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REVIEW

Z-classification: an anatomy-based ridge–sinus–zygoma classification and decision funnel for zygomatic implantology

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Abstract

Objectives The rising demand for zygomatic implants (ZIs) in contemporary dental implantology underscores the need for an anatomy-based categorization system and a surgical decision-making panel that takes into account anatomical, biomechanical, and prosthetic factors to determine the final surgical strategy. This article proposes a new Z-Classification, the anatomical division of the maxillo-zygomatic complex.

Materials and methods The classification was developed from the authors' clinical experience of 882 ZIs placed in 234 patients across two centres over a ten-year period. According to anatomical presentations, 6 classes were described.

Results The classification is intended as a practical framework for preoperative assessment and treatment planning in ZI rehabilitation. It has not yet been validated against clinical outcomes. Additionally, a decision funnel for surgical strategy development and the structured checklists consisting of crucial clinical parameters for long-term success in ZI therapy were proposed.

Conclusion The presented tools will potentially optimize a complex decision-making algorithm in zygomatic implantology.

Clinical Relevance The proposed Z-Classification and the decision funnel carry the potential to reduce the risk of complications associated with zygomatic surgery.

Keywords Zygomatic implants · Atrophic maxilla · Classification · Clinical decision-making · Treatment planning

Introduction

Over the years, the field of dental implantology has evolved significantly, enriched by scientific, biomechanical, and physiological principles, beyond the sole pursuit of implant osseointegration [1, 2]. Considering full-arch implant rehabilitation, the spatial arrangement of implants within the jaw is crucial, as it directly influences mechanical load distribution and, consequently, bone behavior around implants over time [3–5]. When alveolar bone resorption prevents the use of conventional implants for rehabilitating a completely edentulous maxilla, anchoring implants in the zygomatic bone becomes a valid alternative. Rehabilitation with zygomatic implants (ZIs), given its high success rate, avoids bone grafting, reduces the number of surgical sessions, and allows immediate loading with a fixed provisional bridge on the day of surgery [6–9]. The use of the ZIs adheres to the same rules as conventional implantology, i.e., the principles of periodontology, biomechanics, and prosthetically driven planning.

Bone classifications such as Cawood and Howell's six stages of bone resorption, or Lekholm and Zarb's classification based on bone quality, do not accurately describe the surgical technique in zygomatic implantology [10, 11]. The apparent rise in demands, as well as the spectrum of indications for ZIs, suggests the need for an anatomical, clinically applicable categorization system that further facilitates surgical decision-making in zygomatic implantology [12]. Several frameworks are in current use in the planning of ZI treatment. A zone-based analysis of maxillary bone availability determines whether zygomatic anchorage is

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indicated and how many implants are required [13]. The zygoma anatomy-guided approach (ZAGA) classifies the relationship between the implant body and the anterior sinus wall, and describes the trajectory associated with a given wall contour [14]. The original surgical protocol and its subsequent biomechanical analyses describe the osteotomy from the alveolar crest to the zygomatic body and the cortical anchorage obtained along its course [15, 16].

The categorisation presented here addresses a different question: how the residual ridge and the lateral sinus wall, considered together before surgery, determine what the surgeon will be able to see and to engage at the time of operation, and therefore which surgical sequence should be prepared in advance. It describes anatomy rather than technique, and is not proposed as a new surgical method. This framework applies to sites at which zygomatic anchorage has been indicated. Where the residual bone height at an individual site would permit placement of a short or extra-short implant, with or without transcrestal sinus floor elevation, the indication for zygomatic anchorage at that site warrants reconsideration [17, 18]. Therefore, this article aims to present a new classification based on the anatomy of the maxillo-zygomatic complex following alveolar bone resorption. Furthermore, to achieve a comprehensive ZI strategy, a decision funnel for surgical approach development and checklists summarizing essential steps in reproducibility and long-term success of zygomatic rehabilitation are proposed.

Development of the classification

The Z-Classification was developed from the clinical practice of two centres — a private surgical centre in Saint-Dié-des-Vosges, France, and the Implant Center, School of Dental Medicine, University of Belgrade, Serbia — where immediate full-arch maxillary rehabilitations with ZIs have been performed since September 2016. Over this period, 882 ZIs have been placed in 234 patients, predominantly in quad-zygoma configurations, by a single surgeon in each centre, with final prosthetic restorations completed by referring prosthodontists. Anatomical assessment is based on cone-beam computed tomography (CBCT), complemented by three-dimensional printed models when required, and confirmed intraoperatively under direct visualisation.

The indications applied in this practice follow those generally accepted for ZI therapy: advanced maxillary atrophy from edentulous resorption, trauma, cleft sequelae, peri-implantitis or failure of previous bone grafts, together with nonrestorable remaining dentition. Head and neck irradiation and antiresorptive therapy are relative rather than absolute contraindications, and ZI placement has been reported in patients treated for head and neck malignancy and in medication-related osteonecrosis of the jaw [19, 20]; patients presenting with these conditions were not selected for treatment in this practice.

The anatomical categories described below correspond to situations encountered repeatedly in this practice, and the surgical strategies proposed reflect the approach the authors have progressively adopted in them. The figures are reported to describe the clinical context from which the classification arose. No systematic data collection, outcome assessment, or statistical analysis was undertaken for the present article, and the classification has not been validated against clinical outcomes.

Anatomical considerations

Residual alveolar ridge

The maxillary edentulous ridge resorbs horizontally, vertically, or in combination (Fig. 1a through c) [12]. Ridge width and residual height are not interchangeable parameters, and they are used at different stages of the assessment. Width governs the bone available around the circumference of the implant neck at the crest, and therefore the presence of buccal and palatal wall, the support of the peri-implant soft tissues, and the availability of the palatal cortical plate. Height governs the thickness of tissue separating the oral cavity from the maxillary sinus, and therefore the extent to which the machined coronal segment of the implant can be contained within bone and the margin available before crestal remodelling establishes communication.

The residual ridge is accordingly characterised in two steps. The first establishes whether an alveolar ridge is still present at the planned implant site. Where the alveolar crest has been lost entirely, and the crestal surface lies at the level of the sinus floor, ridge width is no longer a meaningful parameter, and the situation is designated as total vertical resorption. Where a residual ridge is present, it is graded by width, measured on cross-sectional CBCT at the level at which the implant platform is planned: a wide ridge measures 6 mm or more, a thin ridge less than 6 mm (Fig. 1d and e). This threshold derives from the geometry of the implant platform. Contemporary ZIs carry a coronal platform of approximately 4 to 5 mm in diameter; taking the lower end of that range, a ridge of 6 mm provides a minimum of approximately 1 mm of bone on both the buccal and the palatal aspect of the platform, which contributes to primary stability, to maintenance of the crestal bone, to soft-tissue support, and to the prevention of vestibular dehiscence. It is a practical value adopted in the authors' workflow and would require adjustment for a platform of

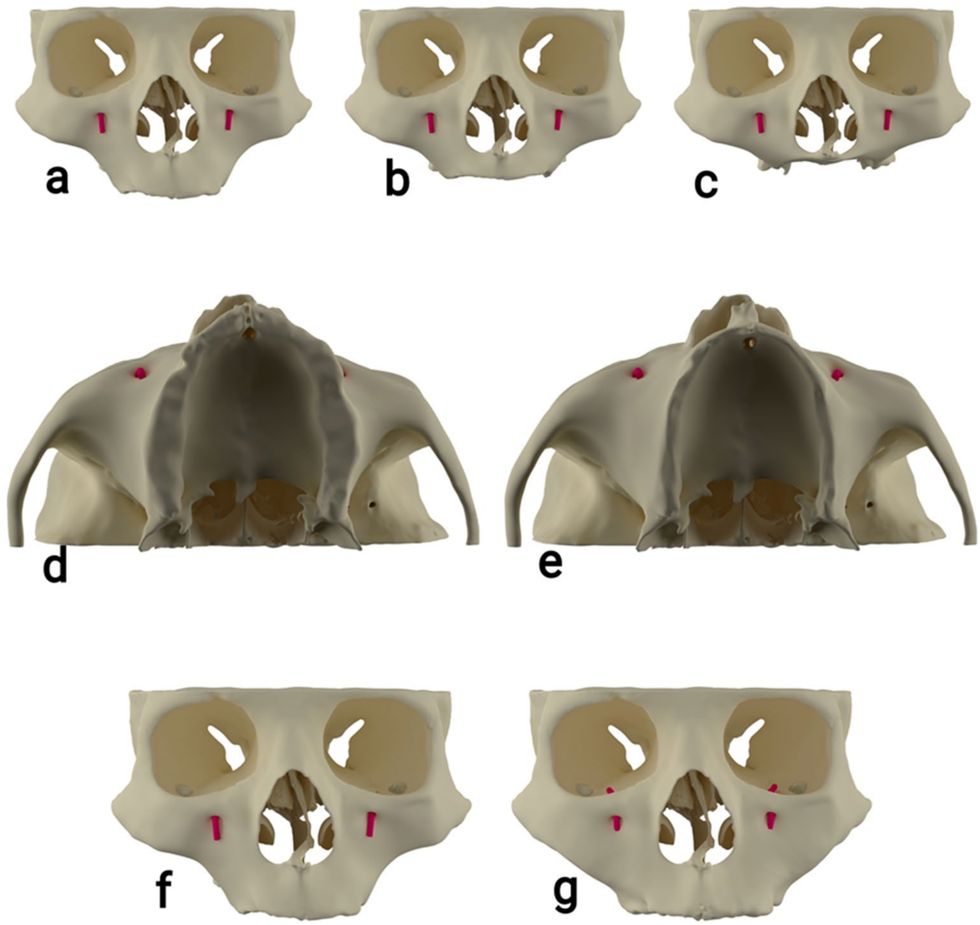

Fig. 1 Anatomical aspects of the maxillary edentulous ridge and the lateral sinus wall. (**a**) Horizontal ridge resorption; (**b**) Vertical ridge resorption; (**c**) Combined horizontal and vertical ridge resorption; (**d**) Wide alveolar ridge; (**e**) Thin alveolar ridge; (**f**) A concave lateral sinus wall; (**g**) A convex lateral sinus wall; (**f**) and (**g**) renderings illustrate the two contour patterns; the criterion by which an individual case is assigned is applied on cross-sectional cone-beam computed tomography (CBCT) at the level of the planned implant path, as described in the text

larger diameter. The residual vertical dimension is handled separately, as the subantral bone height, measured on the same cross-sectional slice as the vertical distance between the crestal bone surface and the sinus floor at the planned crestal entry point, and is applied within the decision funnel rather than used to define the grade. Both parameters are assessed at each planned implant site. A patient may therefore present different Z-grades at different sites; in quad-zygoma rehabilitation, the anterior and posterior sites on the same side commonly share the same lateral wall designation while differing in ridge state and subantral bone height.

The classification therefore rests on three variables: the state of the ridge and the morphology of the lateral sinus wall, which together define the Z-grade, and the subantral bone height, which determines the crestal preparation within a given grade. Ridge width and total vertical resorption are consequently not two points on a single scale but the outcome of a sequential assessment, in which width is evaluated only where a residual ridge is present. Where the ridge has been lost entirely, the clinical presentation at the implant site is the same irrespective of the original width, and the two width categories collapse into one. Intermediate degrees of vertical loss do not generate a separate grade; they are accounted for by the subantral bone height.

Lateral sinus wall

For this classification, the lateral sinus wall is characterised by whether the anterior zygomatic surface remains accessible to direct vision once the flap has been raised, rather than by the degree of its curvature. On a cross-sectional CBCT slice through the planned implant path, a straight line is drawn from the planned crestal entry point to the planned zygomatic entry point. Where the contour of the lateral maxillary wall lies palatal to this line, the anterior zygomatic surface lies outside the sinus and is directly visible; the wall is designated concave (Fig. 1f). Where the wall contour lies buccal to this line, it conceals the zygomatic entry region; the wall is designated convex (Fig. 1g). Intermediate contours, including a flat anterior wall, are assigned by the same criterion, since the parameter of interest here is the accessibility of the zygomatic entry region, not the degree of curvature itself.

Surgical considerations

Zygomatic entry points

The zygomatic buttress provides a limited bone volume that should accommodate ZI while respecting safety margins from the orbital floor, external cortex, and inter-implant distance to maintain bone viability. These constraints become more demanding when the zygomatic bone is narrow or reduced in height.

To visualize and control the entry, the anterior surface of the zygomatic bone should be fully exposed under direct vision, representing a reference landmark for defining the ZI trajectory (Fig. 2a). In cases of concave lateral sinus wall, the anterior zygomatic surface is positioned outside the sinus and is directly visible, so the surgical drilling can be appropriately controlled without additional bone removal (extrasinus ZI trajectory). On the contrary, the convex lateral sinus wall hides the zygomatic entry point inside the sinus cavity. In the authors' protocol, a limited visualisation opening is then prepared in the lateral wall, in order to expose the entry region and to allow the intrasinus portion of the trajectory to be controlled under direct vision. The opening is confined to the lateral wall; it does not extend into the alveolar crest or into the body of the zygoma.

The final implant trajectory results from balancing three anatomical references. The first is the position required for the prosthetic platform, determined by the antero-posterior and bucco-lingual position of the planned teeth and by the residual crestal anatomy. The second is the zygomatic entry point, which determines where the implant may engage the buttress within the available bone volume (Fig. 2b). The third is the apical exit through the external zygomatic cortex, which governs cortical anchorage and the safety margin from the orbital floor. Prosthetically driven planning defines the first; the anatomy of the zygoma constrains the other two. Where the three cannot be satisfied simultaneously, a compromise is required, and anticipating that compromise before surgery is one of the purposes of the present framework.

Intraoperatively, and particularly when implants are placed free-hand, the exposed anterior zygomatic surface provides the most reliable reference for executing the planned trajectory, since it is the only one of the three directly visible throughout the osteotomy.

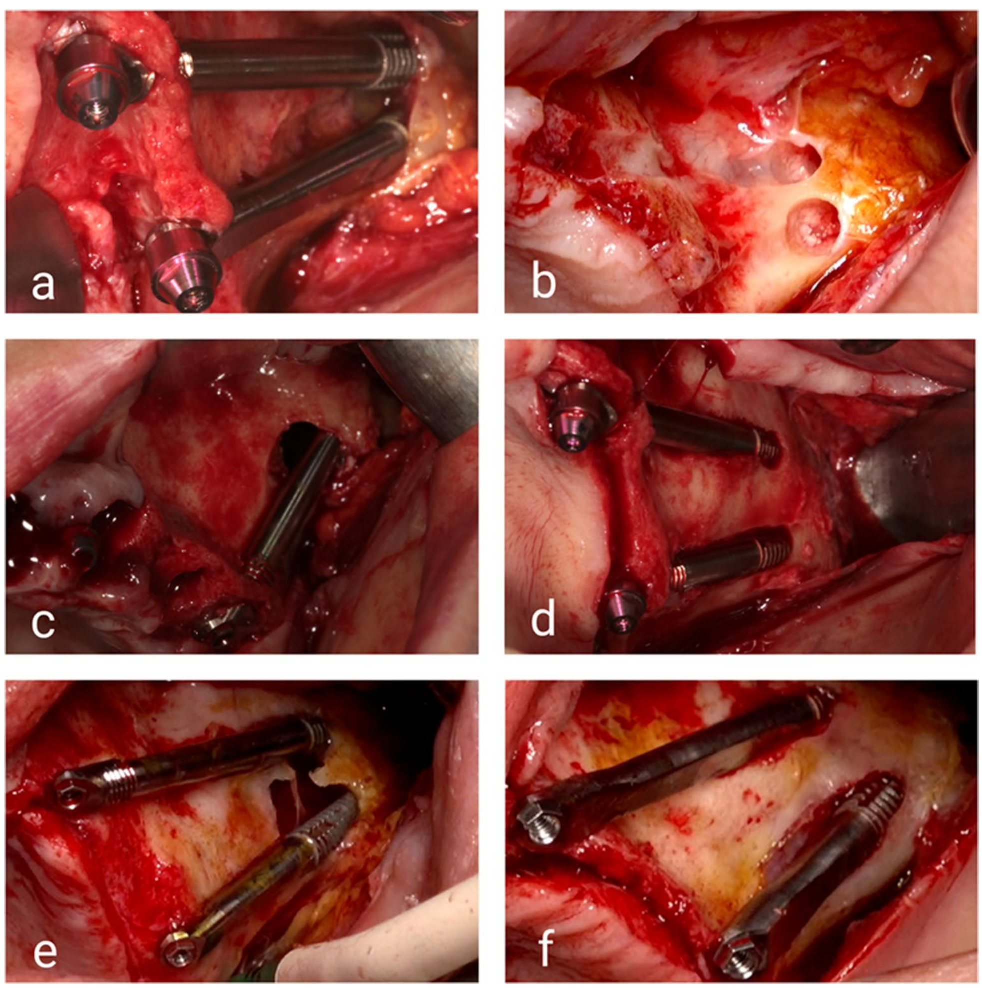

Fig. 2 (**a**) Visualization of the anterior wall of the zygomatic bone and the implant entry point; (**b**) Once the anterior zygomatic wall is exposed, the two entry points are defined; (**c**) Wide ridge, convex sinus wall, ≥2 mm of alveolar bone, and a visualisation opening; (**d**) Thin ridge, convex sinus wall, ≥2 mm of alveolar bone, and a visualisation opening; (**e**) Thin ridge, convex sinus wall, a visualisation opening, and a cervical bone housing; (**f**) Wide or thin ridge, convex sinus wall, <2 mm of alveolar bone, a cervical bone housing, and a vertical visualisation opening

A visualisation opening

In the authors' protocol, a limited visualisation opening is prepared when the zygomatic entry region is concealed by the contour of the lateral wall, so that the planned trajectory and the entry region cannot otherwise be controlled under direct vision (Fig. 2c through f). Severe vertical resorption and pronounced sinus pneumatisation do not in themselves indicate an opening; where the lateral wall remains accessible, the zygomatic entry region can be exposed without one. Moreover, visual control of the surgical field may be achieved by raising a mucoperiosteal flap, in protocols that do not involve an opening of the lateral wall [21, 22].

Depending on what should be monitored, the opening may be vertical (drilling trajectory guidance), horizontal (apical emergence visualization), or inverted L-shaped for combined control. The primary objective of the visualisation opening is not simply to gain access to the sinus cavity. Its main purpose is to provide direct visualization of the anterior zygomatic wall and the planned zygomatic entry points. A convex lateral sinus wall obstructs this visualisation, and is the situation in which the authors prepare a limited visualisation opening.

The opening has no standard dimensions. Its extent is determined by what has to be visualised and by the course the drill must follow.

The vertical extent follows the convexity of the lateral wall. Where the wall becomes convex near the crest, a longer opening is required; where the convexity begins closer to the zygomatic bone, a shorter one is sufficient. The opening extends far enough for the drill and implant to be followed under direct vision throughout the intrasinus portion of the trajectory, until they enter into the zygomatic bone.

The zygomatic bone determines the horizontal extent. It must expose enough of the anterior zygomatic surface to enable a sufficient distribution separation of the two implants' entry points for the intervening bone to remain vital, and with sufficient thickness from the buccal cortex to avoid fracture during insertion.

The inverted L-configuration is used in quad-zygoma rehabilitation. The vertical limb follows the long intrasinus course of the posterior implant where the wall is convex, and the horizontal limb exposes the point at which the anterior implant enters the zygomatic bone (Fig. 3a).

In addition to visualisation, bone lying on the course between the crestal and zygomatic entry point is removed, since bone contacted obliquely by the drill deflects it from the planned trajectory. The bone removed on this account is bone that the implant would traverse in any case; it is not bone that would otherwise support the platform at the crest, which is preserved. The opening is confined to the lateral wall of the sinus and extends neither into the zygomatico-maxillary buttress nor into the alveolar crest.

As mentioned before, the straightforward vision allows the surgeon to control both the osteotomy and implant trajectory throughout the intrasinus portion of the procedure. This underlines the importance of direct perception of the zygomatic entry points rather than solely trajectory planning from the crestal entry point.

Crestal placement versus cervical bone housing

The planning of ZIs includes evaluation of maxillary alveolar bone resorption, sinus anatomy, and the antero-posterior and bucco-lingual positions required for the implant platforms within the prosthetic corridor. As alveolar bone resorbs, crestal positioning with full bone support around the implant platform appears less feasible, suggesting that a new balance among bone availability, prosthetic axis, and surgical safety should be found. The decision between a crestal placement and a cervical bone housing preparation is driven by both anatomical and prosthetic considerations to ensure safe apical anchorage and ideal prosthetic biomechanics. From a biological perspective, preservation of peri-implant crestal bone is essential for long-term implant stability and soft-tissue support [23, 24]. In ZI rehabilitation, the residual subantral bone surrounding the implant neck represents the only local osseous support at the crestal level. From a biomechanical standpoint, the cervical portion of the implant is subjected to functional loading and stress concentration [25]. Movements and micromovements during healing, overload, or inflammatory bone loss associated with peri-implantitis may progressively reduce the already limited bone surrounding the implant collar. Unlike conventional implants, ZIs often traverse the sinus cavity, making the integrity of the crestal bone particularly important. If only a minimal amount of residual bone is present beneath the sinus, subsequent crestal bone loss may result in a direct communication between the oral cavity and the sinus around the implant neck [26]. Such oroantral communication may facilitate bacterial contamination, chronic sinus inflammation, soft-tissue complications, and long-term peri-implant issues.

Crestal ZI placement is possible in cases of a wide alveolar ridge and ≥ 2 mm of subantral bone height. In this approach, ZI is placed through the crest to ensure appropriate mechanical force transmission. In cases of a thin alveolar ridge and ≥ 2 mm of available bone below the sinus, palatalized crestal entry is preferable, as drilling slightly palatal preserves a vestibular bony ridge (Fig. 3b). Initiating the osteotomy at the palatal aspect of the crest does not place the implant platform in the palate. The platform remains within

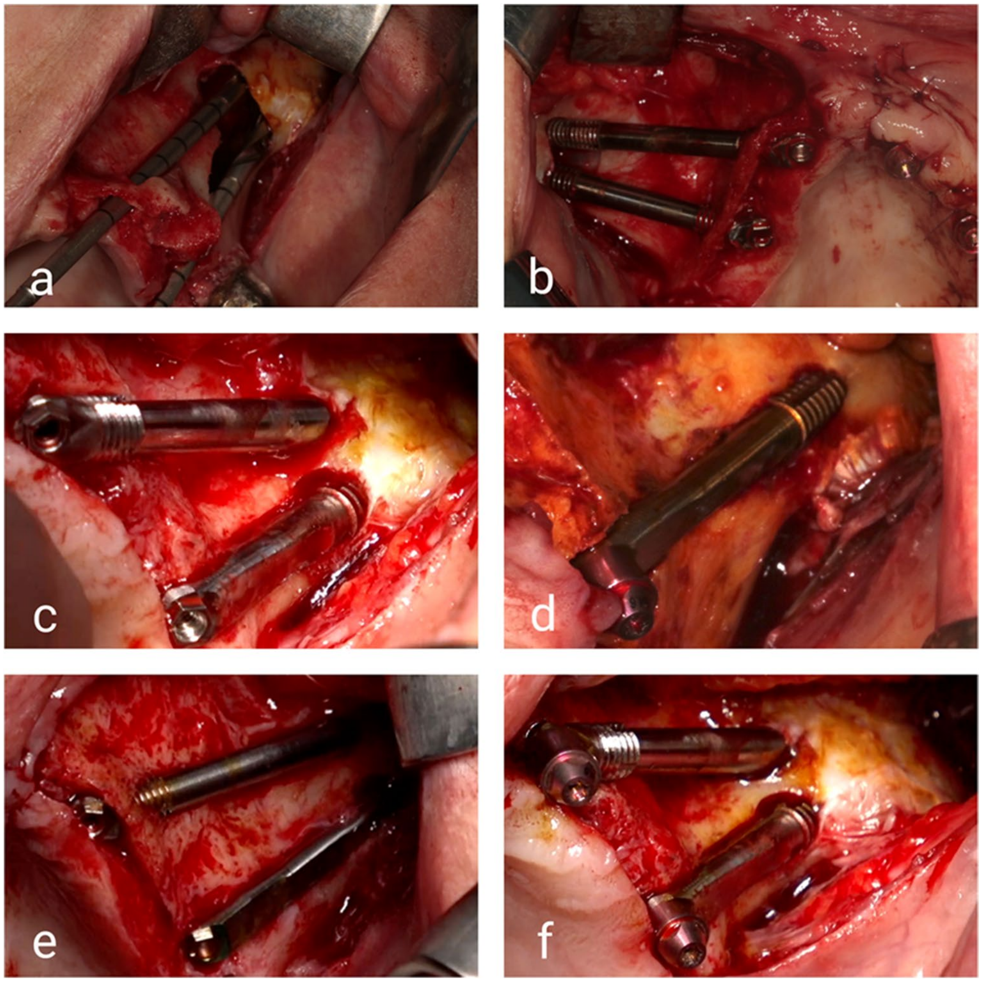

Fig. 3 (**a**) A visualisation opening inverted L-shape to optimize visualization of the drilling path and implant emergence. The opening exposes the drilling path but not the distal exit through the external zygomatic cortex, which is controlled by apex-to-cortex preoperative measurement; (**b**) Where the residual ridge is thin, the osteotomy is initiated at the palatal aspect of the crest so that a vestibular bone wall is preserved around the implant platform. Implants with a fully machined surface are available and may be preferred for the preservation of peri-implant soft tissues where alveolar bone is absent; (**c**) A cervical bone housing. The osteotomy is extended within the contour of the residual crest so that the machined coronal segment of the implant is embedded in the remaining bone and in continuity with the bone contours, rather than emerging from a crest too thin to contain it; (**d**) Wide ridge, concave sinus wall, <2 mm of alveolar bone, and a cervical bone housing; (**e**) Thin ridge, concave sinus wall, ≥2 mm of anterior alveolar bone, <2 mm of posterior alveolar bone with a cervical bone housing and no visualisation opening; (**f**) Wide or thin ridge, concave sinus wall, a cervical bone housing, and no visualisation opening

the crestal contour, and its emergence is more palatal than it would be on a non-resorbed maxilla only to the extent that centripetal resorption has displaced the crest itself relative to the prosthetic corridor. The displacement is attributable to the resorption pattern rather than to the trajectory adopted. Whenever prosthetic alignment allows, a palatalized crestal entry is preferred in thin ridges to maintain a vestibular bone wall around the implant platform. This residual bone contributes to primary stability through quadricortical anchorage, supports the peri-implant soft tissues, and reduces the risk of future vestibular dehiscence. Since correction of vestibular soft-tissue recession around ZIs remains highly challenging, prevention should be considered a primary treatment objective.

When the residual subantral bone height falls below 2 mm, a cervical bone housing is prepared in the authors' protocol rather than a direct crestal entry. Where at least 2 mm is present, the platform is positioned at crestal level, so that the first 2 mm of the implant neck are engaged in bone.

Two considerations support this threshold. The first concerns the nature of the bone contact obtained at the crest. The coronal portion of a zygomatic implant is wide relative to an atrophic ridge, and the implant crosses the crestal plate obliquely rather than perpendicularly. Where the residual height is minimal, the bone contacts one aspect of the neck rather than forming a circumferential collar around it, and the engagement obtained is partial and asymmetrical at the level where a peri-implant soft-tissue seal is most needed. The second concerns the margin available for remodelling. At this level, the residual subantral bone constitutes the entire thickness of tissue separating the oral cavity from the maxillary sinus. Where it measures 2 mm, the vertical bone loss required to establish a communication between the peri-implant sulcus and the sinus is of the same order as the marginal remodelling commonly observed around loaded implants during the first years of function. Physiological remodelling alone may therefore be sufficient to produce an oro-antral communication, before any inflammatory or overload-related loss is taken into account.

The cervical bone housing addresses both. By relocating the platform within the contour of the residual crest, the implant neck is embedded in the remaining bone rather than resting upon it, and the emergence is displaced away from the thinnest part of the plate. The housing is a repositioning of the entry rather than an enlargement of the osteotomy, and it does not remove bone that would otherwise support the platform.

The 2 mm figure is an empirically selected clinical threshold used in the authors' workflow rather than a validated cut-off. It represents the minimum crestal engagement the authors consider acceptable before a housing is preferred, and would differ for an implant of different coronal design.

The residual maxillary crest, rather than the zygomatic bone, is the primary support of the ZI under function. The stresses developed within the implant and the surrounding bone increase as the area of bony support decreases [16, 27]. Wherever subantral bone is sufficient to contain the implant collar, it is engaged and preserved, and the housing is reserved for the settings in which the residual height is already insufficient for containment. Whether this preserves platform stabilisation more effectively than a platform placed at the level of an insufficient crest has not been tested and remains a hypothesis.

Complete coverage of the coronal threads by bone is not attainable in extreme atrophy. Where the residual crest is reduced to a thin plate, part of the coronal surface is necessarily exposed at the time of placement; this reflects the bone that remained available rather than a choice to remove it, and the approach described above is directed at preserving what is present. The implant design used addresses the same constraint from the other side. A threaded coronal portion provides crestal engagement wherever bone is present, while the surface is machined rather than textured to limit bacterial colonisation where it is not [28–30]. For the same reason, implants with a fully machined surface are available and may be preferred where alveolar bone is absent.

Through the cervical bone housing approach, the ideal prosthetic alignment and embedding of the ZI neck within residual bone contours can be achieved (Fig. 3c through f).

Prosthetic aspects

The distance between the access hole on the implant platform and the central fossa of posterior teeth is directly related to the degree of medial alveolar crest resorption. Depending on the resorption degree, the access hole may or may not emerge at the center of the occlusal surface. To facilitate a more favorable prosthetic reconstruction, the implant platform should be angled (55°) [31, 32]. Centripetal resorption decreases thickness and reduces maxillary bone in the sagittal plane. In extreme cases, the situation may resemble pseudo-prognathism, preventing the positioning of the implant head in the anatomical location. To place an implant in the appropriate prosthetic corridor, initial bone volume would need to be recreated using grafting techniques. The ZIs represent a valid, evidence-based alternative to bone grafts, even in complete edentulism with severe horizontal resorption [33]. However, to provide predictable and reproducible results regardless of bone resorption or volume deficiency, a comprehensive protocol of the appropriate treatment for each case is required.

The alignment between the residual ridge and the future prosthetic corridor represents one of the key decision criteria in the treatment algorithm of ZI rehabilitation. Mild to moderate misalignment corresponds to situations in which implant placement through the crest remains compatible with a functional and prosthetically acceptable emergence profile. Conversely, a severe misalignment occurs when implant placement through the native crest would compromise the prosthetic axis, function, esthetics, or hygiene access. Clinical examination and CBCT evaluation alone are frequently insufficient to determine whether the available alveolar ridge would allow a correct prosthetic emergence or whether a cervical bone housing preparation is required. Thus, a virtual tooth setup, prosthetically driven planning, and radiographic guides have a prominent role, as these are often the only reliable methods for assessing the degree of misalignment [34, 35].

Abutments should be placed slightly supragingival if not visible during a forced smile and juxtagingival if visible. The subgingival abutment position may provoke peri-implant soft-tissue inflammation. Furthermore, ZIs loading with a fixed, rigid prosthesis is preferred [6]. The provisional bridge should be manufactured with no distal cantilever. The covering or overhang of the ridge to facilitate hygiene should be avoided, and a smooth transition between the ridge and prosthetic teeth should be provided [13]. The definitive prosthesis should follow the same design rules as the provisional, with a completely passive framework, computer-aided design/computer-aided manufacturing (CAD/CAM) milled and trans-screwed. Any slight lack of passivity may trigger pain and discomfort for the patient, as well as bone loss at the implant level.

Z-Classification and a decision funnel

The proposed Z-Classification presents an anatomical categorization system that divides distinct anatomical situations of the maxillo-zygomatic complex (Table 1). It is important to emphasize that Z-Classification is an anatomical classification rather than a surgical difficulty scale, with each category representing a specific anatomical situation requiring a particular surgical strategy. However, the final complexity of treatment depends on additional anatomical, biomechanical, and prosthetic factors that are evaluated during the decision-making process (Table 1).

Table 1 The Z-Classification and the decision funnel. The Table 1 describes the strategy adopted by the authors and is not presented as a general recommendation. Ridge width and total vertical resorption are the outcome of a sequential assessment in which width is evaluated only where a residual ridge is present; see the text. The lateral sinus wall is characterised by the accessibility of the zygomatic entry region rather than by the degree of curvature, and intermediate contours are assigned accordingly

The Z-Classification		
Z-grade	Alveolar ridge	Maxillary sinus
Z-1	Wide ridge	Concave sinus wall
Z-2	Thin ridge	Concave sinus wall
Z-3	Total vertical resorption	Concave sinus wall
Z-4	Wide ridge	Convex sinus wall
Z-5	Thin ridge	Convex sinus wall
Z-6	Total vertical resorption	Convex sinus wall
The decision funnel		
Z-grade	Visualisation opening	Implant placement
Z-1	Not prepared	< 2 mm subantral bone: cervical bone housing ≥ 2 mm subantral bone: through crest
Z-2	Not prepared	< 2 mm subantral bone: cervical bone housing ≥ 2 mm subantral bone: - Moderate prosthetic misalignment – crestal placement, osteotomy initiated palatally to preserve the vestibular bone wall - Severe prosthetic misalignment – cervical bone housing
Z-3	Not prepared	Cervical bone housing
Z-4	Prepared	< 2 mm subantral bone: cervical bone housing ≥ 2 mm subantral bone: through crest
Z-5	Prepared	< 2 mm subantral bone: cervical bone housing ≥ 2 mm subantral bone: - Moderate prosthetic misalignment – crestal placement, osteotomy initiated palatally to preserve the vestibular bone wall - Severe prosthetic misalignment – cervical bone housing
Z-6	Prepared	Cervical bone housing

Z, grade of the Z-Classification

The strategy adopted in each grade follows from two parameters applied in sequence, together with a prosthetic condition that may override both.

The subantral bone height determines whether a cervical bone housing is prepared. Where the subantral height is at least 2 mm, the platform is positioned at crestal level and the implant is placed through the residual crest; below that, a cervical bone housing is prepared.

When a housing is not required, the ridge width determines the point at which the osteotomy is initiated. In a wide ridge, the osteotomy is initiated within the crest. In a thin ridge, it is commenced from the palatal aspect, and a vestibular bone wall is preserved around the platform.

Alignment between the residual ridge and the prosthetic corridor may require a housing irrespective of the available height, where the platform position obtainable from the native crest would not permit an acceptable emergence profile. In wide ridges, loss of height typically reflects sinus pneumatisation rather than centripetal resorption, and the residual crest generally remains within the prosthetic corridor; severe prosthetic misalignment therefore arises predominantly in association with thin ridges.

The Z-Classification and the decision funnel are intended to reduce the risk of complications associated with zygomatic surgery, such as excessive sinus exposure, external cortical fracture of the zygomatic bone, vestibular dehiscence without corrective options, and palatalised emergence compromising hygiene. This intention has not been tested against outcome data in the present article.

A checklist for ZI treatment

Implant rehabilitation with ZIs requires adherence to essential surgical and prosthetic clinical points of the ZI workflow (Table 2).

Limitations of the framework

Several limitations apply. The classification is derived from the clinical experience of two centres and one surgeon in each, and has not been validated against clinical outcomes; no distribution of cases across the six grades, and no complications or survival data, are reported here. Its reproducibility has not been assessed, and inter-observer agreement in assigning a Z-grade from CBCT remains to be measured. The 6 mm and 2 mm thresholds are practical values adopted in the authors' workflow rather than validated cut-offs, both informed by the geometry of the implant

Table 2 ZI checklist – a reproducibility framework: preoperative planning and intraoperative execution

No.	Clinical point	Why to check	How to manage
Preoperative planning			
No.	Clinical point	Why to check	How to manage
1.	Prosthetically driven planning and virtual set-up	Establishes where the prosthesis requires the platforms, which cannot be determined from the residual anatomy alone	Virtual tooth set-up and radiographic guide; record the antero-posterior and bucco-lingual platform positions required
2.	CBCT analysis and Z-grade assignment	Ridge state and lateral wall accessibility determine what will be visible and what can be engaged at surgery	Assess ridge width, subantral bone height and wall contour at each planned site; assign the Z-grade
3.	Trajectory planning	The trajectory must reconcile the prosthetic platform position, the zygomatic entry point and the apical exit	Plan on CBCT, with 3D printed models where required; identify in advance where the three references conflict
4.	Safety margins and apex-to-cortex distance	Prevents orbital, infraorbital canal, or cortical perforation complications	Plan the trajectory based on CBCT and anatomical landmarks
5.	Anticipated crestal preparation	Ensures correct force distribution and optimal prosthetic axis	Subantral height below 2 mm: cervical bone housing. Otherwise, wide ridge: crestal approach; thin ridge: osteotomy initiated palatally
6.	Anticipated need for a visualisation opening and its type	A concealing lateral wall prevents direct control of the intrasinus trajectory	Decide from wall accessibility; determine the vertical, horizontal or inverted L-extent required
7.	Soft-tissue planning and flap design	Provides the reduction of mechanical stress and peri-implant inflammation	Preservation of gingival tissues during flap elevation and proper repositioning
Intraoperative execution			
No.	Clinical point	Why to check	How to manage
1.	Flap elevation and exposure	Ensures precise entry/exit point planning and proper osteotomy orientation	Adequate flap reflection and stable retractor positioning
2.	Preparation of the visualisation opening where Planned	Allows the drill and the implant to be followed under direct vision as far as their entry into the zygomatic bone	Extend within the lateral wall only, according to wall convexity and zygomatic bone width; do not extend into the buttress or the alveolar crest
3.	Osteotomy, irrigation and debridement	Ensures thermal control during drilling, removes bone debris that may compromise healing, reduces sinus contamination, and optimizes the environment for osseointegration	Maintain continuous external irrigation during osteotomy to prevent thermal injury, then flush the osteotomy sites and sinus cavity with sterile saline to eliminate particles. Apply an appropriate antiseptic solution to exposed bone and the sinus when opened before flap closure
4.	Apex position and transfixation of the external cortex	Transfixation of external cortex required for primary stability	Measure apex-to-cortex distance before implant insertion
5.	Use of the pedicled buccal fat pad where indicated	Provides vascularized soft-tissue coverage over exposed implant surfaces, supports soft-tissue stability, reduces the risk of postoperative dehiscence or implant exposure, and may help seal a large visualisation opening to prevent sinus complications	Maintain the pedicled fat pad and gently position it over the critical area to enhance protection and healing when anatomical conditions require additional soft-tissue support
6.	Correct orientation of prosthetic axes	Prevents mechanical overload and prosthetic difficulties	Verify access direction before implant seating; use angled abutments if needed
7.	Selection of appropriate abutment height	Minimizes risk of mucosal impingement and biological complications	Slightly supragingival or juxtagingival positioning
8.	Tension-free, plaque-friendly suturing	Ensures predictable healing and avoids need to remove provisional prosthesis	Monofilament, resorbable, stable flap positioning
9.	Immediate loading with a rigid provisional	Splinting reduces micromovement and supports immediate function	Fixed full-arch bridge with no distal cantilever
10.	Definitive prosthesis designed for hygiene and passivity	Ensures long-term biomechanical and biological stability	CAD/CAM milled, trans-screwed, smooth transitions, passive fit confirmed

No, number; CBCT, cone-beam computed tomography; CAD/CAM, computer-aided design/computer-aided manufacturing used. The framework applies to sites at which zygomatic anchorage has already been indicated, and does not itself establish that indication. The surgical strategies associated with each grade describe the approach the authors have adopted and are not presented as recommendations of general applicability. Whether the framework improves preoperative decision-making, and whether the proposed strategies reduce complications, are questions the present article does not answer.

Conclusion

In cases where alveolar bone resorption precludes the use of conventional implants for complete maxillary rehabilitation, ZIs offer a predictable alternative. The use of ZIs provides conditions for immediate loading with a fixed provisional prosthesis, eliminates the need for bone grafting, reduces the number of surgical sessions, and reports a high success rate. Traditional bone classifications in the literature lack a precise description for zygomatic implantology. This article introduced a new categorization in zygomatic implantology – the Z-Classification concept, which stratifies anatomical diagnosis through a 6-grade scale. Additionally, the decision funnel for surgical strategy development and the structured checklists of the critical clinical parameters for long-term success in zygomatic rehabilitation were proposed. The presented tools will potentially optimize a complex decision-making algorithm in zygomatic implantology.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethical approval This article reports no individual patient data and no systematic collection of clinical records. Formal ethics committee review was therefore not required.

Competing interests S.Z. directs a continuing education course in zygomatic implant surgery. The other authors declare no competing interests.

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