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Two-Year Outcomes of Tissue-Level and Bone-Level Two-Piece Zirconia Implants: A Case Series

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Abstract

Background/objectives: Zirconia dental implants are increasingly recognised as an alternative to titanium implants due to their biocompatibility and aesthetics. Initially developed as one-piece systems, zirconia implants have evolved into two-piece designs with different platform levels; however, comparative data on their primary and secondary stability– particularly as assessed by resonance frequency analysis (RFA)—and marginal bone dynamics remain limited. This case series aimed to evaluate the implant stability and marginal bone changes of two-piece zirconia implants with bone-level (BL) and tissue-level (TL) platforms in patients missing maxillary premolars. **Methods:** Thirteen zirconia implants (n = 13; 7 BL, 6 TL; Z5-TL/Z5-BL, Z-Systems, Switzerland) were placed in 11 patients with healed ridges. The implant stability quotient (ISQ) was measured immediately after insertion and before prosthetic loading. Lithium disilicate crowns were cemented after four months, and follow-ups were conducted for an average of 35 months (SD = 12). **Results:** Initial ISQ values ranged from 73 to 79, increasing to 76–84 at 3–4 months, indicating high implant stability for both BL and TL implants. The extent of marginal bone loss (MBL) after two years was greater around BL implants (mean 0.46 mm) compared to TL implants (mean 0.2 mm), although probing depths and bleeding on probing remained minimal in both groups, with only one TL implant showing gingival recession. **Conclusions:** Over a short observation period, two-piece zirconia implants with tissue-level platforms appeared to demonstrate superior marginal tissue stability. Further, larger-scale controlled studies are required to confirm these preliminary observations.

Keywords: zirconia implants; ceramic; two-piece; bone-level; tissue-level; implant stability; ISQ

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1. Introduction

Ceramic implants have been used in oral implantology for several decades [1–4]. Ceramic implants were first introduced in 1976 by Prof. W. Schulte, who presented the Tuebingen two-piece implant made of alumina ceramic. These implants remained in clinical use until the late 1990s [5]. However, their high modulus of elasticity (340 GPa) made them prone to fracture, which ultimately contributed to their decline in clinical use. Recent advances in dental materials have made zirconia ceramics a viable alternative to titanium. In particular, 3% yttria-stabilised zirconia exhibits excellent mechanical properties, including high flexural strength (900–1200 MPa) and fracture toughness (7–10 MPa) [4,6,7].

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Zirconia dental implants have been in use for over a decade and have shown acceptable survival and success rates comparable to those of titanium implants. Systematic reviews report a survival rate of 95% in the first year and an annual decrease of 0.5% in the following five years [8–11]. The overall success rate is estimated at 91% [8,11,12]. On the other hand, new findings have raised concerns about titanium implants due to the possible release of particles resulting from mechanical wear, corrosion, bacterial biofilms, or their combinations [13,14]. These particles can have both local and systemic effects, such as hypersensitivity, inflammation, and mutagenicity [14–17]. Higher concentrations of titanium particles have been detected in peri-implant tissues [14,18–20], possibly contributing to the occurrence and progression of peri-implant diseases [14,21]. Zirconia implants have therefore gained popularity as an alternative. However, their resistance to wear, clinical and biomechanical superiority has not been proven [14,22].

Various zirconia implant systems have been developed, although scientific evidence on their short- and long-term results remains limited, as most of the tested brands have been removed from the market. Meta-analyses of favourable two-year survival rates and one-year marginal bone loss (MBL) outcomes have been published in systematic reviews; however, conclusions are based on a limited number of clinical studies [4,10,22,23]. Available studies have shown that zirconia implants achieve comparable osseointegration to implants with a moderately rough titanium surface [4,24–28]. Furthermore, biofilm formation on zirconia surfaces is significantly lower compared to titanium, both in vitro [4,29] and in vivo [4,30], suggesting that zirconia implants may be less prone to plaque-induced peri-implantitis. In addition, Nothdurft et al. [31] found that the fibroblast cell response, which is influenced by material and surface topography, exhibits a significantly higher proliferation rate on zirconia than on titanium alloys, potentially improving the early healing phases after implant placement [4].

The design of zirconia dental implants has evolved alongside advances in material science and clinical needs. Early two-piece ceramic implants featured a transitional collar, creating a tissue-level (TL) platform, while more recently, bone-level (BL) designs have been developed to mimic modern two-piece titanium implants. Despite improvements in ceramic strength, concerns regarding mechanical reliability persist for implant-abutment connections under functional loading. Initially, abutments were cemented to the implant body, but this was replaced by screw-retained connections using screws made from various materials [10]. The most recent innovation, currently available from a single manufacturer, is a zirconia connecting screw, which may offer enhanced biocompatibility and aesthetics. Comparative clinical data on TL and BL zirconia implants are limited, despite their differing effects on soft tissue response, bone preservation, and long-term stability.

Implant stability can be quantitatively assessed using the Implant Stability Quotient (ISQ), a parameter derived from resonance frequency analysis (RFA), a non-invasive technique widely used in clinical practice to monitor osseointegration and support decisions regarding implant loading protocols [32]. ISQ values, whether assessing primary or secondary stability, have, to the best of our knowledge, never been reported in scientific literature for ceramic implants. Similarly, no data exist regarding marginal bone dynamics associated with bone-level ceramic implants. The primary objective of this study was to describe implant stability and peri-implant bone changes of two-piece BL and TL zirconia implants during the first two years following implant placement. We hypothesised that both implant types would demonstrate sufficient stability for successful osseointegration and functional loading. Additionally, we expected TL implants to exhibit reduced MBL and fewer mechanical complications compared to BL implants.

2. Materials and Methods

2.1. Patient Selection

Eleven (n = 11) patients (mean age: 54 ± 12.5 years, range: 38–63; 55% female) with one (n = 9) or two (n = 2) missing maxillary premolars participated in this case series study. Each participant received one or two zirconia implants (length: 10 mm, diameter: 4 mm) with a TL (Z5-TL, Z-Systems; n = 6) or BL (Z5-BL, Z-Systems; n = 7) platform, which were allocated according to a computer-generated randomisation scheme. All participants were informed in detail about the aims, procedures, and requirements of the study and gave written informed consent prior to participation. The study protocol was approved by the National Ethics Committee of the Republic of Slovenia (No. 0120-446, 10 March 2020) and was conducted according to the principles of the Declaration of Helsinki. The inclusion and exclusion criteria are listed in Table 1.

Table 1. Inclusion and Exclusion Criteria.

Inclusion Criteria	Exclusion Criteria
• Aged at least 25 years;	• Insufficient bone volume in the region to install implants measuring 10 mm in length and 4 mm in diameter;
• In good general health;	• Previous implant or graft placement at the surgical site;
• Absence of pathologies of soft tissues, alveolar bone or teeth;	• Active periodontitis;
• One or two missing premolars with sufficient bone volume to insert yttria tetragonal zirconia polycrystal (Y-TZP) implant of at least 3.6 mm in diameter and 10.0 mm long (alveolar bone of at least 12 mm vertical and 6 mm horizontal dimension);	• Heavy smokers (more than 25 cigarettes a day);
• Presence of all other teeth or fixed partial denture in the restoring jaw (not including 3rd molars);	
• Presence of teeth or fixed partial denture in the opposing jaw to reach occlusal contacts at each implant supported crown;	
• No periodontal treatment or usage of antibiotics 12 months prior the study;	

2.2. Surgical Procedure and Follow-Up

Zirconia implants were placed in adult patients with missing maxillary premolars using a partially guided surgical procedure. Intraoral scan data (IOS) and CBCT data were imported into implant planning software (Blue Sky Plan 4.75, Blue Sky Bio, Lilburn, GA, USA) and aligned for accurate spatial orientation. The implant positions were carefully planned according to the anatomical structures, and a custom surgical guide was fabricated (Form2, Dental SG resin, Formlabs, Boston, MA, USA). The implants were placed according to a one-stage surgical protocol by an experienced implantologist (R. G.).

Local anaesthesia was administered by buccal and palatal infiltration with Ultracaine (Hoechst, Germany). A sulcular and mid-crestal incision was made, extending from the most posterior tooth in the dental arch to approximately 1 cm anterior to the planned implant site. A full-thickness mucoperiosteal flap was raised, and the implant osteotomy was prepared according to the sequence specified by the manufacturer (Z-Systems, Oensingen, Switzerland). The drilling protocol was performed with the Counter Sink Drill CS400-1 (Z-Systems, Oensingen, Switzerland). Each patient received a 10 × 4.0 mm implant (either Z5-TL (Figure 1) or Z5-BL (Figure 2)) with identical external implant body geometry. All implants were inserted manually with a ratchet, achieving a torque greater than 30 Ncm. The wound was closed using a microsurgical technique (Prolene, Ethicon, Raritan, NJ, USA). Implant stability was checked with the Osstell© device (Osstell AB, Gothenburg, Sweden) immediately after implant placement and again 3–4 months postoperatively. TL implants were subjected to non-submerged healing. For BL implants, closure screws were placed, the flaps repositioned and sutured. No bone/soft tissue augmentation was performed. Periapical radiographs were taken immediately after the procedure and again after 3–4 months (i.e., before prosthetic rehabilitation). The lithium disilicate ceramic crowns were cemented onto ceramic abutments (Z-Systems, Oensingen, Switzerland), which were screwed into place using zirconia ceramic screws. The follow-up period ranged from 24 to 60 months, with a mean duration of 35 ± 12 months (SD = 12).

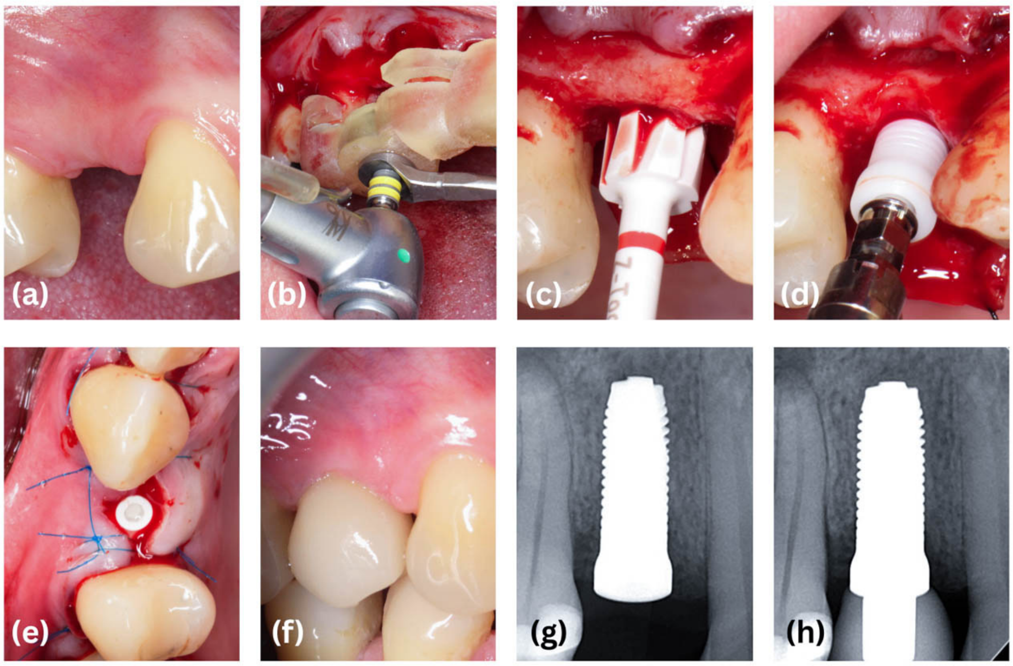

Figure 1. A representative case from the TL group. (**a**) Missing maxillary premolar, (**b**) partially guided implant bed preparation, (**c**) bone profiling with a Neck Expansion Drill, (**d**) manual insertion of the implant with a hand ratchet, (**e**) suturing, (**f**) prosthetic loading, (**g**) baseline radiograph, (**h**) 24-month radiograph.

Clinical and radiographic follow-up examinations were performed at 6-month intervals. Periodontal parameters around implants were recorded by an experienced calibrated periodontist (R.G.) using a manual Williams probe (POW6, Hu-Friedy, Chicago, IL, USA) at six sites per implant. These parameters included probing pocket depth (PPD), bleeding on probing (BOP), and recession (TRec), with the implant/abutment-crown junction as the reference point. All periapical radiographs were analysed by a single experienced examiner (R.G.) using ImageJ software (U.S. National Institutes of Health, version 1.48u4). To standardise the measurements, each image was calibrated using the known implant length of 10 mm as a reference. The marginal bone loss (MBL) was measured on the mesial and distal sides of each implant, defined as the most coronal radiodense bone-to-implant contact. The two measurements were averaged to obtain one value per implant. The MBL was calculated as the difference in bone height between the time immediately after implant placement and 24 months after loading.

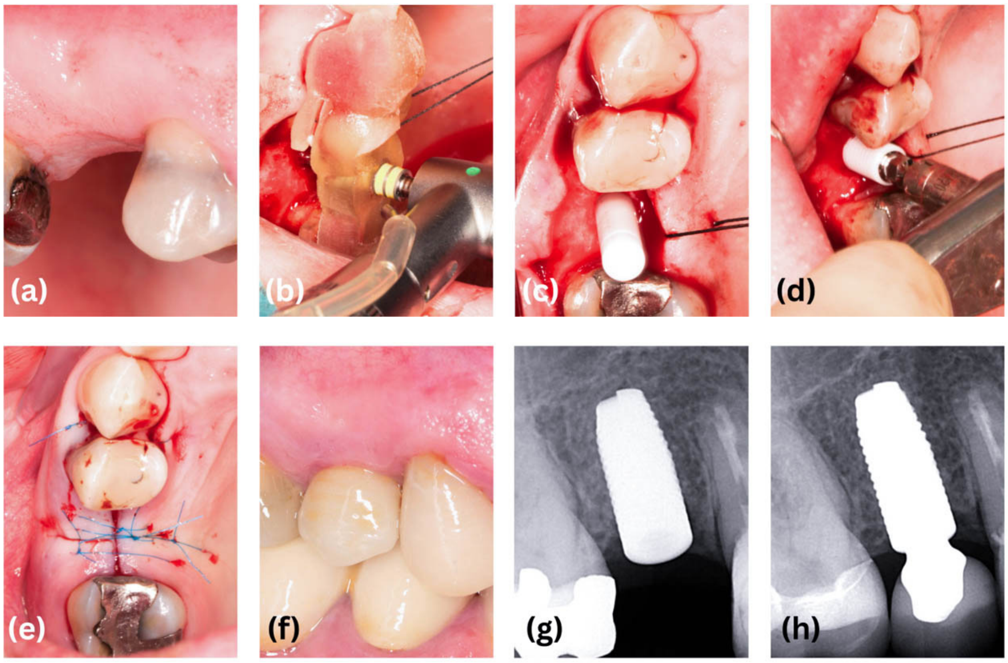

Figure 2. A representative case from the BL group. (**a**) Missing maxillary premolar, (**b**) partially guided implant bed preparation, (**c**) position verification with a depth gauge, (**d**) manual insertion of the implant with a hand ratchet, (**e**) suturing, (**f**) prosthetic loading, (**g**) baseline radiograph, (**h**) 24-month radiograph.

2.3. Statistical Analysis

The results are presented using descriptive statistics. As this is a case series study, only descriptive statistical data are given without any attempt to assess statistical significance between the two implant types. Both survival and success rates were evaluated. Survival was defined as the presence of the implant-crown complex at any follow-up time point. Success was defined as the absence of progressive inflammatory lesions, increased probing depths or tissue recession, and tolerating a maximum of 1 mm of MBL per year in the first two years.

This case series has been reported in line with the PROCESS Guideline [33].

3. Results

3.1. Descriptive Statistics

All patients were healthy and did not have any chronic systemic diseases or require pharmacological therapy. Apart from the missing maxillary premolars, the other teeth were healthy and required little to no conservative or prosthetic treatment. Thirteen (n = 13) zirconia implants were placed: six (n = 6) TL implants and seven (n = 7) BL implants.

The initial implant stability quotient (ISQ) measured immediately after implant placement was high and similar between both groups, with mean ISQ values of 74 (range: 73–76) for TL implants and 75 (range: 70.5–77) for BL implants. The healing phase was uneventful in all patients. ISQ values were measured again before the start of prosthetic treatment, and showed an increase in implant stability, with mean ISQ values of 80 (range: 76–84) for TL implants and 81 (range: 77–84) for BL implants after 3–4 months. All implants were restored with lithium disilicate crowns cemented on ceramic abutments and fixed with a single-use zirconia screw. All ceramic abutments were screw-retained with a special disposable screwdriver (torque value: 15 Ncm), followed by cementation (RelyX, 3M ESPE) of lithium disilicate ceramic crowns (IPS e-max CAD, Ivoclar).

The mean follow-up period was 35 ± 12 months, during which the peri-implant tissues remained healthy in both groups (Table 2). The plaque index, which was determined at each follow-up examination, showed no or only a very thin layer of plaque at the implant sites [34]. A PPD of more than 4 mm was not detected at any site. The median bleeding on probing (BOP) was low, although it was slightly more frequent in the BL group (10%) than in the TL group (5%). Probing depths were stable and measured 2.7 mm (range: 2.2–3.1 mm) for TL and 2.8 mm (range: 2.3–3.1 mm) for BL implants. Tissue recession was minimal, with a median of 0.2 mm (range: 0–2 mm) for TL implants and 0 mm (range: 0–0.2 mm) for BL implants. The MBL was greater for BL implants, with a median value of 0.46 mm (range, 0.15–1.54 mm), compared to TL implants (median, 0.2 mm; range, 0–0.78 mm). Both implant types had complete cumulative survival and success rates of 100% (13/13 implants) two years after loading.

Table 2. Peri-implant Soft Tissue and Marginal Bone Parameters 2 Years after Loading *.

Ceramic Two-Piece Implants	Tissue Level/TL (n = 6)	Bone Level/BL (n = 7)
No. of sites with PPD > 4 mm	0/24	0/28
Bleeding upon probing (%)	5 (0–12)	10 (2–16)
Probing depth (mm)	2.7 (2.2–3.1)	2.8 (2.3–3.1)
Tissue recession (mm)	0.2 (0–2)	0 (0–0.2)
Marginal bone loss (mm)	0.2 (0–0.78)	0.46 (0.15–1.54)
Cumulative survival (2-years postloading)	6/6	7/7
2-years postloading success	5/6 (tissue recession)	6/7 (significant bone resorption)

* Data are presented with medians (M) and interquartile ranges (IQR), Probing Pocket Depth (PPD).

3.2. Observed Complications

Apart from MBL, which was observed in both implant types, two main complications occurred exclusively in the BL implant group: fracture of the fixation screw and exposure of the platform. While MBL was more pronounced around the BL implants (mean 0.46 mm, max. 1.54 mm), only minor bone remodelling was observed in the TL implant group (mean 0.2 mm, max. 0.78 mm). Tissue recession exposing the implant body only occurred in the TL implant group.

3.2.1. Fracture of the Fixation Screw (Figure 3)

During abutment fixation of one Z5 BL implant, the zirconia ceramic fixation screw broke. Radiographic and SEM/EDS analyses revealed fracture patterns indicating torsional stresses and the presence of oxide inclusions that likely contributed to the mechanical failure. The fractured screw fragment was successfully removed with an ultrasonic instrument and replaced. The implant remained functionally stable for 24 months after repair.

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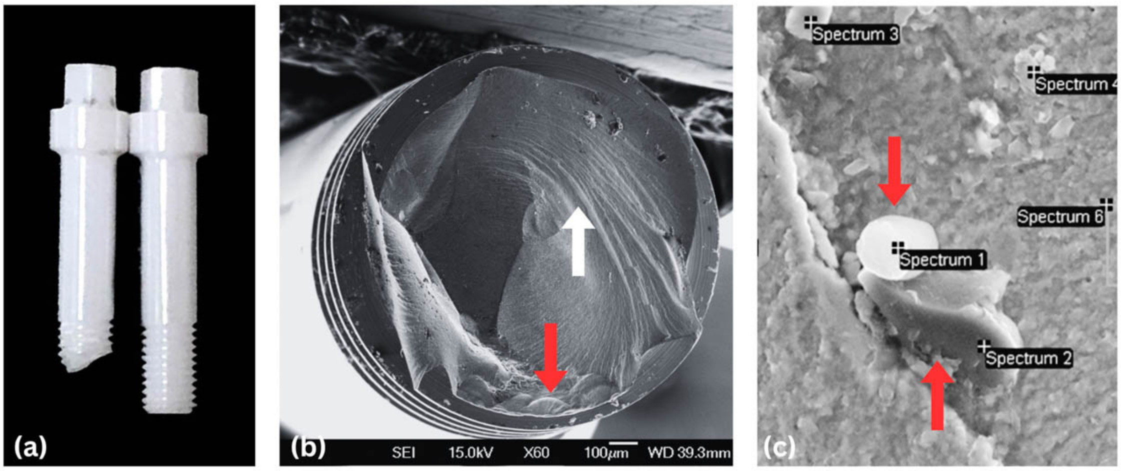

Figure 3. (**a**) The broken ceramic screw (**left**) compared to the standard ceramic screw (**right**); (**b**) Surface of the broken ceramic screw under SEM (scanning electron microscope), showing evidence of torsional loads as curved lines (white arrow) and unusual half-circle-like notch marks (red arrow); (**c**) Energy Dispersive Spectroscopy (EDS) revealed Al-rich and K-rich precipitates (red arrow) on the fractured surface.

3.2.2. Marginal Bone Loss

The MBL was greater in BL implants compared to TL implants over a two-year period. After six months, 3 out of 7 BL implants showed signs of MBL of about 1 mm. The expected slight MBL was observed in 3/6 of the Z5-TL implants. One Z5-BL implant showed clinically relevant MBL of 1.54 mm and platform exposure six months after surgery, as determined clinically and radiographically prior to loading. Treatment included replacing the BL abutment with a TL abutment, thereby restoring the clinical situation (Figure 4).

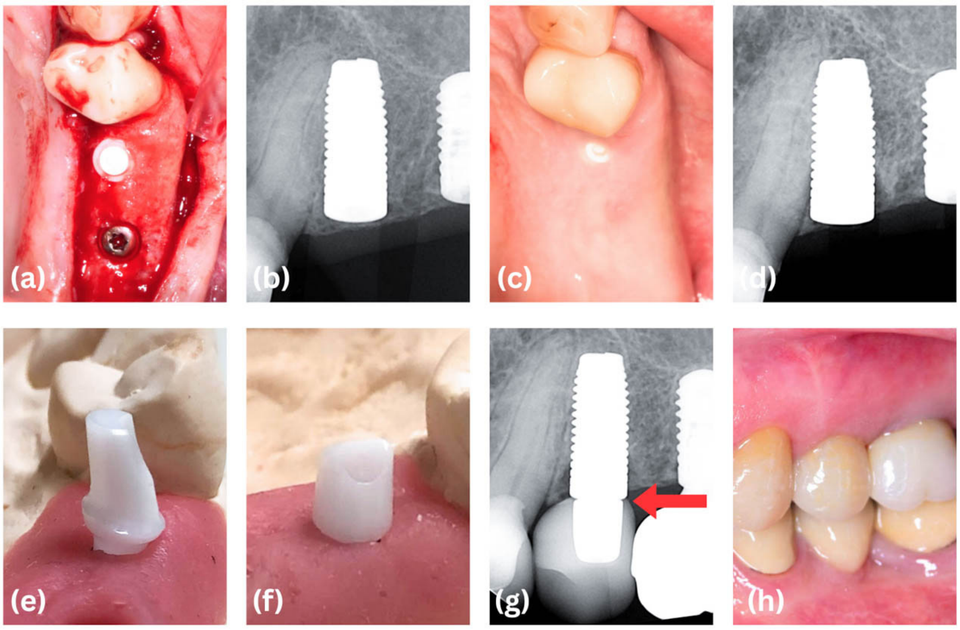

Figure 4. (**a**) Z5-BL implant case, (**b**) baseline radiograph, (**c**) platform exposure after osseointegration, (**d**) 24-month radiograph showing minor marginal bone remodelling, (**e**) stock abutment with gingival recession, (**f**) off-label use of a tissue-level abutment, (**g**) ceramic restoration in direct contact with the implant shoulder (red arrow), (**h**) final restoration.

3.2.3. Tissue Recession

Tissue recession was observed in a Z5-TL implant during the follow-up examination after XYZ months (Figure 5). Despite the otherwise stable mucosa in most cases, this single tissue recession was a localised soft tissue complication. The recession was noted visually and confirmed at follow-up, although the implant remained functional and stable.

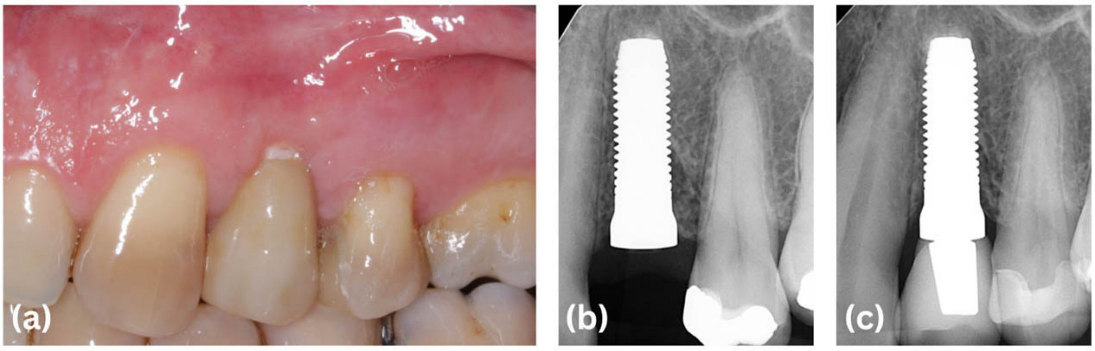

Figure 5. (**a**) Gingival recession in a Z5-TL implant case, (**b**) baseline radiograph, (**c**) 24-month radiograph showing minor marginal bone remodelling.

4. Discussion

In this case series study, the survival and success rates of prosthetic rehabilitations on ceramic implants with two different platform types, BL and TL, were evaluated. To the best of our knowledge, the use of ceramic BL implants with a zirconia connecting screw has not been described in the literature; therefore, we found no reports on primary and secondary stability, marginal bone dynamics, or technical problems in the fabrication of suprastructures for comparison. The results indicate that marginal bone dynamics are greater with BL-type ceramic implants compared to TL-type implants despite similar implant body design. An unexpected complication was encountered involving the delicate screw connecting the abutment to the body of the bone-level implant—a fracture of the fixation screw—which was successfully managed with additional corrective measures. After monitoring the dental implants for over two years, we can confirm that the tissue adjacent to the implant has adapted well and that no additional pathological changes have been detected to date.

The introduction of two-piece zirconia dental implants represents a significant advancement in ceramic implant technology, providing clinical flexibility comparable to titanium implants while meeting patient demands for biocompatibility and aesthetics. One-piece ceramic implants supporting single crowns or short fixed partial dentures demonstrate high success and survival rates of approximately 98%, as reported by Jung et al. [35] and Balmer et al. [36], with no significant differences related to implant length or diameter over various follow-up periods. The low failure rates in these studies are likely due to the predominance of 4.0 mm and 4.5 mm diameter implants, which show higher survival compared to implants $\leq$ 3.5 mm in diameter, known to be more susceptible to fatigue fractures [4,10,36–38]. Although fractures of zirconia implants are a major concern—older aluminium oxide implants were withdrawn due to material weakness—recent ceramic implants have not shown implant body fractures [39,40]. Biological complications were minimal, with only one peri-implantitis case reported by Balmer et al. [4], while Jung et al. [35] and Oliva et al. [41] noted three early failures, and Oliva et al. [41] additionally reported four late failures. This is consistent with systematic reviews indicating that early failures are more frequent in one-piece implants, potentially caused by masticatory or tongue movements affecting stability and osseointegration [10,42]. Nevertheless, failure rates for one-piece ceramic implants after five years remain low, ranging between 1.5% and 5% [43].

In contrast, clinical data on two-piece zirconia implants are limited. Current literature reports survival rates ranging from 83% to 95.8% for two-piece implants of varying diameters and lengths [41,44–47], although the study with the highest survival rate excluded eight early failures and did not specify their dimensions. Common complications in two-piece zirconia implants include peri-implantitis and abutment fractures, likely related to bacterial accumulation, cement leakage, and mechanical stresses at the implant-abutment junction [10,48–51]. Notably, earlier studies predominantly employed cemented abutments on tissue-level implants, whereas our study used a screw-retained abutment approach, which may affect complication profiles [52].

All gingival sites around the zirconia implants in the present study showed no signs of inflammation, no changes in probing depth, and no progression of MBL after the initial bone remodelling. During the healing phase after implant placement, bone remodelling may lead to a reduction in the MBL. In other studies with two-piece implants, MBL values similar to those in this study were determined, namely 0.81 mm MBL after five years [48,49] and 0.7 mm after 5.6 years [4]. Although some studies report increased MBL over longer follow-up periods, these findings are based on small sample sizes or are attributable to a limited number of implants exhibiting greater loss [49]. In another study on two-piece implants, 24 implants were found to have no MBL after five years, while five implants showed an average MBL of 1.25 mm, and eight implants showed marginal bone gain [53].

A recent systematic review and meta-analysis compared the survival and success rates of zirconia and titanium dental implants based on randomised controlled trials (RCTs) with at least 12 months of follow-up. The analysis included data from two RCTs comprising 100 zirconia and 99 titanium implants, showing no statistically significant difference in survival rates between the two materials at short-term follow-up. Zirconia implants demonstrated similar clinical and radiographic outcomes to titanium implants, with a trend toward higher aesthetic scores, particularly relevant for implants in the aesthetic zone. However, zirconia implants showed a higher incidence of early failures and some mechanical complications, such as fractures. The review highlights a lack of long-term data and heterogeneity in the included studies, underscoring the need for further long-term RCTs to clarify the clinical performance and durability of zirconia implants compared to titanium [54].

From a mechanical point of view, the two-piece implant design brings additional considerations. Although zirconia has excellent flexural strength and fracture toughness, its susceptibility to fracture under complex loading conditions was problematic in previous generations of ceramic implants. The introduction of the two-piece system raises questions about the mechanical stability of the abutment-implant connection, which is critical for long-term success. These concerns highlight the need for more clinical studies with longer follow-up periods to evaluate the durability of these systems. Nevertheless, the biological advantages of zirconia, particularly presumably reduced biofilm formation and favourable soft tissue integration, could make two-piece zirconia implants an attractive option for patients at increased risk of periimplantitis. Initial studies have shown that zirconia surfaces are less susceptible to bacterial colonisation, which could help to reduce the incidence of plaque-induced peri-implant disease compared to titanium.

To summarise, while two-piece zirconia implants offer promising potential in terms of aesthetics, biocompatibility, and reduction in biofilm-related complications, their mechanical performance and long-term outcomes have not yet been sufficiently investigated. High-quality clinical studies are necessary to confirm the efficacy and durability of these systems compared to the gold standard, titanium implants.

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The limited sample size and the lack of formal statistical analysis, including power calculation, represent inherent limitations of this descriptive study. Another limitation of this study is the lack of a standardised paralleling technique for periapical radiographs, which may introduce variability in MBL measurements. Although implant length was used as a reference to estimate potential magnification, minor discrepancies due to radiographic angulation cannot be completely ruled out. A similar radiographic analysis approach has been used in previous studies [55]. Nevertheless, these data provide valuable insights and will facilitate accurate sample size calculations in the future.

5. Conclusions

This case series presents initial data on the primary and secondary stability, bone remodelling, and technical issues of Z-systems two-piece zirconia implants after a minimum of two years' follow-up. The implants demonstrated good survival rates and maintained healthy peri-implant tissues throughout the study period. However, technical and biological complications—such as screw fractures, platform exposure, marginal bone loss (MBL), and increased bleeding on probing—were more common with BL Z-system implants. Preliminary results indicate that Z-systems TL ceramic implants may offer improved marginal bone stability and fewer mechanical complications, although one case of gingival recession was observed in the Z-systems TL group. As this study is at a preliminary stage with a small sample size, these findings should be interpreted with caution and require validation in larger, controlled clinical trials.

Author Contributions: Conceptualization, R.G. and Č.O.; methodology, R.G., B.Ž. and Č.O.; software, T.K. and S.Ž.G.; validation, R.G., Č.O. and S.Ž.G.; formal analysis, R.G., Č.O., B.Ž. and S.Ž.G.; investigation R.G., K.P., B.Ž., Č.O. and S.Ž.G.; resources, R.G. and Č.O.; data curation,; R.G., Č.O. and S.Ž.G.; writing—original draft preparation, S.Ž.G.; writing—review and editing, R.G., Č.O., K.P., T.K. and S.Ž.G.; visualisation, R.G. and Č.O.; supervision, R.G. and Č.O.; project administration, R.G., Č.O. and S.Ž.G. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the National Ethic Committee of the Republic of Slovenia (No. 0120-446, 10 March 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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Conflicts of Interest: The authors declare no conflicts of interest.

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