCT) is a crucial preoperative tool for evaluating the zygomatic implant location, sinus condition, and implant trajectory. It aids in assessing the amount of bone that remains in the alveolar crest and zygomatic arch. Careful consideration must also be given to elements including implant angulation, predicted emergence site, and the interaction between the lateral wall, maxillary sinus, and implant body. For implant stability, at least 7 mm of anchorage into the zygoma is required, with a greater amount necessary when placing two implants.

Assessing a patient with a resorbed maxilla for zygomatic implants requires both 2D and 3D radiographic evaluation. Bedrossian described the use of 2-dimensional radiographic assessment for this purpose.[13] Three zones

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make up the maxillary arch: the premaxilla (Zone 1), the bicuspid region (Zone 2), and the molar region (Zone 3). Two or four axial implants in Zone 1 along with zygomatic implants in the posterior maxilla are required if there is insufficient bone in Zones 2 and 3. (Figure 4) In cases of total maxillary atrophy, where all three zones are deficient, the quad-zygoma concept is the preferred approach.[11] (Figure 5)

➢ *Original Branemark Surgical Technique*

As per the initial protocol, each patient received a stomach tube and a sealing throat pack during the general anesthetic and nasal intubation procedure. Local anesthesia should be administered using maxillary nerve blocks, vestibular infiltration, and either infiltration or percutaneous blocks positioned laterally and superiorly to the zygomatic notch, just lateral to the orbital rim. A mid-crestal incision is preferred by the current technique, with vertical releasing incisions made anterior to the operative site and along the posterior infra-zygomatic crest. The zygomatic arch's anterior boundary and vertical ridge are its main markers, while the lateral orbital border is recognized to avoid orbital interference. The lateral maxillary sinus wall, the alveolar crest, and the central and posterior zygomatic complex are exposed by raising a mucoperiosteal flap. A retractor preserves soft tissues and guarantees visibility. Drilling direction and starting point, typically in the second premolar or first molar region, are determined using an indicator. The implant's anticipated course from the sinus floor to its apex is followed by creating a 10 mm bone window on the lateral maxillary sinus wall. After being gently separated from the sinus walls, the sinus membrane is reinstalled inside the cavity. The alveolar process and zygomatic bone are penetrated by sequential drilling (2.9 mm diameter long twist drills, 2.9 mm-3.5 mm pilot drill, and 3.5 mm twist drill), and the implant length is determined using a depth gauge. Then, either by hand or with a motorized instrument, the self-tapping zygomatic implant is positioned, making sure the palatal hole is not widened, especially in patients with thin basal or alveolar bone. Locally harvested bone fragments can be placed around the implant if needed to reduce spaces between the palatal bone and the implant surface. The flap of the mucoperiosteum is sutured and a cover screw is inserted. Abutment connection is usually done with regular or straight/angulated multiunit Branemark abutments following a six-month healing time.[8, 14, 15]

➢ *Modifications of Original Surgical Technique*

Common mistakes in zygomatic implant osteotomy include incorrect anterior or palatal positioning due to access difficulties or inexperience. This can result in improper implant emergence, causing complications. Concerns about titanium implants causing maxillary sinus infections were addressed in a 2004 study by Branemark and Petruson, which found no inflammation or infection in the Schneiderian membrane, supporting the safety of the procedure, as confirmed by experienced clinicians.[16]

Modifications to the OST have been proposed, including osteotomy techniques that position the mid-portion of the implant outside the maxillary sinus. Comparing these techniques with the OST is essential to evaluate their potential risks and benefits, ensuring optimal outcomes for zygomatic implant placement.

The "exteriorized" or "extra-sinus" approach was introduced as a technique that avoids maxillary antrostomy. The beginning, terminus, and implant trajectory are anatomically the same as in the OST method. The mid-portion of the implant is positioned extra-sinus, not because of a specific surgical procedure, but because of the lateral maxillary sinus wall's natural concavity. In 2008, Malo further modified the extra-sinus approach by removing maxillary alveolar bone, simplifying the procedure but eliminating bi-cortical anchorage.[17] This raised concerns about biomechanical stability, as the implant relied solely on zygomatic bone, unlike the quad-cortically stabilized zygoma implant in the OST technique.

Zygomatic implants are typically positioned intrasinus, which causes the implant head to palatal emerge. But doing so may make the prosthetic bulkier, which could impact comfort and speech. An extrasinus technique provides a more crestal emergence, enhancing prosthetic results and lowering the risk of chronic sinusitis, whereas intrasinus implantation preserves the implant body inside the sinus.[18]

➢ *Complications*

The removal of zygomatic implants (ZIs) because of recurrent sinusitis or chronic discomfort, infections in the maxillary sinus, and intraoral soft tissue infections are among the problems linked to ZI surgery that have been documented in the literature. Additional problems include subcutaneous malar emphysema, orbital cavity penetration, face or periorbital hemorrhage, gingival hyperplasia, oroantral fistula formation, transient sensory nerve impairments, and mild nasal bleeding that lasts one to three days.[5]

II. RECENT DEVELOPMENTS OF THE ZYGOMATIC FIXTURE TECHNIQUE

➢ *Immediate Loading*

With a fixed implant-supported complete denture, immediate loading allows patients to undergo joint surgery or prosthetic therapy without waiting for osseointegration to take place. Because the rigid splinting of angled implants absorbs axial and lateral loads, stabilizing the rehabilitation system, the application of ZIs in immediate functionality is particularly promising.

Clinical studies have shown positive outcomes for immediate or early loading of zygomatic implants in edentulous maxillae. Ostman et al. reported a 0.8% failure rate in 123 implants over one year.[19] Bedrossian et al. found no failures in 28 zygomatic and 55 conventional implants after 12 months.[20] Davo et al. observed no losses in 36 zygomatic implants but three failures in 68 conventional implants over 6–29 months.[21] Though short-term, these studies support immediate or early loading as a viable approach.

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➢ *Placement Under Local Anesthesia*

The use of oral or intravenous sedation in conjunction with local anesthetic has simplified the process, making it appropriate for skilled surgeons for procedures lasting less than 1.5 hours. Four simultaneous techniques are used in the local anesthetic technique:

- Using 3.6 ml of lidocaine and posterior superior alveolar nerve block, infiltration anesthesia (1:50,000 epinephrine) is administered in the buccal sulcus from the central incisor to the third molar, approximately 1 cm palatal to the bone crest.
- Infra-orbital nerve block by oral means with 1.8 ml of either prilocaine with felypressin or lidocaine (1:50,000 epinephrine).
- Using 1.8 ml of lidocaine (1:50,000 epinephrine) or prilocaine with felypressin, sphenopalatine ganglion blocks are placed into the greater palatine foramen.
- Infiltration anesthesia using 3.6 ml of lidocaine (1:50,000 epinephrine) via the skin surrounding the zygomatic area.

Patients tolerate this approach well, and it enables surgeons to operate on a conscious patient with efficiency.[10]

➢ *Flapless Placement of Zygomatic Implants using Dynamic Navigation*

Dynamic navigation has various advantages over static guidance for dental implant placement, including the ability to use a flapless approach that allows "direct vision" of the surgical site on the computer screen. This method also lowers morbidity, complications, and expenses. Furthermore, dynamic navigation allows for real-time verification of implant location during surgery as well as changes to the surgical plan, which static guiding methods do not allow.

Davidson et al. suggested a stereolithographic template-guided flapless technique for zygomatic implants.[22] Flapless implant insertion has several advantages, including the preservation of soft tissue, shorter operating times, increased comfort, and faster recovery.[23,24] Placing a zygomatic implant without flap elevation might be problematic due to limited visibility and accessibility, problems protecting the sinus membrane, challenges in obtaining the desired location, and the possibility of injuring neighbouring critical structures. Dynamic navigation has recently made it easier to transmit preoperative planning to the surgical field, resulting in better zygomatic implant placement.[25]

All implants, with the exception of one in the flapless group, experienced osseointegration in a randomized clinical study conducted by Bhalerao et al. (2023). With average apical and coronal variations of 5 mm and 3 mm, respectively, the flapless and conventional groups' implant accuracy differed statistically significantly ($p < 0.01$). Three cases of Schneiderian membrane perforation occurred. The study concluded that flapless zygomatic implant placement, guided by dynamic navigation, was safe and accurate.[26]

III. DISCUSSION

Restoring a severely atrophied maxilla and partially resected maxilla with implants presents challenges for both surgeons and prosthodontists. In cases requiring only conventional implant placement, extensive bone grafting, sinus upliftment, and onlay grafts with substantial donor bone are often necessary. Zygomatic implant rehabilitation offers several advantages, including the avoidance of unnecessary bone grafts, a shorter treatment duration, no need for donor sites, and continuous use of transitional prostheses by the patient. This approach improves patient compliance, providing a stable, well-tolerated, and aesthetically pleasing removable or fixed prosthesis at treatment completion.[8,14,15,27,28]

Zygomatic implants are recommended for the atrophied edentulous maxilla due to several key benefits. With an osseointegration success rate above 96%, they require fewer surgical interventions, as bone harvesting or grafting is often unnecessary. The procedure reduces operating and working time for the surgeon and can be performed in an office setting. The precise placement of the implant ensures the access screw hole aligns with the first molar's central groove. Unlike traditional implants, it also eliminates the need for custom-made abutments and additional dental or laboratory work. Compared to grafting operations, zygomatic implants are more economical.[29]

IV. CONCLUSION

To sum up, zygomatic implants provide a very successful alternative to complicated bone grafting techniques for individuals with significant maxillary atrophy. They provide notable benefits in terms of both functionality and appearance, with a high success rate, shorter operation times, and immediate loading capabilities. The development of advanced surgical techniques, such as flapless placement guided by dynamic navigation, further enhances their accuracy and safety. Overall, zygomatic implants are a cost-effective, reliable option for restoring the edentulous maxilla, improving patient outcomes and quality of life.

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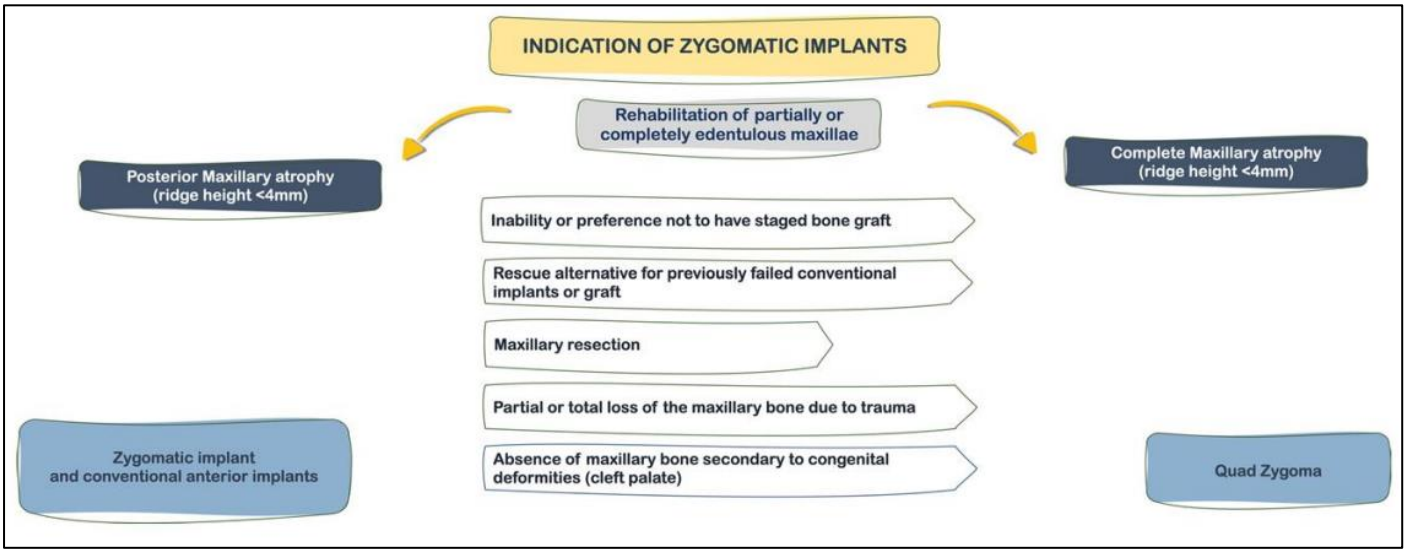

Fig 1 Indications of Zygomatic Implants
(Image courtesy: Polido WD, Machado-Fernandez A, Lin WS, Aghaloo T. Indications for zygomatic implants: a systematic review. International Journal of Implant Dentistry. 2023 Jul;9(1):17)

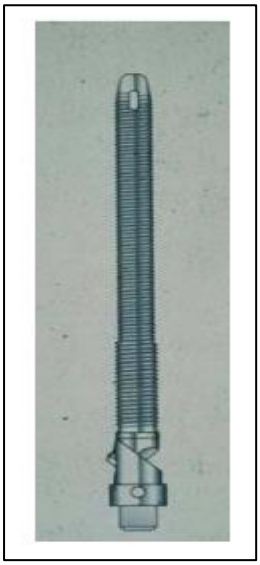

Fig 2 The Zygomatic Implant.
(Image courtesy: Aeran, H., Singh, G., Seth, J., & Agarwal, A. Zygomatic implants–Changing face of implant dentistry)

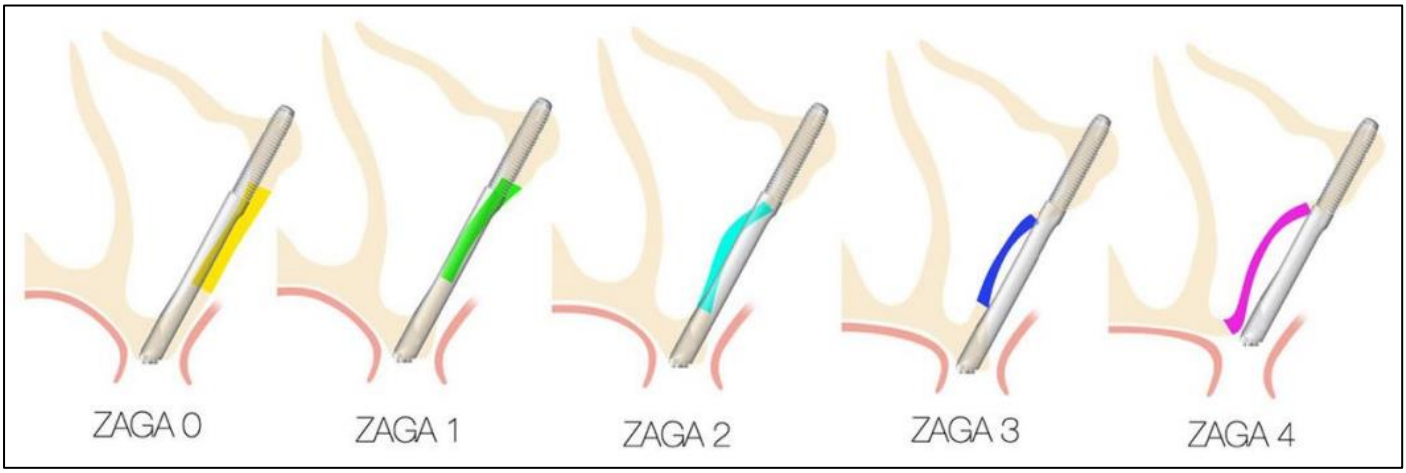

Fig 3 The ZAGA Classification
(Image courtesy: Bedrossian E, Brunski J, Al-Nawas B, Kämmerer PW. Zygoma implant under function: biomechanical principles clarified. International Journal of Implant Dentistry. 2023;9(1):15)

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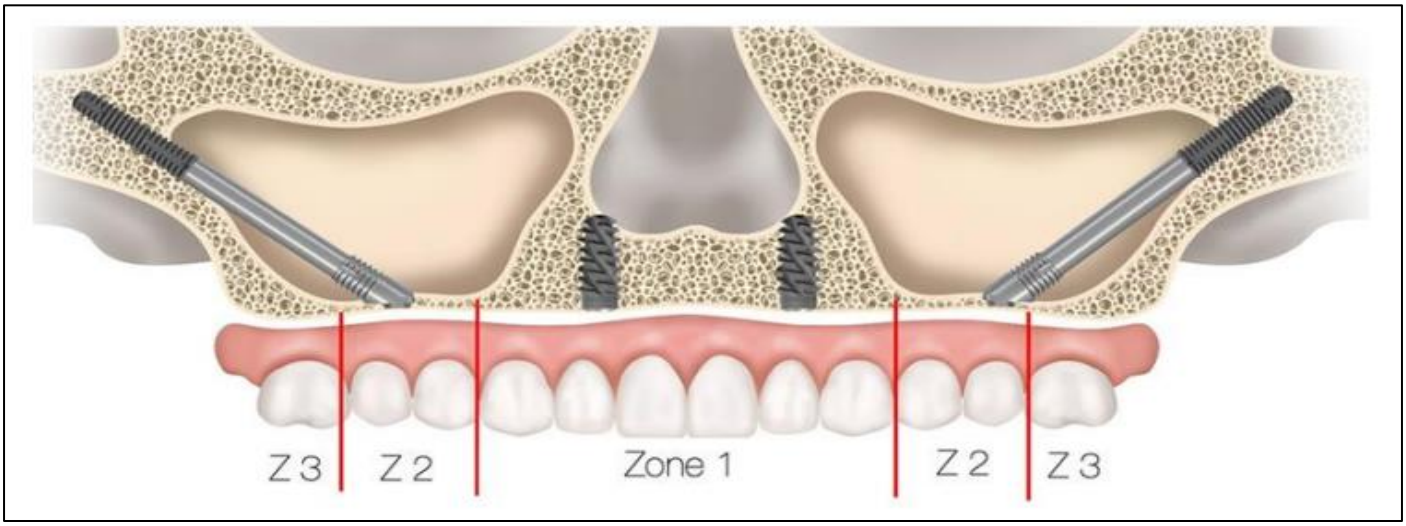

Fig 4 Zones of the maxilla determine the indication for the zygoma concept
(Image courtesy: Bedrossian E, Brunski J, Al-Nawas B, Kämmerer PW. Zygoma implant under function: biomechanical principles clarified. International Journal of Implant Dentistry. 2023;9(1):15)

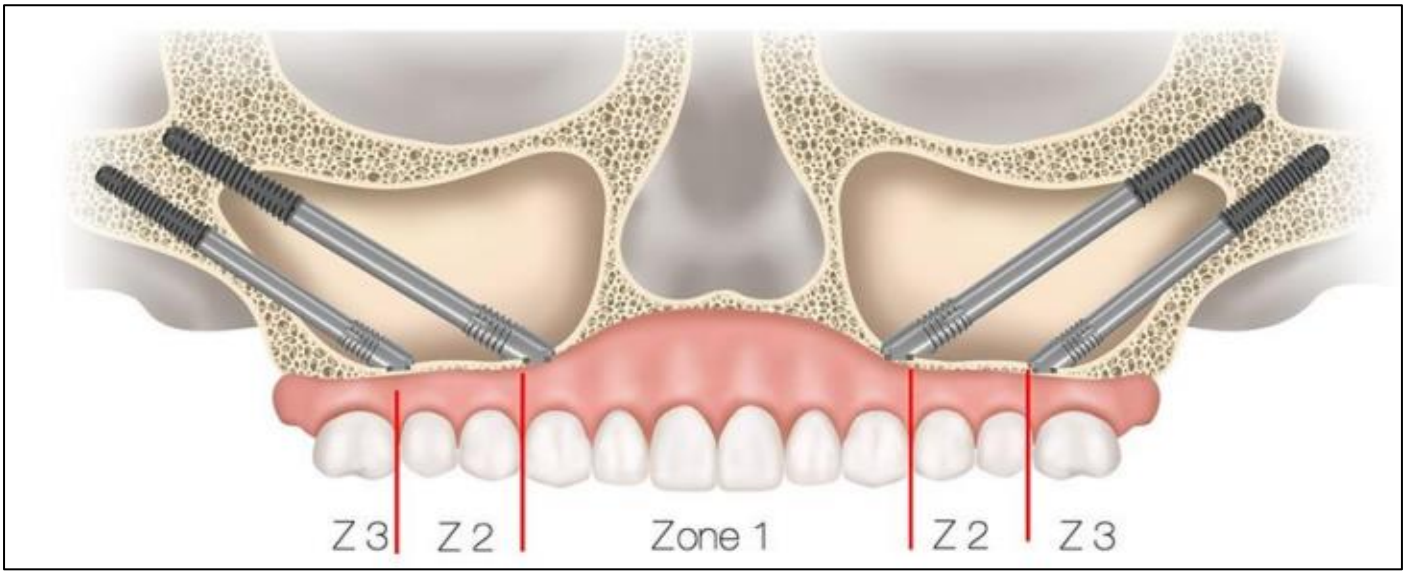

Fig 5 Zones of the Maxilla Determine the Indication for the Quad-Zygoma Concept
(Image courtesy: Bedrossian E, Brunski J, Al-Nawas B, Kämmerer PW. Zygoma implant under function: biomechanical principles clarified. International Journal of Implant Dentistry. 2023;9(1):15)