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The Rehabilitation of Partially Edentulous Maxilla With Unilateral Zygomatic Implants: A Retrospective Study up to 23 Years Follow-Up

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ABSTRACT

Objectives: This retrospective study aimed to evaluate the clinical outcomes associated with zygomatic implant (ZI) rehabilitation in partially atrophic edentulous maxillae over a mean follow-up period of more than 10.3 years.

Methods: All consecutive patients underwent ZI rehabilitation between 1999 and 2020, with a minimum follow-up period of 3 years. The primary outcome was the implant survaival rate. Secondary outcomes included the prosthesis success rate, complications, and Oral Health-Related Quality of Life.

Results: Of the 21 patients, treated with 27 ZIs and 48 conventional implants (CIs), 9 (42.9%) were females. The mean follow-up was 10.3 ± 5.7 years (range 3.2–23.4). ZI and CI survival rates were 100% and 97.9%, respectively, with one CI that failed. Eleven patients received 12 CIs placed in the pterygoid and tuberosity region. Most of the implants (81.33%) were immediately loaded, with 17 patients (80.9%) receiving 21 acrylic bridges. Of the total of 26 definitive prosthesis, the success rate was 96.1%. Local inflammation ($n = 2$) and soft tissue recession ($n = 1$) were reported as complications, occurring at a mean follow-up of 4.5 and 3.2 years, respectively. The mean score of the OHIP-14 questionnaire was 1.19 ± 1.99.

Conclusions: Unilateral ZI rehabilitation was a predictable option for patients with partially atrophic edentulous maxilla who have experienced previous graft or implant failures, or who require immediate loading. Splinting the ZI with CI for restoration appeared to be essential in unilateral ZI treatment. Complications were infrequent and could be managed effectively, with patient-reported outcomes indicating normalization in quality of life.

1 | Introduction

The zygomatic implant (ZI) treatment is recognized as a graftless solution for edentulous patients with severely atrophic maxillae (Brånemark et al. 2004). The outcomes have proven successful in the long term, reducing treatment time and providing immediate loading restoration for these challenging patients (Roper et al. 2023). Originally, the zygoma anchorage solution was developed for patients with maxillary deficiencies, particularly in cases of hemimaxillectomy (Parel et al. 2001). The reconstruction has demonstrated favorable functional results and patient satisfaction, offering an alternative to the traditional flap and grafting

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approach (Roper et al. 2023). However, the application of ZI in the partially edentulous maxilla rehabilitation still lacks evidence.

In the early 2000s, a couple of reports detailed the outcome of ZI use with delayed loading in partially edentulous maxillae as an alternative to graft approach (Parel et al. 2001; Pham et al. 2004). Subsequently, Davo et al. reported five patients who underwent partial restoration with the combination of ZI and conventional implants (CIs) with immediate loading, demonstrating a 100% 5-year survival rate (Davó, Malevez, and Pons 2013). Goker's study involving 32 patients treated with 34 ZIs and 31 CIs for partial edentulous rehabilitation reported no ZI failures over an average follow-up of 34 months (Goker et al. 2022). A recent systematic review outlined a protocol for the unilateral ZI treatment involving the placement the ZI splinted with one or more CIs in the edentulous side (Polido et al. 2023). However, the authors cautioned about the limited scope and number of studies, involving merely 14 patients, for evaluating these treatment outcomes and establishing possible indications (Polido et al. 2023). As compared to the use of ZI in full-arch rehabilitation, the biomechanical feasibility of splinting ZI with CI for partial bridges raises concerns due to the scarcity of data (Ujigawa et al. 2007), and the evidence supporting the use of unilateral ZI rehabilitation, in general, is still significantly weaker than that for established treatments like maxillary sinus floor elevation or short implants.

In 2023, the ITI consensus report in ZI critically evaluated unilateral rehabilitation in partially edentulous maxillae, with findings suggesting a need for broader research due to limited studies and short follow-up periods (Al-Nawas et al. 2023). Therefore, the aim of this retrospective study was to evaluate the survival, complications, and patient-reported outcomes associated with ZI rehabilitation in partially edentulous maxillae in consecutive patients, with a mean follow-up period of more than 10 years.

2 | Material and Methods

2.1 | Study Design and Population

This retrospective study included a cohort of patients who underwent rehabilitation in the partially edentulous maxilla with the ZI between November 1999 and February 2020 in the Department of Implantology and Maxillofacial Surgery of Medimar International Hospital in Alicante, Spain. The follow-up period ended in February 2024 with a minimal 36 months. The manuscript was prepared according to the Strengthening the Reporting of Observational Studies (STROBE) in Epidemiology (Vandenbroucke et al. 2007). The participants signed a general informed consent form as part of the hospital's standard protocol prior to the treatment, which adhered to the principles outlined in the Declaration of Helsinki on clinical research. The committee board of Health Centers, Services and Establishments, Hospital Vithas Medimar (Number 80), approved the use of human data for the study.

The inclusion criteria for ZI placement were as follows:

- Patients with partially edentulous maxilla with insufficient bone height and width in an edentulous area involving more than three teeth;
- Patients with a history of unsuccessful bone grafting or failure of CI treatment; maxillary posterior/anterior bone height ranging between 1 and 3 mm (Division d of Misch's Classification, Misch 1988);
- Insufficient bone width in the posterior/anterior maxillary area to place regular diameter implants without additional massive bone grafting or insufficient bone height for CI even with a tilted approach;
- Requirement for immediate prosthesis loading or refusal of bone grafts.

The exclusion criteria for ZI placement were as follows (Davó et al. 2023):

- General contraindications for implant surgery;
- History of radiation therapy in the head and neck in 1 year (> 70 Gy);
- Current heavy smoking (> 20 cigarettes/day);
- Restricted mouth opening (< 3 cm);
- Untreated maxillary acute or chronic sinusitis.

2.2 | Preoperative Evaluation

A panoramic and computed tomography (CT) or cone beam CT (CBCT) scan was carried out for diagnosing the degree of maxillary atrophy and planning treatment with dedicated software (Nobel Clinician; Nobel Biocare AB, Göteborg, Sweden). Atrophy was categorized according to Misch's Classification (Misch 1988). Occlusal relationships, mouth opening, intermaxillary distance, and status of the mandibular dentition were registered. Patients diagnosed with periodontitis who should retain the affected teeth were treated with antibiotics preoperatively. Patients diagnosed with maxillary sinusitis were treated before proceeding with the implant surgery. Patients with a smoking status were educated on the possible negative impact of smoking on the success of treatment. From 2006 onward, the ZI trajectory was planned according to a prosthetically driven implant positioning using the anatomy-guided approach (AGA) (Kämmerer et al. 2023).

Implant distribution adhered to the general principle of achieving optimal occlusion load, avoiding cantilever, and maintaining the integrity of the prosthetic reconstruction. In the CI planning, if the bone of the maxillary tuberosity was sufficient, the regular-sized implant was placed using an undersized drilling protocol to improve primary stability, while being splinted with ZI. If the tuberosity could not accommodate an implant, a pterygoid implant was angled at 45°–60° during insertion into the dense pterygoid bone, where the anchorage in the cortical bone engaged the pterygoid plate, also enhancing stability (Rodríguez et al. 2012).

The position and numbers of ZI and CI depended on the patient's atrophy:

- Patient presented three tooth gaps; at least two implants were planned (one ZI in the posterior zone and at least one CI in the anterior zone) (Figure 1).

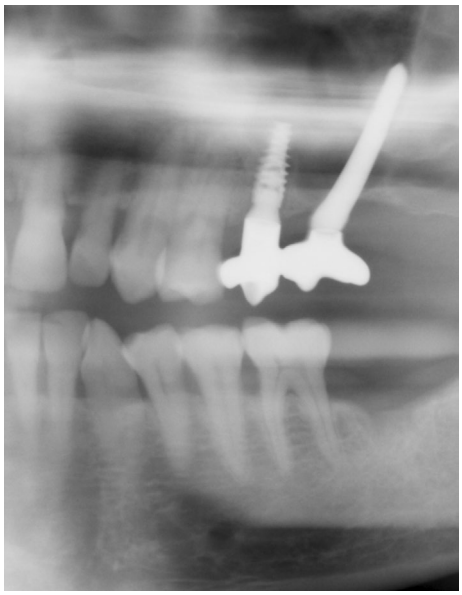

FIGURE 1 | Patient presenting with a three-tooth gaps: One ZI and one CI were planned and placed for the rehabilitation.

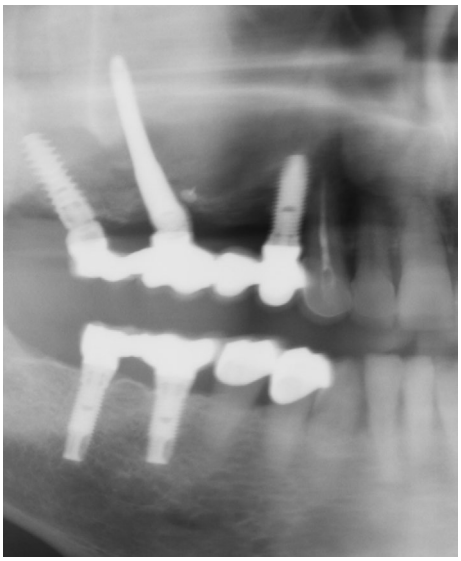

FIGURE 2 | Patient presenting with a four–six-tooth gaps. At least three implants were planned for the rehabilitation. In the case of insufficient residual bone in the premolar region, CI was planned to be placed in the tuberosity.

- Patient presented four– six tooth gaps: at least three implants were planned (either one ZI combined with two CIs or two ZIs combined with one CI). When possible, one ZI was placed in the first molar site and two CIs in the premolar sites. In patients with insufficient residual bone in the premolar region, a tuberosity or pterygoid implant was placed (Figures 2 and 3, Rodríguez et al. 2012; Sun et al. 2023).
- Patient presented more than six teeth gaps: at least four implants were placed (one ZI and three or four CIs) (Figure 4).

2.3 | Surgical Protocol

All surgeries were performed by the same surgeon (R.D.). From 1999 to 2016, 17 surgeries were conducted under general anesthesia; from 2016 onward, nine subsequent operations were managed with local anesthesia (Ultracin; Aventis Pharma, Paris, France), which was infiltrated in the maxillary vestibulum, around the area of the zygomatic bone, 1 cm palatally to the bone crest, without a need for IV sedation. The zygomatic area was exposed via an incision in the posterior maxilla, followed by a vertical releasing incision anterior to the surgical site. To improve the visibility of the drilling direction and the starting point at the crest, a small lateral bone window was made with spherical diamond burs (Komet Dental, Lengo, Germany). If needed, the maxillary sinus membrane was carefully elevated. ZIs were directed toward the zygomatic bone, anchoring them in the maxillary residual process and the zygomatic bone.

From 1999 to 2006, the classic intra-sinus technique described by Branemark was used for placing ZI (Figure 5). The original technique kept the implant platform palatal to the crestal ridge, followed the zygomatic crest into the sinus, and engaged in the zygoma (Brånemark et al. 2004). The sinus membrane was carefully dissected through a small lateral bone window to avoid membrane perforations. After 2006, the AGA technique was used for ZI insertion: the ZI trajectory was chosen according to the relationship between the ZI body and the maxillary sinus lateral wall, positioning the implant into intra-sinus, extra-sinus, or lateral wall of the maxilla (Figures 6, Davo et al. 2010). The alveolar process and the zygomatic bone were prepared with three drills used sequentially: a spherical bur and a cylindrical bur (ø 2.9 mm, Nobel Biocare AB or Straumann, Basel, Switzerland; or ø 3.5 mm, Nobel Biocare AB). Drilling was performed under constant saline irrigation to prevent overheating. ZIs were engaged at the zygomatic bone level avoiding impingement in the orbital cavity or the infra-temporal fossa. ZIs (Nobel Biocare AB, Göteborg, Sweden or Straumann, Basel, Switzerland) were inserted with a contra-angle handpiece with the torque preset above 35 Ncm, with the final adjustments for proper placement made using a manual wrench. After implant placement, multi-unit abutments (MUA; Nobel Biocare AB or Straumann) were placed, and the wound was closed with interrupted resorbable sutures (Vicryl Ethicon, Ohio, USA). Postoperatively, patients were given oral amoxicillin/clavulanic acid (875/125 mg) (GlaxoSmithKline, London, UK) or clindamycin (300 mg) (Pfizer, New York, USA), twice a day for 1 week; ibuprofen (600 mg) (Pfizer) 4 times a day during meals for 1 week (patients were instructed not to take ibuprofen in the absence of pain); xylometazoline hydrochloride (nasal decongestant) (Novartis, Basel, Switzerland) 1 mg, five drops twice a day for 2 weeks; and 0.2% chlorhexidine rinses (Isdin, Barcelona, Spain) twice a day for 2 weeks. All complications and adverse events were recorded.

2.4 | Immediate Loading, Prosthesis Design, and Follow-Up

For the patient who met the immediate loading criteria (insertion torque over 35 Ncm) and required immediate restorations, an impression was taken, and an acrylic bridge with temporary abutments was delivered within 48 h (Davó, Malevez, and Pons 2013). Immediate bridges had light contact in centric

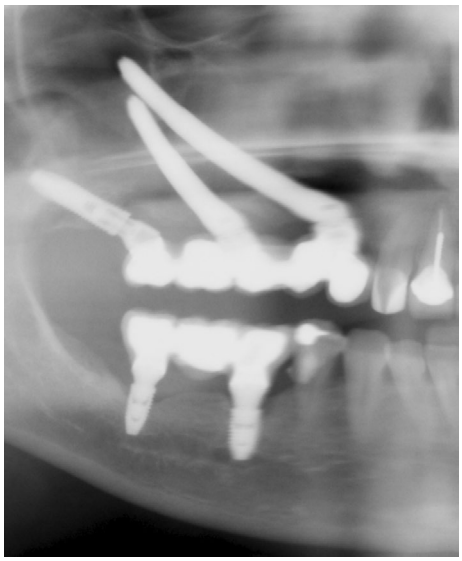

FIGURE 3 | In the case with insufficient residual bone in the premolar region, CI was placed tilted as pterygoid implant.

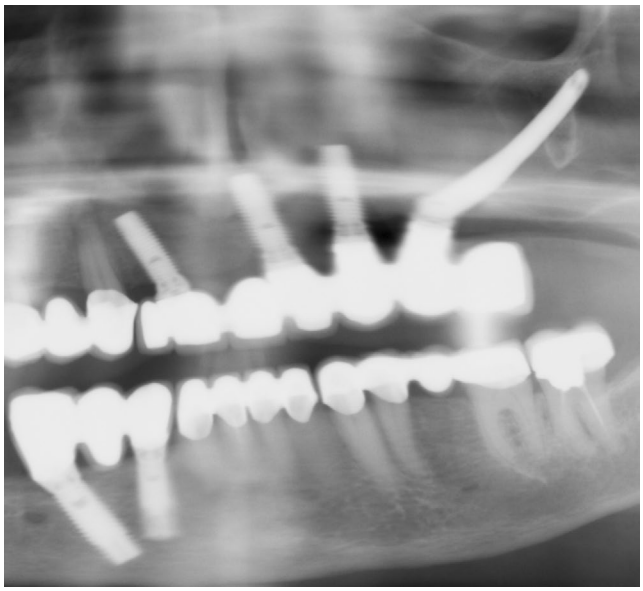

FIGURE 4 | Patient with seven teeth gaps. Four implants were placed (one ZI and three CIs).

occlusion and no contact in lateral or protrusive movements. Patients undergoing immediate loading were scheduled for follow-up appointments for occlusion checks and oral hygiene monitoring at 2 weeks, 1, and 3 months before the final impression was made.

Three months post-implant placement surgery, impressions were taken and a screw-retained implant-supported fixed bridge was delivered (Figures 5c and 6c). For treatment monitoring, panoramic radiographs were taken annually at each follow-up visit, while CT or CBCT scans were performed for patients presenting symptoms suggestive of complications, such as orofacial pain, swelling, local inflammation, infection, or sinus disorders. The prosthesis was removed either during the annual follow-up or in response to any complications reported by the patients.

2.5 | Study Endpoint and Statistical Analysis

The primary outcome measure of this study was the survival rates of ZI. Implant failure was defined as the loss of implant integration or unsolvable maxillary chronic pain/sinusitis or complications of the implant-prosthetic complex resulting in the removal of the implant.

The secondary outcomes were complications, such as sinusitis, local inflammation, soft tissue recession, and prosthetic mechanical problems. The perception of the Oral Health-Related Quality of Life (OHRQoL) was assessed by means of the self-administered oral health impact profile (OHIP-14) after loading of the definitive prosthesis (Slade 1997). It consisted of 14 questions, to which a score from 0 to 4 points could be assigned (totaling 0–56), with lower scores indicating a better quality of life. The normality of the data was evaluated using the Shapiro–Wilk test, and homoscedasticity was verified with Levene's test. Both assumptions were satisfied, allowing us to proceed with a standard *t*-test. The *t*-test was used to calculate the *t*-statistic and *p*-value to compare the mean OHIP-14 scores between two groups of patients: those with a follow-up of more than 10 years and those with a shorter follow-up. A *p*-value of < 0.05 was considered statistically significant. Analyses were conducted using the R and SPSS statistical software packages.

3 | Results

Although initially the study included 24 patients, 3 were excluded (2 did not attend follow-ups and 1 died due to unrelated cause), resulting in 21 remaining (12 male and 9 female) with the mean age of 54.5 ± 9.3 years. They received a total of 27 ZIs, which had a mean length of 43.8 ± 4.7 (range 35–52.5 mm) and comprised 21 Nobel Zygoma TiUnite (Nobel Biocare AB, Göteborg, Sweden) and six Straumann Zygomatic implants (Straumann, Basel, Switzerland). Five patients received two ZI-supported bridges (one on each side), while 17 were treated with only one ZI-supported bridge. Forty-eight CIs, with a mean length of 12.9 ± 1.7 mm (range 10–20 mm), were placed and splinted to 27 ZIs.

Prior to ZI surgery, three patients had a history of unsuccessful outcomes from previous treatments, which included one maxillary lateral sinus floor lift and guided bone regeneration (GBR) failure, and two experienced implant failures. In relation to Misch's Classification, all patients presented division d in the ZI implanted site (Misch 1988). Patient and implant data is shown in Table 1.

The mean follow-up period of ZI was 10.3 ± 5.7 years (range 3.2–23.4 years). Three patients (14%) had a mean follow-up from 3 to 5 years, 9 (43%) from 6 to 10 years, and 9 (43%) over 10 years.

3.1 | Implant Survival and Prosthesis Successful

The survival rate was 100% for ZI and 97.9% for CIs with only one CI lost 1 year after placement. A majority of patients (17; 80.9%) were eligible and desired immediate loading. They received 21

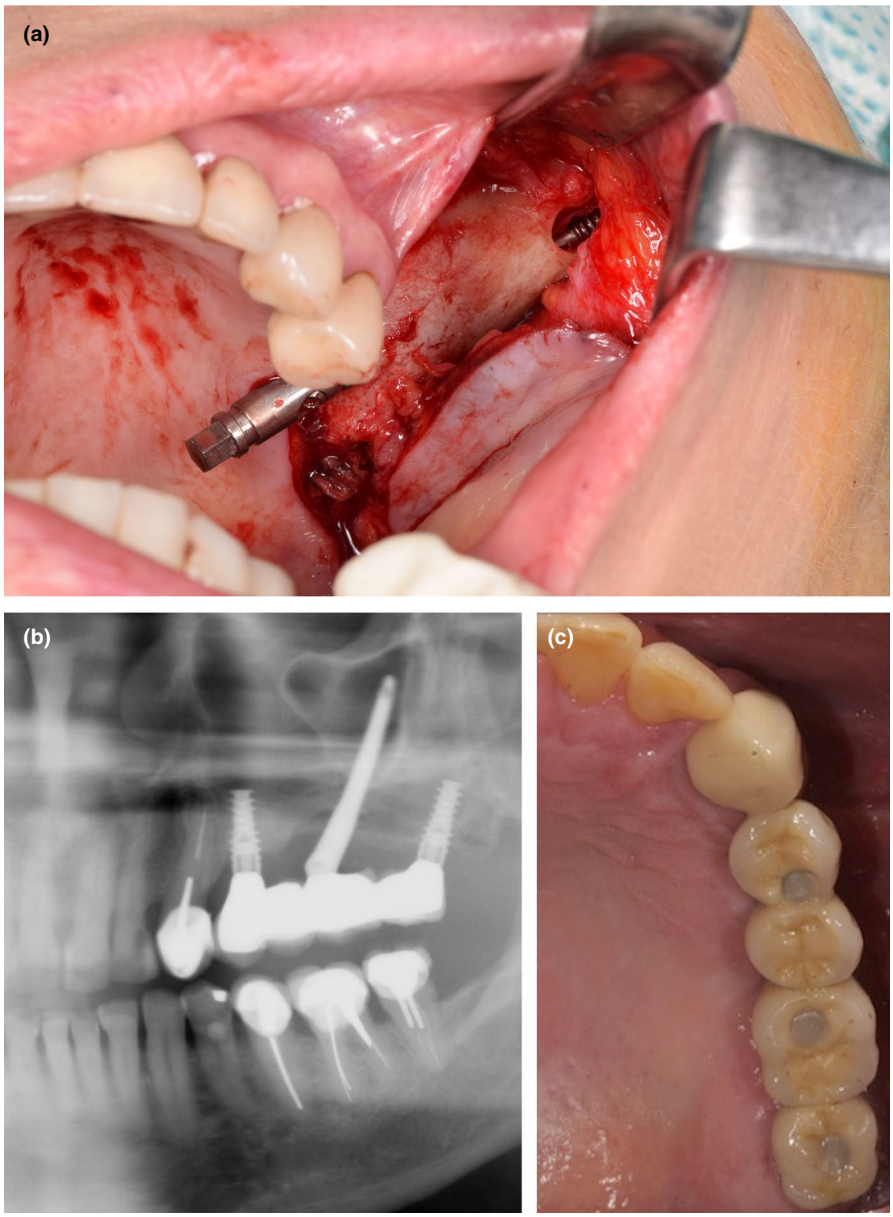

FIGURE 5 | (a) The insertion of ZI was through the intra-sinus pathway. A CI was placed posteriorly. (b) the panoramic radiograph showing that the patient had received one ZI and two CIs for the fixed bridge rehabilitation. (c) Intra-oral photograph showing the restoration of a unilateral ZI functioning successfully after 4 years of follow-up.

of ZIs and 40 of CIs, which were loaded with 21 bridge prostheses (80.7%). Those patients (5; 23.8%) who did not request immediate restoration had delayed loading. The implant distributions and rehabilitation units are provided in Table 1.

Twenty-six implant-supported fixed bridges were delivered ($n = 26$), with only one prosthesis failure. One patient initially underwent unilateral rehabilitation on the partially edentulous left side, achieving 8 years of functional loading. Subsequently, the remaining teeth were extracted, and the patient received an additional ZI and a CI on the right side. These implants were then splinted with the left-side implants to facilitate a full-arch reconstruction.

Nineteen patients received 24 (92.3%) zirconia bridges as final restoration, and two patients had metal and acrylic bridges (7.7%). To avoid extensive cantilevers, 11 patients had seven CIs placed in the pterygoid region (with 1 patient receiving a 30° angular MUA, 3 receiving a 17° angular MUA, and 2 a straight MUA) and five in the tuberosity (with all five receiving a straight MUA). Additionally, 5 patients (23%) with five bridges had a cantilever of one crown (1 first molar and 4 s molars) due to insufficient bone in the posterior maxilla. This approach was also taken in the case that had an implant failure.

3.2 | Surgical, Biologic, and Mechanical Complications

No significant surgical complications were reported during the procedures. One ZI experienced a buccal soft tissue recession of 3–4 mm after 3.2 years of placement, for which implantoplasty

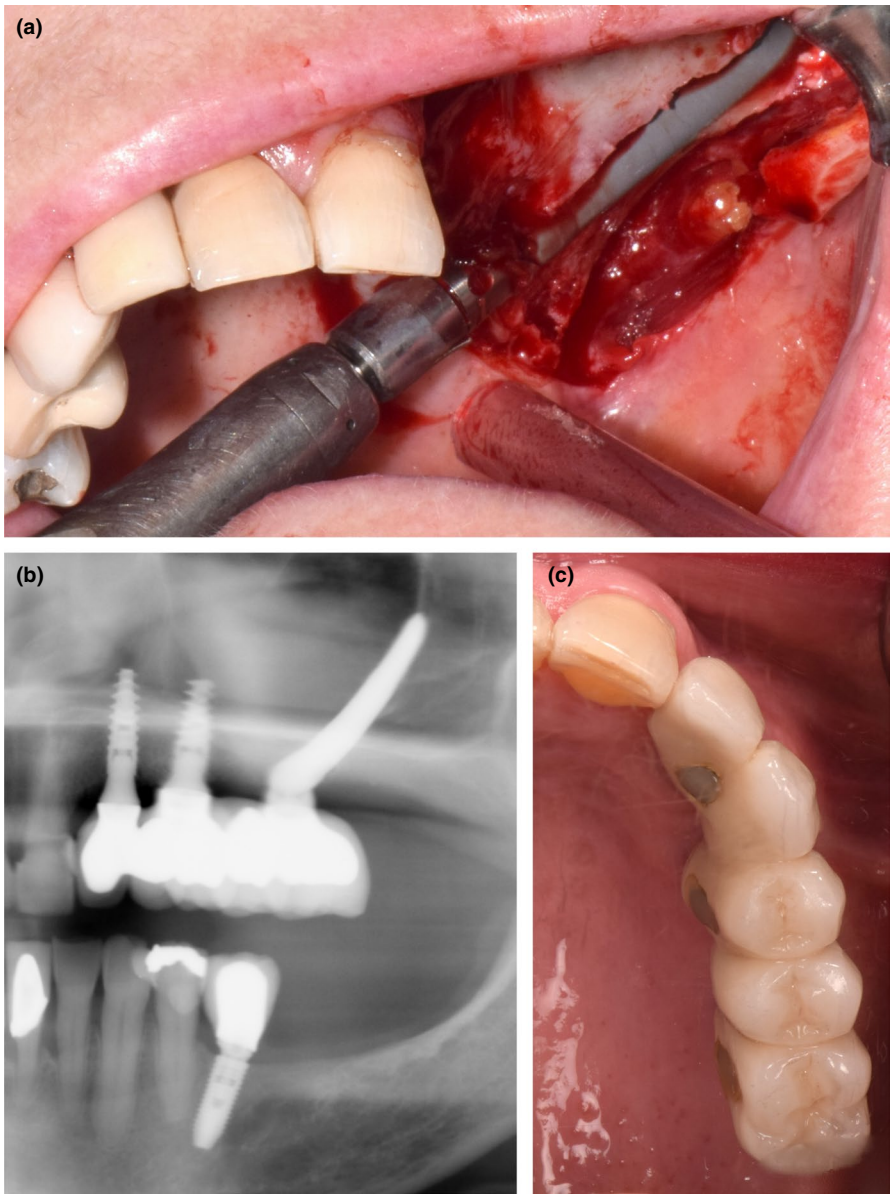

FIGURE 6 | (a) The insertion of ZI was through the lateral wall of the sinus pathway. (b) The panoramic radiograph showing that the patient received one ZI in the first molar region and two CIs in the anterior region for fixed bridge rehabilitation. (c) Intra-oral photograph showing the restoration of a unilateral ZI functioning successfully after 9 years of follow-up.

was performed. Two patients experienced local orofacial inflammation at a mean of 4.5 years after placement, manifested as pain and facial swelling, but they recovered with anti-inflammatory medication. Sinusitis was not observed, neither through the type of the acute symptoms nor radiographic diagnostics. Furthermore, one abutment screw fractured 5.2 years post loading.

3.3 | Patients Reported Outcomes

All patients (100%) completed the OHIP-14 questionnaire. The mean score was 1.19 ± 1.99. Patients with a follow-up of more than 10 years ($n = 9$) showed lower mean scores, reflecting a more favorable perception of their quality of life as compared to those ($n = 12$) with a shorter length of follow-up (0.79 ± 0.67 vs. 1.50 ± 2.58), although differences were not significant ($p = 0.21$).

4 | Discussion

The present study assessed the clinical outcomes of the use of unilateral ZI with CI for rehabilitation in partially edentulous atrophy maxilla, demonstrating a high survival and successful rate. To our knowledge, this is the first study that focused on this treatment modality and the accompanying patient-reported outcomes, furnishing an average observation period exceeding 10-year. The findings suggest that this treatment is predictable and its complications are manageable, offering a viable alternative for patients with previous failed implantation or grafting treatment. Moreover, it could enable the provision of immediate

TABLE 1 | Baseline characteristics of patients and implants.

Characteristics		Number (%)
Patients[a]		
Sex	Men	12 (57.1)
	Women	9 (42.9)
Health history	Hypertension	2 (9.5)
	Hypothyroidism	0 (0)
	Cancer	0 (0)
	Use of diphosphonates	0 (0)
	Ischemic heart disease	0 (0)
	Sinusitis (treated)	1 (4.7)
Smoking status	Yes	7 (33.3)
	No	14 (66.7)
Previous failed implant/Bone grafting	Yes	3 (14.2)
	No	18 (85.8)
Bone atrophy (Misch's classification)	Division d	21 (100)
Implants[a]		
ZI system	Nobel Biocare	21 (77.7)
	Straumann	6 (22.3)
ZI surgical approach	Branemark approach	3 (11.1)
	AGA	24 (88.9)
ZI length, mm	35.0	3 (11.1)
	37.5	1 (3.7)
	40.0	3 (11.1)
	42.5	5 (18.5)
	45.0	8 (29.6)
	47.5	2 (7.4)
	50.0	4 (14.8)
	52.5	1 (3.7)
ZI position	Canine	2 (7.5)
	First premolar	1 (3.7)
	Second premolar	4 (14.8)
	First molar	20 (74.0)
Abutment of ZI	Straight multi-unit abutment	24 (88.9)
	17° multi-unit abutment	3 (11.1)
CI position	First incisor	4(8.3)
	Lateral incisor	2(4.1)
	Canine	7(14.5)
	First premolar	15 (31.2)
	Second premolar	7 (14.5)
	First molar	0 (0)
	Second molar	1 (2.0)
	Tuberosity	5 (10.4)
	Pterygoid region	7 (14.5)
Abutment of CI	Straight multi-unit abutment	40 (83.4)
	17° multi-unit abutment	7 (14.5)
	30° multi-unit abutment	1 (2.1)

(Continues)

TABLE 1 | (Continued)

Characteristics		Number (%)
Prosthesis[a]		
Implants distribution[b]	CZ	6 (23.0)
	CCZ	5 (19.2)
	CZC	1 (3.8)
	CZP	6 (23.0)
	CZT	5 (19.2)
	ZZP	1 (3.8)
	CCCZ	1 (3.8)
	CCCCZ	1 (3.8)
Loading protocol	Immediate loading	21 (80.7)
	Delay loading	5 (19.3)
Rehabilitation units	3	6 (23.0)
	4–6	15 (57.7)
	> 6	5 (19.3)
Fixation type	Screw-retained	26 (100)
Material	Ceramic bridge	24 (92.3)
	Hybrid bridge	2 (7.7)
Posterior cantilever	Yes	5 (19.3)
	No	21(80.7)

Abbreviations: AGA, anatomical-guided approach; C, conventional implant; P, pterygoid implant; T, implant placement in tuberosity; Z, zygomatic implant.
[a]The total number of patients, ZIs, CIs, and prostheses were 21, 27, 48, and 26, respectively.
[b]The implant distribution was by order from anterior to posterior.

restoration for patients meeting the necessary criteria and requirements.

Nowadays, the majority of the evidence of unilateral ZI treatment stems from patients using ZI-supported obturators to treat post-hemimaxillectomy defects (Molinero-Mourelle et al. 2020). Clinical outcomes for these patients have varied widely, with overall survival rates ranging from 77% to 100% (Hackett, El-Wazani, and Butterworth 2020). This variation might be attributed to tumor recurrence, thickness of the soft tissues, or loss of osseointegration (Chrcanovic, Albrektsson, and Wennerberg 2016). The primary cause of failure in this treatment may be the lack of ridge anchorage and recurring inflammation around peri-implant tissue. In the present study, which focused on continuous maxillae, all patients had atrophic residual ridges, but without loss of continuity, and soft tissues around the ZI head were able to remain stable. This could explain the better survival observed in partially edentulous patients compared to those with maxillary defects.

Previous unsuccessful experiences with sinus floor elevation or implant treatment were among the criteria for enrolling patients in the study. Sinus floor elevation in cases of insufficient posterior bone height is still considered the gold standard for implant therapy. However, the patients with the extremely severe bone atrophy usually need with a combined horizontal and/or vertical GBR (Corbella, Taschieri, and Del Fabbro 2013). Reliability of these procedures depends on several risk factors that may affect the surgical procedure and outcomes, such as the presence of sinus septa, membrane thickness, vascularity, types of defect, and dehiscence (Testori et al. 2019). ZI is considered a valid option for patients with a severely atrophic edentulous maxilla who have experienced treatment failures or complications.

Moreover, while most evidence continues to support staged rehabilitation involving lateral sinus lift procedures, only a limited number of studies have demonstrated the feasibility of achieving immediate loading in cases with limited bone quantity. In the present study, 80.9% of patients opted for the immediate loading protocol, which was possible due to the primary stability of the implant. Therefore, ZI solutions for the partially edentulous maxilla are not limited to cases of implant/grafting failure but also can benefit patients requiring immediate function.

The qualification of surgeons performing zygomatic implant procedures was addressed in the ITI ZI Consensus, which emphasizes that clinicians must possess the necessary skills and experience to effectively manage potential difficulties and complications (Al-Nawas et al. 2023). Although major complications, such as orbital penetration, appear to be rare, the surgical technique for placing ZI still presents significant challenges due to the zygoma's irregular shape and the length of the implants (Kämmerer et al. 2023). This complexity makes ZI placement one of the most demanding tasks for dentists and oral surgeons. Particularly in partially edentulous cases, the limited operational space for preparing the implant site poses a substantial difficulty. Surgeons must carefully protect the opposing teeth, which may obstruct the drilling trajectory and complicate implant placement. In the author's experience, the use of a contra-angle handpiece is highly reliable for unilateral ZI procedures in partial edentulism. The surgical navigation system appears to be an excellent tool to enhance the safety and precision of ZI

placement (Wu et al. 2022; Fan et al. 2023), which improves the learning with increased practice (Wang, Zhuang, et al. 2022). Although to date no study has specifically focused on utilizing this technique for the unilateral ZI approach, the reports of ZI use in hemimaxillectomy cases implied acceptable accuracy with the navigation approach (Wang, Fan et al. 2022).

This study portrays the evolution of surgical techniques over a 23-year period. Prior to 2006, three ZIs in three patients were placed using the Brånemark intra-sinus approach, palatally entering the residual ridge and reaching the zygoma bone through the maxillary sinus (Brånemark et al. 2004). Subsequently, all other placements adhered to the anatomy-based AGA, such as intra-sinus, extra-sinus, and in-the-sinus-wall techniques (Davo et al. 2010). Recent systematic reviews have shown that both the Brånemark and AGA techniques demonstrated high implant survival across 25 studies (Kämmerer et al. 2023). However, the Brånemark intra-sinus approach was associated with a higher risk of sinusitis and peri-implant inflammation than AGA. In the present study, sinusitis was not observed, likely due to the specific parameters, including the limited number of patients and the use of unilateral procedures, which may have contributed to this outcome. Additionally, the intra-sinus technique was avoided in cases where the patient's sinus concavity was not pronounced (Davó and Fan 2024). Larger studies with a more extensive patient cohort are needed to fully assess the potential risk of sinusitis in cases of unilateral ZI rehabilitation.

The concept of splinting in ZI rehabilitation was introduced in both the classic and quad approaches to achieve cross-arch stabilization for immediate rehabilitation and definitive prosthesis in completely edentulous patients (Vrielinck et al. 2022; Davó et al. 2023). In a recent study by Davo, involving 56 patients with the quad approach, a 97.7% survival rate was reported after 8 years (Davó et al. 2023). All patients received an immediate loading protocol, suggesting that immediate restoration could offer benefits in stabilizing ZIs through cross-arch stabilization. Finite element analysis showed that splinting only two ZIs unilaterally can lead to overload under masticatory forces (Ujigawa et al. 2007). Therefore, the splinting of unilateral ZI with at least one CI remains a fundamental treatment principle. In the present study, a minimal placement approach was applied in six patients who presented with a gap of three teeth, utilizing a single ZI and a single CI. As a result, the placement of two implants was considered sufficient for rehabilitation. Moreover, if an additional CI had been feasible, the use of a ZI would not have been necessary. However, in Goker's study, which involved 34 patients treated with unilateral zygoma (Goker et al. 2022), three patients (two with two ZIs and one with one ZI) underwent exclusively ZI rehabilitations, indicating a need for further investigation into the long-term feasibility of such treatment.

The use of regular-length CIs in conjunction with ZIs in the severe edentulous maxilla has been recommended since the early studies by Prof. Branemark and Prof. Malevez (Brånemark et al. 2004; Malevez et al. 2004). Both studies demonstrated that short implants had a lower survival rate compared to regular-length implants when splinted with ZIs in the edentulous maxilla. This protocol has also been followed by the author in unilateral ZIs rehabilitation. More recently, Vrielinck and colleagues (Vrielinck, Blok, and Politis 2022) reported cumulative survival rates of CIs in ZI treatments at 10, 15, and 20 years, with survival rates of 90.5%, 81.6%, and 67.7%, respectively. Significant risk factors for CI failure included bruxism, overdenture design, and the use of implants shorter than 10 mm. Based on this evidence, the use of short implants in combination with ZIs is not recommended.

Patients treated with ZI rehabilitation experienced immediate prosthetic reconstruction in both function and anatomy, achieved through less invasive surgery (Al-Nawas et al. 2023). The present study employed OHIP-14 questionnaires to assess overall satisfaction, yielding a normalization level (1.19 ± 1.99) that is comparable to the score following lateral maxillary sinus augmentation (2.4 ± 3.7, Schiegnitz et al. 2017), which stands at 1.19. The limitations of the present study included its retrospective design and the small sample size (Talari and Goyal 2020). Additionally, CT/CBCT imaging was only systematically documented for patients with major complications, making it impossible to accurately assess the trajectories of all ZIs. Further clinical studies (especially randomized control trials) should assess the feasibility of unilateral ZI treatment compared with extra short implant rehabilitation or maxillary sinus floor augmentation in the partially edentulous maxilla.

5 | Conclusion

The ZI treatment represented a predictable option for patients with partially atrophic edentulous maxilla who have experienced previous graft or implant failures, or who require immediate loading. Splinting ZI with CI in the restoration was considered important in unilateral ZI treatment. Complications were infrequent and could be managed effectively, while the patient-reported oral health-related quality of life indicated normalization.

Author Contributions

Shengchi Fan: conceptualization, data curation, investigation, writing – review and editing, writing – original draft, methodology, formal analysis, project administration. **Ruben Davo:** conceptualization, methodology, data curation, investigation, visualization, writing – original draft, writing – review and editing. **Bilal Al-Nawas:** writing – review and editing, supervision, project administration. **Eduard Valmaseda Castellón:** writing – review and editing, supervision, formal analysis.

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Ethics Statement

The ethical approval from the review board of Hospital Medimar Internacional to use human data for the study was obtained.

Conflicts of Interest

Dr. Ruben Davo serves as an advisor and global speaker for Nobel Biocare; Dr. Eduard Valmaseda-Castellón is a recipient of grants, including non-financial support, and/or personal fees from MozoGrau, Inibsa Dental, Dentaid SL, BioHorizons Iberica, Laboratorios Silanes, Geistlich Pharma AG, and Mundipharma. Other authors declare no conflicts of interest.

Data Availability Statement

The data are available from the corresponding authors upon reasonable request.

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