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Case Report

Conservative management of a cervically fractured zygomatic implant using a novel titanium device: a technical report with biomechanical validation and 24-month follow-up

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ABSTRACT

Fracture of a zygomatic implant is an uncommon but clinically challenging complication. Conventional management generally involves implant removal or alternative anchorage strategies, both of which may require extensive surgery, increase patient morbidity, and compromise an existing implant-supported rehabilitation.

This technical report describes the development, biomechanical validation, and first clinical application of a novel prosthetic rescue device for the conservative management of cervical fractures of zygomatic implants while preserving the osseointegrated apical segment.

A customized Grade V titanium device incorporating an internal threaded connection and supplementary self-tapping fixation screws was specifically designed to restore the fractured implant. Biomechanical performance was assessed by dynamic fatigue testing according to ISO 14801. The device was subsequently used in a 60-year-old woman presenting with a cervical fracture of a zygomatic implant. Placement was performed using a surgical guide, and the device was secured with an insertion torque of approximately 20 Ncm.

Fatigue testing demonstrated mechanical resistance exceeding five million loading cycles under a maximum load of 129 N. At the 24-month follow-up, the patient remained free of mechanical or biological complications, with stable clinical and radiographic findings and successful maintenance of the implant-supported prosthetic rehabilitation.

This case suggests that the proposed prosthetic rescue device may represent a minimally invasive alternative to implant removal in carefully selected cases of cervical fracture of zygomatic implants with a stable osseointegrated apical segment. Further clinical studies are required to confirm the reproducibility, long-term mechanical performance, and clinical predictability of this approach.

1. Introduction

Fracture of a zygomatic implant is an uncommon but potentially devastating complication, as it may compromise the biomechanical stability of complex implant-supported rehabilitations and necessitate extensive surgical procedures associated with increased patient morbidity [1,2].

Rehabilitation of the severely atrophic maxilla with zygomatic implants has become a predictable treatment option when conventional implant placement is not feasible, demonstrating high survival rates and favorable long-term functional outcomes [3,4].

Despite these encouraging results, both biological and mechanical complications may occur during long-term follow-up. Among them, implant fracture represents a rare but clinically challenging event that may jeopardize the stability of the prosthetic rehabilitation and considerably complicate subsequent treatment [5,6].

When fracture of a zygomatic implant occurs, management has traditionally relied on implant removal or the identification of alternative prosthetic anchorage sites. However, these approaches often require extensive surgical procedures, increase patient morbidity, and may compromise immediate prosthetic rehabilitation, particularly in patients restored with full-arch implant-supported prostheses [7,8].

From a biomechanical perspective, implant fractures are generally considered the consequence of cyclic fatigue caused by repeated functional loading over time [9]. In zygomatic implants, these mechanical demands may be further influenced by implant length, angulation, and the biomechanical characteristics of full-arch rehabilitations in severely

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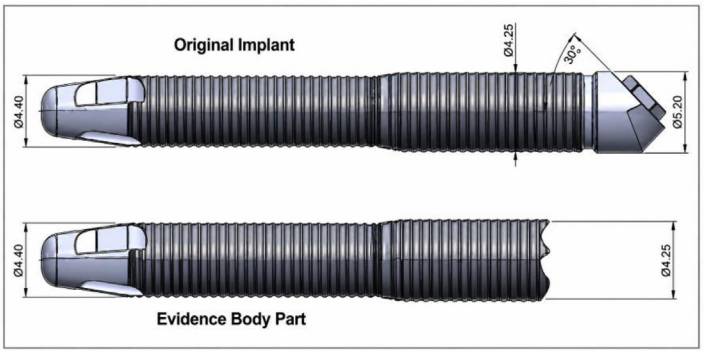

Fig. 1. Schematic of a standard implant and fractured test specimen.

atrophic maxillae [10]. Consequently, the development of conservative strategies capable of preserving the osseointegrated implant remnant may represent a clinically relevant and less invasive therapeutic alternative.

To the best of our knowledge, no previous publication has described a prosthetic rescue device specifically designed for the conservative management of cervical fractures of zygomatic implants while preserving the osseointegrated apical segment.

Therefore, the aim of the present technical report was to describe the development and first clinical application of a novel prosthetic rescue device for the conservative management of cervical fractures of zygomatic implants, including its biomechanical validation by dynamic fatigue testing according to ISO 14801 and its clinical performance after a 24-month follow-up.

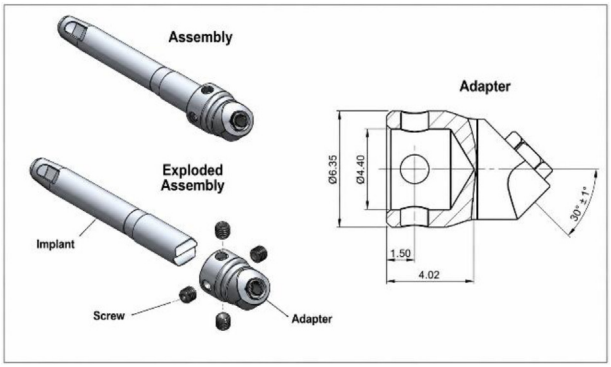

Fig. 2. Schematic and assembly of samples with device.

2. Technical-clinical case

2.1. Development and biomechanical validation of the prosthetic rescue device

Implant fracture is generally considered the result of mechanical fatigue caused by repeated functional loading over time, even when applied forces remain below the ultimate strength of the material [9]. In zygomatic implants, these mechanical demands may be further influenced by implant length, angulation, and the biomechanical characteristics of full-arch rehabilitations in severely atrophic maxillae [10] (Fig. 1).

To provide a conservative alternative to the removal of cervically fractured zygomatic implants, a customized prosthetic rescue device was developed in collaboration with the Research and Development Department of S.I.N. Implant System (São Paulo, Brazil). The device was manufactured from Grade V titanium alloy (Ti-6Al-4 V), a material widely used in implant dentistry because of its excellent mechanical properties and biocompatibility.

The device was designed to reproduce the prosthetic geometry of the original implant while incorporating an internal threaded connection that allowed direct fixation to the remaining implant body after fracture. To enhance mechanical stability and permit prosthetic alignment, four lateral holes were incorporated for supplementary fixation screws. These screws were self-tapping, eliminating the need for additional drilling during placement (Fig. 2).

The mechanical performance of the system was evaluated by dynamic fatigue testing performed in accordance with the ISO 14801 standard, which represents the internationally accepted reference method for the mechanical evaluation of endosseous dental implant systems and implant–abutment connections [11,12].

Previous studies have demonstrated that the design of the implant–abutment interface significantly influences fatigue resistance and fracture behavior under cyclic loading [9,13,14].

In the present study, the implant–device assembly successfully withstood 5 million loading cycles under a maximum load of 129 N, demonstrating mechanical performance within the range reported for external hex implant connections evaluated under comparable fatigue-testing conditions (Fig. 3).

These findings support the mechanical feasibility of the proposed prosthetic rescue device and suggest that it may provide adequate mechanical stability for clinical application in carefully selected cases.

Nevertheless, the mechanical behavior of implant-supported systems is influenced by multiple factors, including implant geometry, implant–abutment connection design, material properties, and functional loading conditions [15]. Consequently, the proposed device should be considered primarily for cervical fractures in which the apical zygomatic anchorage remains stable and osseointegrated, as disruption of this anchorage would likely compromise the mechanical performance and clinical applicability of the proposed approach.

2.2. Initial impression

This study was conducted as a clinical case report. According to institutional guidelines, ethical committee approval was not required. Written informed consent was obtained from the patient for the treatment and for the publication of clinical data and images.

A 60-year-old woman presented to the Department of Oral and Maxillofacial Surgery at with a fractured zygomatic implant in the left posterior maxilla. The fracture occurred approximately seven years after implant placement.

The patient's medical history was non-contributory, with no relevant systemic diseases, ongoing pharmacological treatment, or known allergies.

The patient had previously undergone rehabilitation of a severely atrophic maxilla using two zygomatic implants in the posterior regions and two conventional axial implants in the anterior maxilla (S.I.N. Implant System, São Paulo, Brazil), supporting a full-arch fixed implant-supported prosthesis with a titanium framework and acrylic resin teeth Table 1.

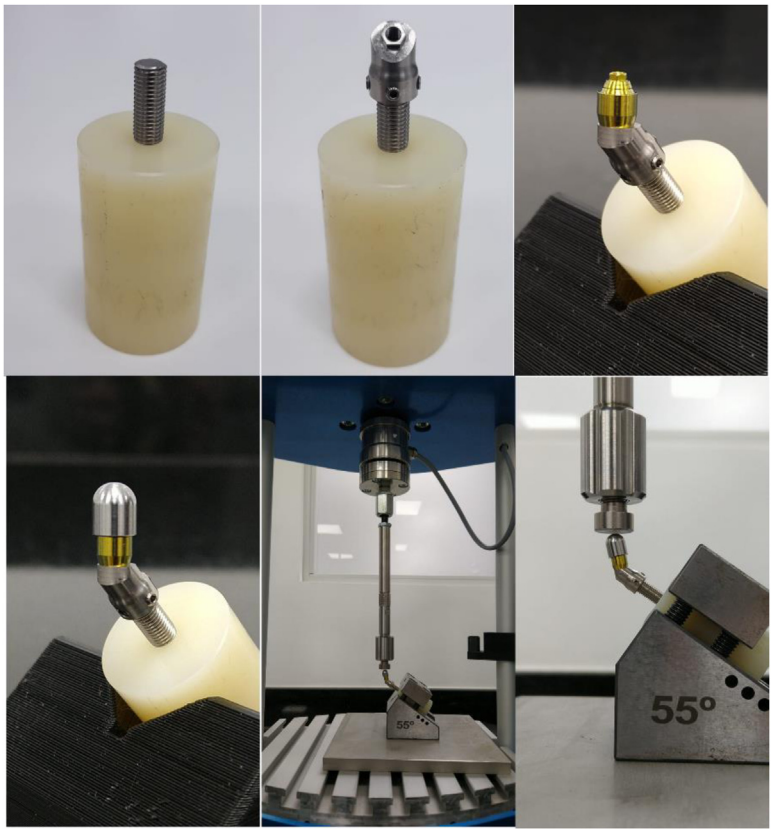

Fig. 3. Schematic and assembly of samples during dynamic and static tests according to ISO 14801 normative reference.

3. Diagnostic assessment

Clinical and radiographic examination confirmed a cervical fracture involving the prosthetic head of the left zygomatic implant. Computed tomography demonstrated that the intermediate and apical portions of the implant remained immobile and appeared to preserve osseointegration, making a conservative treatment approach feasible (Fig. 4).

3.1. Surgical procedure

The patient underwent surgical treatment under local anesthesia, a full-thickness mucoperiosteal flap was elevated to expose the fractured implant remnant.

A customized surgical guide, previously designed during the digital planning phase, was used to facilitate accurate positioning of the prosthetic rescue device.

The device was threaded into the remaining implant body until the most favorable prosthetic orientation was achieved. Additional stabilization was obtained using self-tapping lateral fixation screws. An insertion torque of approximately 20 N·cm was applied during final fixation.

Three of the four available fixation screws were placed because access to the most palatal screw was limited by prosthetic instrumentation. The flap was repositioned and closed using 5−0 silk sutures (Fig. 5).

Table 1
Timeline.

Time	Event
Seven years after implant placement	Implant fracture diagnosed
Baseline	Clinical examination and CBCT
Surgery	Placement of rescue device
Prosthetic phase	New framework fabricated
24 months	Clinical and radiographic follow-up

3.2. Prosthetic rehabilitation

Following stabilization of the rescue device, a new prosthetic framework was fabricated to accommodate the modified implant

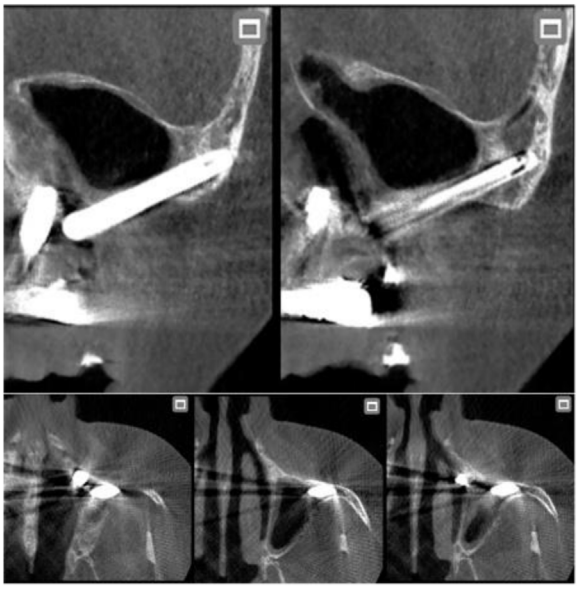

Fig. 4. Initial computed tomography with the 3 standard planes of section: axial, coronal, and sagittal of the maxillofacial region were taken. Fracture of the head and cervical segment of the second quadrant zygomatic implant was identified.

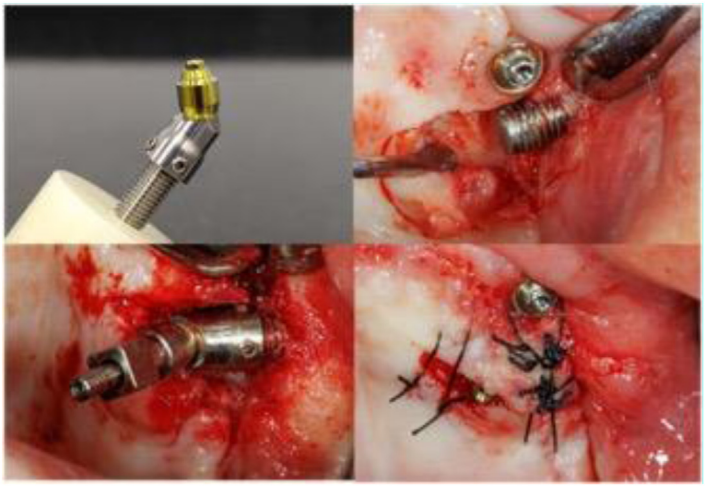

Fig. 5. Intraoperative aspect of the prototype device placement and suturing.

configuration, allowing restoration of function while preserving the existing implant-supported rehabilitation.

3.3. Clinical follow-up

Clinical and radiographic follow-up was performed over a period of 24 months. Throughout the observation period, the patient remained free of pain, inflammation, or mechanical complications. Serial radiographic examinations and three-dimensional imaging demonstrated stable integration of the implant–device assembly and satisfactory functional performance of the prosthetic rehabilitation (Figs. 6 and 7).

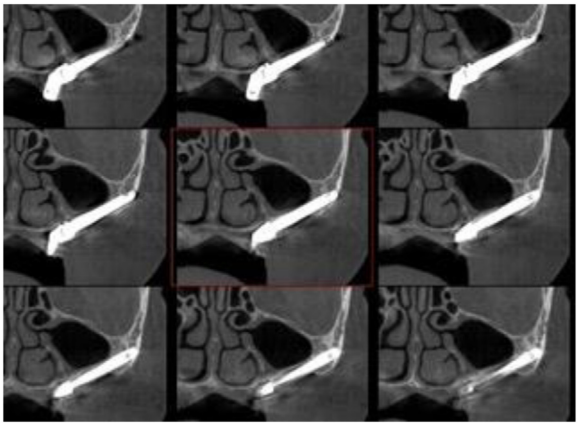

Fig. 6. Final computed tomography where the prototype passive fit to the remaining zygomatic implant may be verified.

4. Discussion

Fracture of a zygomatic implant is an uncommon but clinically significant complication that presents a complex therapeutic challenge. Beyond the mechanical failure itself, treatment planning must address the preservation of prosthetic function while minimizing additional surgical morbidity in patients who have often undergone extensive rehabilitation of a severely atrophic maxilla. Consequently, management should be individualized according to the location of the fracture, the stability of the remaining implant segment, and the feasibility of maintaining the existing implant-supported prosthesis [6,16].

Because of the rarity of zygomatic implant fractures, evidence-based treatment recommendations remain unavailable. Consequently, therapeutic decision-making is largely guided by clinical judgment and must consider the location of the fracture, the integrity of the residual implant, prosthetic requirements, and patient-related factors. When preservation of the fractured implant is not feasible, treatment usually involves implant removal followed by alternative surgical or prosthetic rehabilitation, procedures that are often technically demanding and associated with increased morbidity [17,18].

The present technical report introduces a novel prosthetic rescue concept for the conservative management of cervical fractures of zygomatic implants. Rather than considering implant removal as the only therapeutic option, the proposed approach preserves the osseointegrated apical segment and restores prosthetic function through a specifically designed prosthetic rescue device. This strategy aims to minimize surgical morbidity while maintaining the existing implant-supported rehabilitation [19].

A major strength of the present technical report is that the clinical application of the prosthetic rescue device was preceded by biomechanical validation. Dynamic fatigue testing performed according to ISO

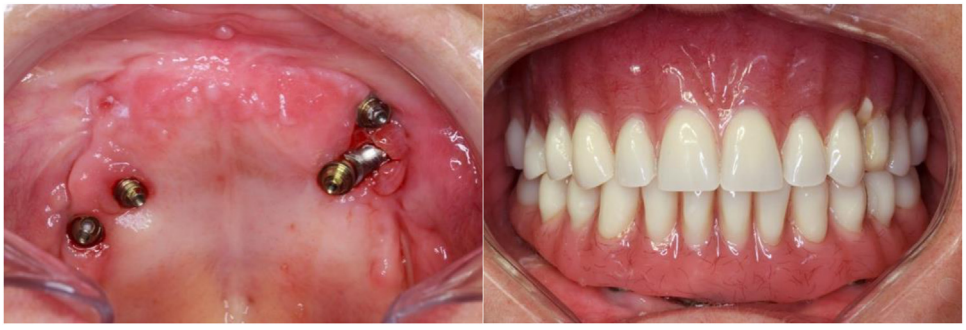

Fig. 7. Intraoral 24 months follow-up examination demonstrates a favorable status.

14801 provided objective evidence of the mechanical performance of the implant–device assembly before clinical use. Although in vitro fatigue tests cannot fully reproduce the complex loading conditions encountered in the oral environment, they remain the reference method for the mechanical assessment of implant-supported systems and provide valuable information regarding the expected mechanical behavior of newly developed devices [12,20].

The favorable mechanical performance observed during fatigue testing can be explained, at least in part, by the biomechanical principles that guided the design of the prosthetic rescue device. The device was developed according to established biomechanical principles to achieve a stable connection between the implant remnant and the prosthetic reconstruction. The combination of an internal threaded connection and supplementary self-tapping fixation screws was developed to improve mechanical stability while optimizing load distribution. Although the biomechanical performance of implant-supported restorations depends on multiple clinical and prosthetic variables, the fatigue test results support the mechanical feasibility of the proposed design [9,13,14].

This favorable performance observed during fatigue testing was consistent with the clinical outcome obtained after 24 months of follow-up. No biological or mechanical complications were observed during the observation period, and both clinical and radiographic examinations confirmed stable function of the implant–device assembly, consistent with the outcome assessment criteria proposed for zygomatic implant rehabilitation.[21] Although longer follow-up is required before definitive conclusions can be drawn, these preliminary findings are in agreement with long-term clinical observations reported for zygomatic implant-supported rehabilitations [22].

From a clinical perspective, the principal advantage of the proposed technique is the preservation of an osseointegrated and functional zygomatic implant that would otherwise be removed. Consequently, this approach may reduce surgical morbidity while maintaining the existing implant-supported prosthetic rehabilitation. These advantages are particularly relevant in patients with severely atrophic maxillae, in whom reconstructive alternatives are often technically demanding and associated with greater surgical complexity [16,23].

However, the proposed technique also has important limitations. The principal mechanical concern remains the possibility of fatigue-related fracture affecting either the prosthetic rescue device or the remaining implant structure during long-term function [21]. Although no complications were observed during the 24-month follow-up period, this observation time remains insufficient to draw definitive conclusions regarding long-term mechanical performance.

Furthermore, the prosthetic rescue device was specifically developed for cervical fractures in which the apical zygomatic anchorage remains stable and osseointegrated. Consequently, the proposed strategy should not be considered a universal solution for all fractured zygomatic implants but rather a conservative alternative for carefully selected clinical situations. In addition, the device currently represents a customized prototype and is not commercially available, which may limit its immediate reproducibility in other clinical centers. Nevertheless, the successful outcome observed in the present case supports the feasibility of the concept and may provide the basis for the future development of similar rescue systems.

5. Conclusions

The present technical report describes a novel prosthetic rescue concept for the conservative management of cervical fractures of zygomatic implants by preserving the osseointegrated apical segment and maintaining implant-supported prosthetic function. Biomechanical validation according to ISO 14801, together with the favorable clinical outcome observed after 24 months, suggests that this approach may represent a feasible and minimally invasive alternative to implant removal in carefully selected cases.

Nevertheless, this technique should currently be considered a proof of concept, as its indication is limited to fractures with a stable osseointegrated apical segment and the proposed prosthetic rescue device remains a customized prototype. Further clinical studies involving larger patient cohorts and longer follow-up periods are required to confirm the long-term mechanical reliability, clinical predictability, and reproducibility of this conservative treatment strategy.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Fernando Duarte: Investigation, Data curation, Project administration, Writing – original draft. **Carina Ramos:** Methodology, Writing – original draft, Investigation. **Michel Soares:** Conceptualization, Resources. **Natalia Martínez-Rodriguez:** Methodology, Validation, Formal analysis. **Cristina Barona-Dorado:** Methodology, Writing – review & editing. **José María Martínez-González:** Conceptualization, Writing – review & editing, Supervision.

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