

New **zygomatic** implant design

Adapting to the anatomy

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Introduction

This article introduces and explains the rationale for the two different designs of the Straumann zygomatic implant, which is the result of a collaboration between the authors and engineers over the last several years. It is based on many years of the application of evidence-based clinical principles and clinical outcomes using this zygomatic implant and on common fundamental values.

The evidence-based principles began with Per-Ingvar Brånemark in 1977 in severely atrophied maxillae caused by trauma, congenital conditions or tumour resection. Over the past three decades, many studies have reported a high success rate for rehabilitation with zygomatic

implants. Furthermore, retrospective studies span many years,^{1,2} and many take into consideration implant survival, patient satisfaction, and success and function of the prostheses.³ A recent systematic review in 2016, which included 68 studies and a total 4,556 zygomatic implants placed in 2,161 patients, reported a cumulative survival rate of 95.21% after 12 years of follow-up and concluded that zygomatic implants can be placed in patients with a high predictability of success.⁴ Therefore, zygomatic implants in combination with conventional implants in the anterior maxilla (Figs. 1 & 2) can be considered a valid alternative to grafting procedures in the atrophic maxilla (Figs. 3 & 4). The efficacy of this type of implant has also been highlighted in cases where total absence of the maxillary alveolar bone does not al-

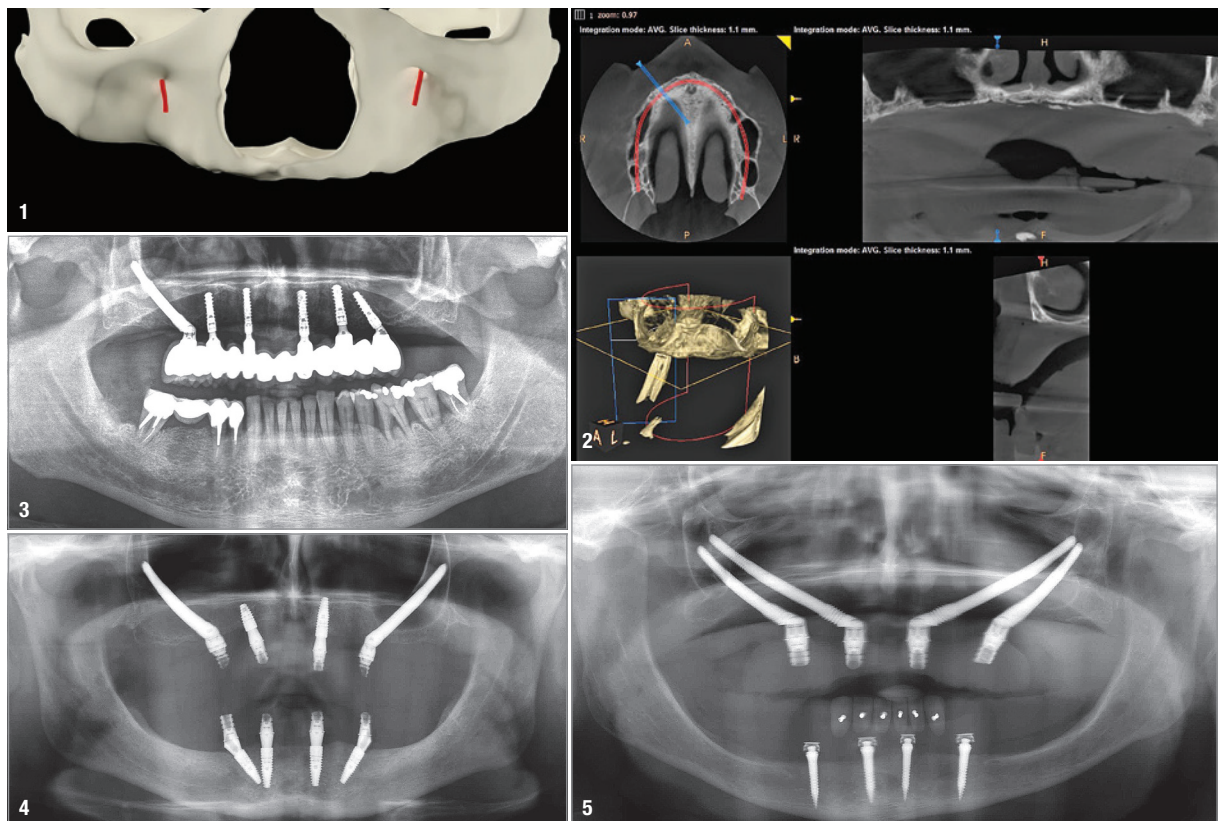
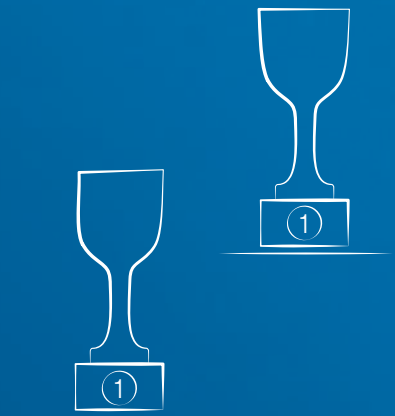


Fig. 1: Extremely resorbed maxilla visualised via 3D printing. **Fig. 2:** Severe alveolar bone resorption and maxillary sinus pneumatization. **Fig. 3:** One zygomatic implant in combination with conventional implants placed where the bone quantity was sufficient. **Fig. 4:** Two zygomatic implants with two conventional implants. **Fig. 5:** Four zygomatic implants in extremely resorbed maxilla.

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low for the placement of axial implants in the anterior maxilla; instead, the “quad zygoma” concept is considered (Fig. 5). Implant teams should bear in mind that the use of zygomatic implants is considered an advanced procedure, and surgeons placing this type of implant should be aware of the potential complications and the management of such complications.⁵

The common fundamental values are the importance of the patient, the service being provided to him or her, and the complications that we wish to avoid. The ultimate goal is to rehabilitate the masticatory function and aesthetics of the atrophied maxilla using a surgical and prosthetic procedure that is as safe and sustainable as possible. Implant design is crucial, and the key elements of success must be fully understood. An effective zygomatic implant requires multiple strategies, and each of its constituent parts must have a benefit, increase success and reduce risks. Changes to the original design include thread design and distribution, surface enhancement, implant diameter, angulation of the implant platform and modifications to the middle portion of the implant, resulting in two different zygomatic implant designs: round and flat.

Threads and primary stability

Primary stability must be obtained in cases of severe alveolar bone resorption and maxillary sinus pneumatization combined with poor bone quality.⁶⁻⁸ This crestal bone situation does not allow for the placement of a conventional dental implant without bone augmentation techniques such as sinus floor elevation or onlay bone grafting from an intra-oral or extra-oral donor site. Zygomatic implants are fixtures inserted through the residual alveolar crest, the final entry being into the base of the zygomatic bone and the exit of the apex of the implant at the lateral cortex of the zygomatic bone. Depending on the anatomy of the maxilla, the contour of the lateral maxillary sinus wall determines whether the middle portion of the implant is inside or outside of the sinus.

Thus, an optimised thread pitch is needed in the portion of the implant that crosses the zygomatic bone, and a coronal thread and micro-thread are needed for the crestal part. In the crestal bone, being D4 bone, achieving sufficient primary and secondary implant stability can be challenging. We must therefore achieve the highest possible osseointegration in the zygomatic bone. That is why the apical portion of the implant is tapered and sandblasted (Fig. 6) for better bone-to-implant contact. The tapered design provides good grip and anchoring and is an important factor in primary stability, allowing for an immediate loading protocol. Freedman et al. showed in their 2013 and 2015 finite element analysis studies that the primary support of occlusal loads is the crestal bone, which is preferred.^{7,8} To enhance the stability of the zygomatic

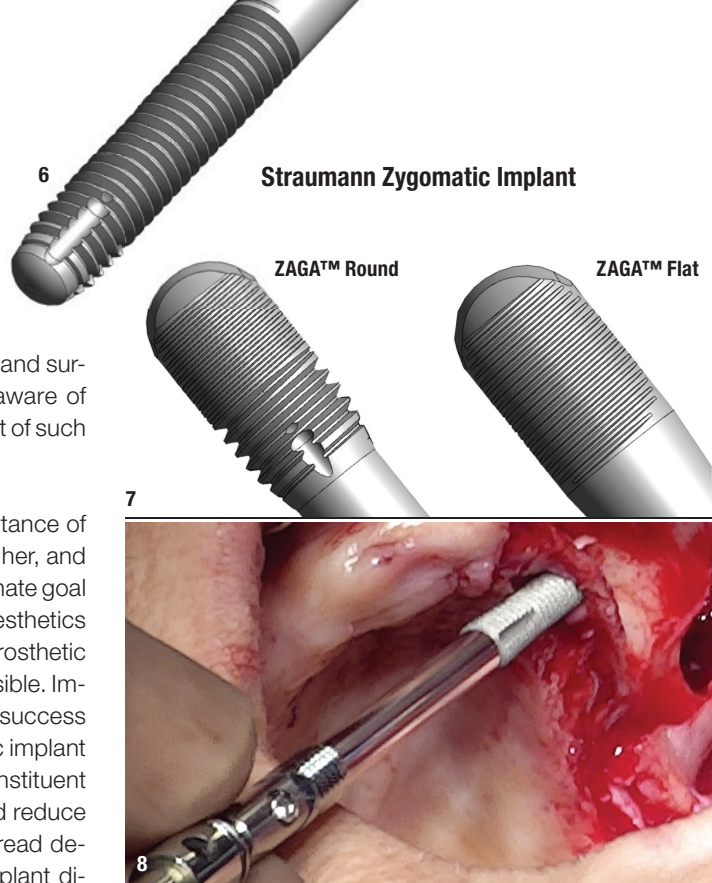


Fig. 6: Tapered design and sandblasted surface. **Fig. 7:** Coronal threads and micro-threads. **Fig. 8:** The combination of the two surfaces.

matic implant at the maxillary crest, coronal threads and micro-threads are present (Fig. 7). These stabilise the implant at the crest and stabilise the final bone level in line with the threads. In cases where the minimal crestal bone resorbs over time, the potential for peri-implantitis is minimised by the machined surface of the crestal threads.

Surface and efficiency

Each surface, whether machined or rough, has a specific benefit.⁹ Straumann® Zygomatic Implants combine the two, depending on their usefulness in each part of the implant (Fig. 8). The sandblasted rough surface inside the zygoma improves bone apposition on to the titanium surface and ensures higher osseointegration values in shorter healing times during the crucial transition between initial mechanical stability and secondary biological stability. This surface, combined with a high-grip design, allows for safer and faster osseointegration. However, it is important to wait six months for osseointegration before placing the definitive prosthesis, as a severely atrophied maxilla is being rehabilitated.

Bacterial adhesion and biofilm formation on the implant surface are often early steps towards peri-implantitis. This consideration led to the choice of a machined surface for the crestal part, which has threads and micro-threads to reduce bacterial colonisation and bone loss around the implant neck. All implants are clinically integrated and stable in the bone tissue; however, the machined surface requires more osseointegration time, but will have less bacterial adhesion. Moreover, immediately above the ma-



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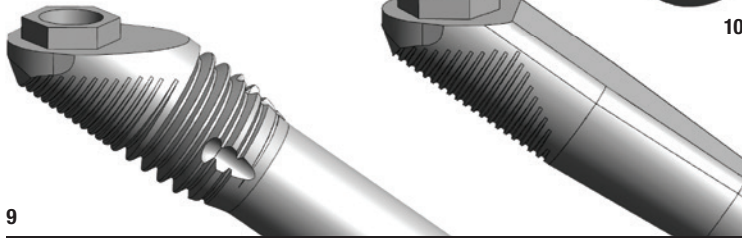
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Straumann Zygomatic Implant

ZAGA™ Round



ZAGA™ Flat

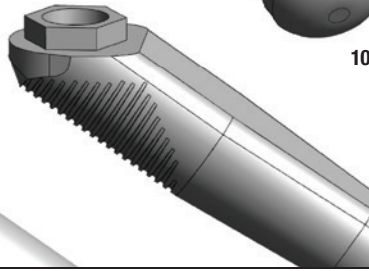


Fig. 9: Tissue-level neck for periodontal stability. **Fig. 10:** The tip of the Straumann® Zygomatic Implant is round and smooth.

chined part with threads within the bone, the platform of the implant, which is in contact with the gingiva, forms a neck-like tissue level that is smooth and without threads. Literature has confirmed that the source of sinus infections is not the presence of titanium within the sinus, but the introduction of bacteria into the maxillary sinus from the peri-implant sulcus in cases where crestal bone is absent.

The machined surface of the implant collar has resulted in the periodontal success of Straumann® Tissue Level implants. The same surface has been reproduced on the new Straumann® Zygomatic Implant, for which stability of the peri-implant soft tissue is essential to avoid oral-antral communication at the implant platform (Fig. 9). By the same token, the tip of the Straumann® Zygomatic Implant is round and smooth to help minimise the risk of soft-tissue irritation (Fig. 10). Subperiosteal infections, swelling and skin irritation are caused by an overextended apical portion due to incorrect measurement and excessive implant length, or the creation of particles and a lack of cleaning and irrigation during osteotomy preparation.⁵ The correct surgical procedure must avoid this problem, and the apical portion of the implant must transfix the zygomatic bone for quadricortical stabilisation, but must not protrude outside. The smooth and round tip of the Straumann zygomatic implant comes close to the zygomatic bone surface and will not cause damage.

Diameter and safety

When the flap is raised and the zygomatic bone is visualised, we can see that the surface for anchorage of the



Fig. 11: Placement of two tips in the zygomatic bone.

implants is not particularly large. Indeed, it is necessary to consider placing two zygomatic implants on each side. There are two positions for the placement of zygomatic implants (Fig. 11). The upper position is for the anterior implant in quad zygoma cases, and the lower position is for posterior zygoma cases in all other cases. Therefore, the surgeon should be conscious of the apical position of the zygomatic implant, even in cases where quad zygomatic implants are not planned. By keeping the apex of the zygomatic implant in the lower position, if needed, additional zygomatic implants may be placed in the upper position in cases where the anterior implant fails and there is no residual bone. Furthermore, the tip should not be set too low so as not to fracture the zygomatic bone, nor should it be set too high so as not to penetrate the orbit or the infratemporal fossa.

Owing to the long length of the implant and the complicated maxillary-zygomatic structure, it is crucial to have total mastery of the surgical procedure, meaning experienced surgeons with comprehensive training are required. To prevent penetration into the orbit or the infratemporal fossa, the basic surgical factor is direct visualisation of the tip of the drills as the osteotomies are prepared and of the tip of the implant as the fixture is inserted. As a result, the larger the implant, the greater the difficulty and risk. The size of the Straumann® Zygomatic Implant is ideal for improving patient safety: 2.6 mm at the apex and 3.4–3.9 mm for the tapered and threaded apical portion.

Two designs and different anatomical situations

The ZAGA (Zygoma Anatomy-Guided Approach) anatomic description takes into account the various relationships between both the implant platform and the middle portion of the zygomatic implant with the crest and the lateral maxillary wall (Fig. 12).^{10,11} The anatomical classification ranges from ZAGA 0—straight lateral maxillary wall with the platform on the crest and the middle portion of the zygomatic implant inside the sinus—to ZAGA 4—the most extreme resorption of the maxillary sinus with or without significant concavity of the lateral maxillary sinus wall. The presence of bone around the implant platform allows for better occlusal force distribution and connective soft-tissue fibre insertion. This buccal bone has a crucial influence on the stability of the facial gingival margin. In this case, the Straumann® Zygomatic Implant ZAGA™ Round should be used (Fig. 13). Indeed, the coronal threads and micro-threads stabilise the implant in the residual crestal bone, as well as at the bone level in line with the threads, and at the gingiva level in a sustainable manner.

However, in cases of extreme maxillary resorption and concavity of the sinus wall such as ZAGA 4, or in cases of total or partial maxillectomy, the zygomatic implant

Straumann Zygomatic Implant

ZAGA™ Round
ZAGA™ Flat

will be immediately below the soft tissue of the vestibule. Vestibular dehiscence is difficult to prevent. This exposure of the platform and the threads is due to muscle pull on the unattached soft tissue. To minimise this risk in these cases, the ideal implant is the Straumann® Zygomatic Implant ZAGA™ Flat because the flattened shaft allows the neck and the body to be as submerged in the bone crest as possible (Figs. 14 & 15). The partial distribution of the coronal threads helps to attain maximum bone-to-implant contact and completely seal the bone wound. Therefore, this implant, being firmly seated in the bone, allows for high anchoring despite severe atrophy. The flattened middle part and flattened coronal part without vestibular threads do not compress soft-tissue vascularity. Therefore, they do not cause irritation over the subperiosteal portion of the implant, and they avoid exposure and minimise long-term soft-tissue response.

A 55° platform, screw-retained abutment and prosthetic versatility

Zygomatic implants are inserted from the residual alveolar or basal bone to the frontal portion of the zygomatic bone. The axis between the bone crest and the zygomatic bone is upwards and outwards. Furthermore, the emergence position of the zygomatic implant can be at a more medial position compared with standard maxillary implants. There must be angulation between the body of the implant and the head. An angled head is preferred to a straight implant head offset by a highly angled abutment for mechanical reasons. The one-piece angled head with an external hex connection increases mechanical strength, guaranteeing long-term mechanical behaviour. The 55° platform provides a higher angle and versatility for the restorative occlusal table, allowing for its location and emergence in the prosthetic arch (Figs. 16 & 17). In most cases, despite resorption, all screw access holes come out on the occlusal aspect, and the implant neck in the bone crest, and are surrounded by bone as far as possible. The skills and abilities of the surgeon are necessary to achieve this and place a Straumann® Zygomatic Implant ZAGA™ Round.

Unfortunately, severe resorption of the maxillary crest is centripetal and decreases in the sagittal plane and can be similar to pseudo-prognathism in extreme cases. This discrepancy between the two jaws creates problems in rehabilitation because placing the implant head in the anatomical dental position means that it exits alveolar bone. In this ZAGA 4 anatomy, the zygomatic implant is placed outside of the crest and has lateral bone support at the implant platform. In this case, the bone is not sufficient to cover the middle portion or neck of the implant. It is important to perform an osteotomy, ensuring maximum coverage of the middle body and neck, and to place a Straumann® Zygomatic Implant ZAGA™ Flat, as

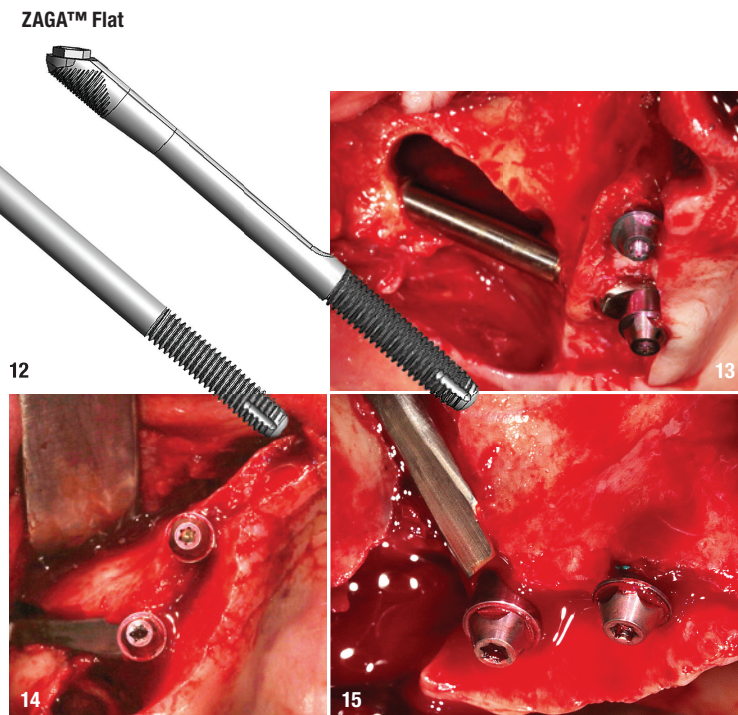


Fig. 12: Two designs for different anatomical situations. **Fig. 13:** Straumann® Zygomatic Implant ZAGA™ Round with coronal part surrounded by bone. **Fig. 14:** Straumann® Zygomatic Implant ZAGA™ Flat submerged as far as possible into bone crest. **Fig. 15:** The flattened middle part does not compress soft-tissue vascularity.

its coronal design and coronal micro-thread are adapted to this situation.

The optimal abutment height of between 1.5 and 4.5 mm can be chosen at the end of surgery, and the abutment will be torqued to 35Ncm (Fig. 18). A specific zygomatic screw-retained abutment was developed to ensure compatibility with the Straumann bone-level (BL, BLT, BLX) prosthetic portfolio for fixed prostheses (Fig. 19). This

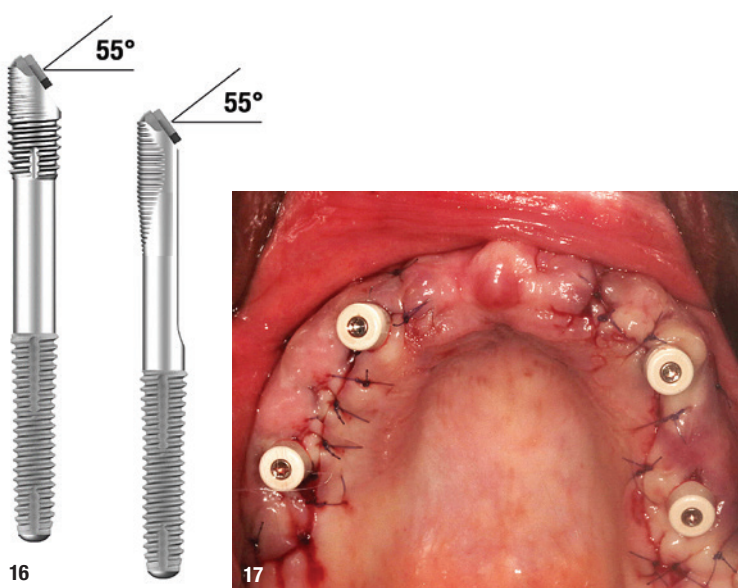


Fig. 16: The 55° platform provides a higher angle and versatility for the prosthesis. **Fig. 17:** Healing caps on the screw-retained abutments and crestal emergence on the prosthetic arch.

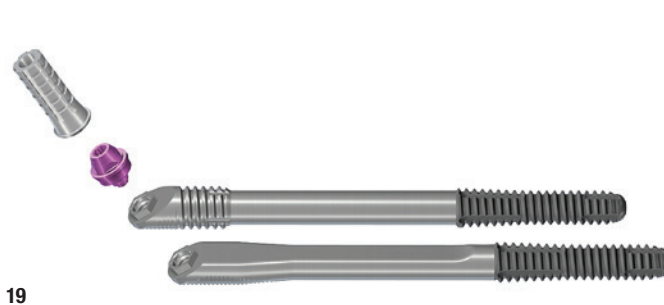
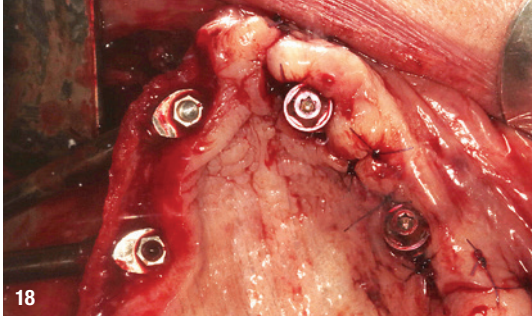


Fig. 18: One side with screw-retained abutment and one side before screwing on the abutments. **Fig. 19:** Specific zygomatic screw-retained abutment developed to ensure compatibility with the Straumann bone-level prosthetic portfolio. **Fig. 20:** CAD/CAM high-precision milled titanium bar (Createch Medical). **Fig. 21:** A prosthetic design without any concavity that might trap food and with spaces for cleaning.

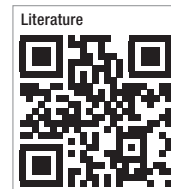
means that the prosthetic steps, whether for a temporary or definitive fixed restoration, are managed using existing products: Straumann screwdriver, impression copings, provisional titanium copings, and CAD/CAM high-precision milled titanium bar or cobalt–chromium framework (Createch Medical). Prosthodontic rehabilitation also plays an important role, and it is important to emphasise the design of a prosthesis without any concavity that could trap food and with cleaning spaces (Figs. 20 & 21).

Conclusion

When fixed rehabilitation for completely edentulous patients cannot be achieved using conventional implants only owing to bone resorption, there are two surgical alternatives: grafting and a graftless solution. Bone grafting is a long process in cases of severe atrophy, and sometimes the intra-oral donor sites are not sufficient and an extra-oral donor site is needed. Moreover, grafted bone resorption is common and unpredictable. A graftless solution using zygomatic implants is an effective option in atrophic jaws, and according to substantial data, it is a safe option in the management of severely resorbed edentulous maxillae. It decreases the time between surgery and fixed restoration, allows for a quick return to normal life thanks to immediate loading,¹² and increases comfort and quality of life for patients.¹³ Obviously, the use of zygomatic implants by surgeons who are not comfortable with the maxillofacial anatomy, the specific surgical protocol and the prosthetic vision is not recommended.

The Straumann® Zygomatic Implant ZAGA™ Round and Straumann® Zygomatic Implant ZAGA™ Flat designs are the result of the work and collaboration of three surgeons and engineers. Usually, the Straumann® Zygomatic Implant ZAGA™ Round is inserted through the maxillary crestal bone and is apically stabilised in the zygomatic bone. Individual anatomical differences mean

that there can be various relationships between the zygomatic implant and the ridge and the lateral maxillary wall. Moreover, each side may be different in the same patient. When the bone volume and the sinus are not sufficient to maintain close contact between the crestal bone and the implant (ZAGA anatomy Type 4), the implant body and neck must be as submerged as possible in the bone crest in order to avoid soft-tissue compression and dehiscence. In such cases, the Straumann® Zygomatic Implant ZAGA™ Flat implant is indicated. Each implant has been designed to adapt to the patient's anatomical situation, and each part of the implants has been designed to be effective and safe.



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