



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

Comparative Clinical Analysis Between Zirconia and Titanium Implants in Single-Tooth Rehabilitations: A Systematic Review

Comparative Clinical, Radiographic, and Esthetic Outcomes of Zirconia and Titanium Implants in Single-Tooth Rehabilitations: A Systematic Review

Andrei Correa Guandalini - ILAPEO Faculty - a_guandalini@hotmail.com

Nayara Diniz de Queiroz - UNESP - Araraquara - nayara.diniz@unesp.br

Flávio Magno Gonçalves – Tuiuti University of Paraná - flavio.goncalves@utp.br

Lélio Fernando Ferreira Soares – UNESP – Araraquara - leliosoaresss@hotmail.com

José Stechman Neto – Tuiuti University of Paraná - stechman1@gmail.com

André Misquillusi Moreira – Tuiuti University of Paraná - andre.moreira@utp.edu.br

Élcio Marcantonio Júnior - ILAPEO Faculty - elcio.marcantonio@unesp.br

Summary

Objectives: To comparatively evaluate the clinical, radiographic, and aesthetic performance of zirconia and titanium dental implants used in single-tooth restorations, through a systematic review and meta-analysis of randomized controlled trials (RCTs). **Material and Methods:** This systematic review was conducted according to the PRISMA 2020 guidelines and registered in PROSPERO (CRD42024541703). Only RCTs that directly compared zirconia and titanium implants in single-tooth restorations, with a minimum follow-up of 12 months after prosthetic placement, were included. Searches were conducted in ten electronic databases up to January 2025. The risk of bias was assessed using the Cochrane RoB 2 tool. A random-effects meta-analysis was performed for marginal bone loss (MBL), peri-implant probing depth (PPD), and aesthetic outcomes assessed by the Pink Esthetic Score (PES). The certainty of the evidence was assessed using the GRADE approach. **Results:** Eight RCTs met the eligibility criteria. Qualitative analysis indicated a higher incidence of fractures and mechanical failures associated with zirconia implants in studies with longer follow-up. Quantitative synthesis revealed no statistically significant differences between zirconia and titanium implants in MBL (MD = -0.02 mm; 95% CI: -0.22 to 0.19; p = 0.88), PPD (MD = -0.01 mm; 95% CI: -0.28 to 0.26; p = 0.94) or aesthetic results (MD = 0.15; 95% CI: -0.18 to 0.48; p = 0.38).

Implant survival was comparable in the short term, but zirconia showed greater variability over prolonged observation periods. **Conclusions:** Zirconia implants exhibit similar clinical and radiographic behavior to titanium implants in single-unit restorations in the short and medium term. However, the higher risk of mechanical complications with zirconia implants should be considered in clinical planning. Further long-term studies are needed to confirm the biomechanical stability of this material.

Keywords: Dental implants; Zirconia; Titanium; Single tooth restoration; Systematic review; Meta-analysis.

Abstract

Objectives: To comparatively evaluate the clinical, radiographic, and aesthetic performance of zirconia and titanium dental implants used in single-tooth restorations, through a systematic review and meta-analysis of randomized controlled trials (RCTs). **Material and Methods:** This systematic review was conducted according to the PRISMA 2020 guidelines and registered in PROSPERO (CRD42024541703). Only RCTs that directly compared zirconia and titanium implants in single-tooth restorations, with a minimum follow-up of 12 months after prosthetic placement, were included.

Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

Searches were conducted in ten electronic databases until January 2025. The risk of bias was assessed using the Cochrane RoB 2 tool. A random-effects meta-analysis was performed for marginal bone loss (MBL), peri-implant probing depth (PPD), and aesthetic outcomes assessed by the Pink Esthetic Score (PES). The certainty of the evidence was assessed using the GRADE approach. Results: Eight RCTs met the eligibility criteria. Qualitative analysis indicated a higher incidence of fractures and mechanical failures associated with zirconia implants in studies with longer follow-up. Quantitative synthesis revealed no statistically significant differences between zirconia and titanium implants in MBL (MD = -0.02 mm; 95% CI: -0.22 to 0.19; $p = 0.88$), PPD (MD = -0.01 mm; 95% CI: -0.28 to 0.26; $p = 0.94$) or aesthetic results (MD = 0.15; 95% CI: -0.18 to 0.48; $p = 0.38$). Implant survival was comparable in the short term, but zirconia showed greater variability over prolonged observation periods. Conclusions: Zirconia implants exhibit clinical and radiographic behavior similar to titanium implants in single-tooth restorations in the short and medium term. However, the higher risk of mechanical complications in zirconia implants should be considered in clinical planning. Further long-term studies are needed to confirm the biomechanical stability of this material.

Keywords: Dental implants; Zirconia; Titanium; Single-tooth restoration; Systematic review; Meta-analysis.

1. Introduction

The rehabilitation of edentulous areas through dental implants has become one of the cornerstones of modern dentistry. This advancement began with the studies of Brånemark, who introduced the concept of osseointegration was explored, and for the first time, commercially pure titanium implants were used in the 1960s (1). Since then, titanium has established itself as the material of choice for dental implants, which is widely documented in the literature for its high rate of survival, biocompatibility and mechanical resistance (2). Over the years, the development of treated and micro-roughened surfaces has further increased predictability clinically, favoring primary stability and promoting a more intimate contact between bone and implant (2–4). As a result, titanium implants have begun to exhibit performance reliable even in challenging clinical situations, such as immediate loading, bone regeneration and areas of low bone density (5).

Despite the clinical and scientific success of titanium implants, some limitations have been observed, especially in relation to aesthetics and biocompatibility. The grayish coloration of this material may compromise the final result in aesthetic areas, especially in patients with thin gingival phenotype or bone resorption in the vestibular plate (6). In addition, there are case reports of hypersensitivity to titanium, presence of metallic particles in peri-implant tissues and possible correlation with inflammatory responses, especially in acidic environments or with mechanical overload (7,8). These concerns, added to the growing aesthetic demands of patients and the search for metal-free materials have fueled interest in alternatives.

In this context, zirconia (ZrO_2), especially in its tetragonal polycrystalline form, yttrium-stabilized (Y-TZP) has emerged as a promising material (9,10). Initially introduced into dentistry for use in prosthetic infrastructures due to its high resistance to



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

fracture, abrasion and its white coloration, similar to a natural tooth (11,12),

its use as

Dental implant material dates back to the late 1990s and early 2000s (13).

Despite initial enthusiasm, the first zirconia implants had limitations.

important features, such as only the option of single-body implants, the absence of angled abutments,

difficulties in prosthetic fitting and relatively high fracture rates, associated with

The mechanical fragility of the ceramic material and its low toughness in adverse oral environments.

(14,15) . These factors limited, for some time, its wider clinical adoption.

However, in the last two decades, significant technological advances have made implants

Zirconia is a viable alternative to titanium. The introduction of two-piece implants, improvements in

Sintering processes, microstructure control, and surface modification, now with

suitable roughness to promote osseointegration, increased its resistance to fatigue and

reduced fracture rates (16,17). In parallel, preclinical and clinical studies have demonstrated

less bacterial adhesion, more controlled inflammatory response, and superior aesthetic performance in

anterior regions (18–20). These characteristics position zirconia as a promising option.

especially in patients with aesthetic requirements or in cases of hypersensitivity to metals.

Several systematic reviews and meta-analyses have already been conducted with the aim of

Compare zirconia implants to titanium implants. Many of these reviews incorporate data from studies.

with reduced follow-up time, heterogeneous methodologies, or methodologies that do not compare

directly the two materials under standardized experimental conditions (21–23). However, it

It is important to recognize that the literature in this area is still in its early stages. Such limitations do not invalidate the...

The value of these studies is evident, but they reflect the inherent difficulties stemming from the still limited number of research projects.

randomized clinical trials are available to date (24,25). Given this scenario, the need arises

from an updated review, with rigorous inclusion criteria, focused exclusively on essays.

randomized controlled trials (RCTs) that directly compare zirconia and titanium implants in

humans, under controlled clinical monitoring and with objective and standardized outcomes.

Thus, the main objective of this systematic review is to compare, through RCTs, the

Clinical behavior of zirconia and titanium dental implants, considering parameters such as

Implant survival, marginal bone loss, biological and technical complications, outcomes

aesthetics and patient perception.

2. METHODOLOGY

PROTOCOL AND REGISTRATION

The protocol for this systematic review was developed in accordance with the guidelines of



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and was registered in International Prospective Register of Systematic Reviews (PROSPERO) platform under number CRD42024541703.

ELIGIBILITY CRITERIA

Inclusion and exclusion criteria were defined based on the PICOS acronym (Population, Intervention, Comparison, Outcomes, and Study Design) for the selection of studies.

P (Population): Studies with patients who received single-unit rehabilitations were included with dental implants.

I (Intervention): The intervention was the installation of zirconia implants.

C (Comparison): The comparison group consisted of patients who received implants of titanium.

Outcomes: Clinical, radiographic, and aesthetic results were evaluated, including: Implant survival rate, marginal bone level, periodontal parameters, and complications.

S (Study Type): Only randomized controlled trials (RCTs) with a minimum follow-up period of 12 months after the prosthesis is fitted.

In vitro studies, animal studies, case reports, case series, and studies were excluded. Observational studies and studies with incomplete data or without an adequate control group.

SOURCES OF INFORMATION AND SEARCH STRATEGY

A comprehensive search was conducted in ten electronic databases (PubMed, Scopus, Web of Science, Embase, Cochrane, LILACS, Livivo, Google Scholar and Proquest), including Publications up to January 2025 and updated in August 2025. References were managed with EndNote® software for removing duplicates. All searches are tailored to each database. The data is described in Appendix 01.

STUDY SELECTION AND DATA EXTRACTION

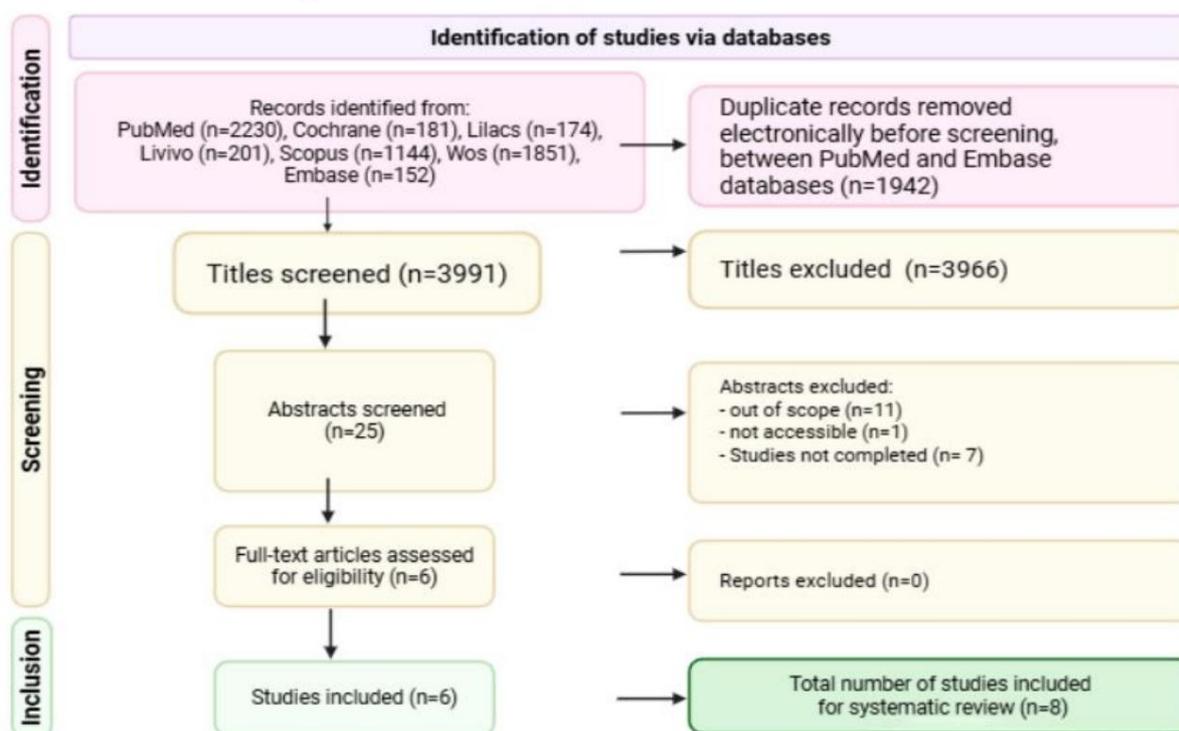
The selection of studies was carried out in two phases (title/abstract screening and text reading) (complete) by two independent reviewers, using Rayyan® software. An exercise in Calibration was performed prior to the selection process. The initial search resulted in 3,991 articles, of which... Of these, 25 advanced to the full-text reading phase, resulting in the inclusion of 6 studies. Subsequently, the search was updated, which identified 847 new articles. Two The articles in this update were selected and retained during the full-text reading phase. All

Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

The selection phases were conducted using Rayyan® software. Data extraction was carried out by the same two independent reviewers (LFFS and NAS), using a form Standardized. Disagreements in both stages were resolved by consensus or through evaluation of a third reviewer. The complete study selection process is illustrated in the flowchart PRISMA (Figure 1).

Figure 1. PRISMA Flow Diagram

PRISMA flow diagram



ASSESSING THE RISK OF BIAS IN INDIVIDUAL STUDIES

The risk of bias of the included RCTs was assessed by two independent reviewers (LFFS and NAS) using the Cochrane RoB 2 (Risk of Bias 2) tool. Each study was classified as "Low risk of bias," "some concerns," or "high risk of bias." A detailed assessment of The risk of bias for each included study is presented in Figure 2 and Supplementary Table S2.

Figure 2. Risk of bias – Cochrane RoB 2 tool.

Study ID	Study ID	Experimental	Comparator	Outcomes	Blinded?	SI	SD	SO	SR	SB	Overall	Risk Level
Pavel2022	Pavel et al., 2022	Two-piece zirconia implants (Zirconium core L*)	Two-piece titanium implants (Zirconium core L*)	Implant survival rate at 24 months	1	Green	Yellow	Green	Green	Green	Green	Low risk
Dellavalle2024	de Bock et al., 2024	Zirconia (TZU) implant (Zirconium core L*)	Titanium (Ti) bone level implant (Zirconium core L*)	Marginal bone level (MBL) change at 1 year	1	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns
Ruderman2024	Rui Heo et al., 2024	Single-piece ceramic dental implants	Single-piece titanium dental implants	Implant Crown aesthetic index (CAI)	1	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns
Ruderman2022	Rui Heo et al., 2022	Single-piece ceramic dental implants	Single-piece titanium dental implants	Implant Crown aesthetic index (CAI)	1	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns
Keller2020	Keller et al., 2020	Two-piece zirconia implants	Two-piece titanium implants	Marginal Bone Loss (MBL)	1	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns
Quaranta2024	Quaranta et al., 2024	One-piece zirconia implant (PURE Ceramic implant (F 4.3 mm, 2LA*))	Two-piece titanium implant (Standard Plus implant (F))	Marginal bone level (MBL) change from baseline	1	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns
Sherlock2022	Sherlock et al., 2022	Two-piece zirconia implant (STRALOS HEALUX) with a screw-retained titanium duplicate crown (SC) on a PEEK base abutment	Two-piece titanium implant (CARLOS screw-free) with cumulative survival rate of the screw-retained	Cumulative survival rate of the screw-retained	1	Green	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns
Kahn2023	Kahn, 2023	Zirconia dental implants	Titanium dental implants	Implant survival rate at 12 months	1	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Some concerns

The data were synthesized in a qualitative manner, describing the findings of the studies. included. Additionally, a quantitative meta-analysis was performed for the outcomes that They presented clinical and methodological homogeneity. Subgroup and sensitivity analyses were performed to test the robustness of the results.

META ANALYSIS

Quantitative data were extracted for peri-implant clinical parameters, including loss. Marginal bone marrow (MBL), peri-implant probing depth (PPD), and Pink Aesthetic Score. (PES), were analyzed using a random-effects meta-analysis and presented as Mean difference (MD) values with 95% confidence intervals (95% CI). Heterogeneity The analysis of the studies was evaluated using the inconsistency statistic (I^2), and was considered substantial when $I^2 > 50\%$ (26). Publication bias was assessed visually using graphs. in a funnel. A significance level of 5% was applied to all analyses, which were performed using the meta package (version 4.18-0) in RStudio (version 4.0.4).

To assess the certainty of the evidence for the meta-analysis outcomes, the following approach was used. GRADE, applied through the GradePro tool (McMaster University and Evidence Prime Inc., Hamilton, Ontario, Canada).

3. RESULTS

SELECTION AND CHARACTERISTICS OF STUDIES

After a calibration exercise between the two reviewers, the initial electronic search resulted in 3,991 records. After removing duplicates and screening titles and abstracts, 25 articles were selected. selected for full-text review. Of these, six ECRs met the criteria of Eligibility criteria were included in the qualitative and quantitative synthesis. The reasons for exclusion at this stage... Full text details are provided in Supplementary Table S3.

An updated search was subsequently performed, resulting in 847 records. additional. After screening, two studies were selected for full-text review and Both met the inclusion criteria. These two trials were therefore incorporated into the analysis. In conclusion, a total of eight RCTs were included in this systematic review and meta-analysis.

All included trials evaluated rehabilitations with single implants, comparing



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

Directly using zirconia and titanium implants, with follow-up periods ranging from 12 to 80 days. months after prosthetic loading. Both the anterior and posterior regions were represented, with older studies focusing predominantly on anterior maxillary sites and more advanced trials recent, including later regions.

Regarding implant design, the studies evaluated single-piece zirconia implants. (one-piece) and two-piece, while titanium implants served as controls in all the trials. The older RCTs primarily investigated body zirconia implants. unique, while more recent studies have focused on two-piece zirconia systems, reflecting Advances in implant design, prosthetic versatility, and surface modification. Although the Implant surfaces, prosthetic protocols, and loading strategies have varied. Across the studies, all trials employed assessments of clinical and radiographic outcomes. standardized.

The primary outcomes included marginal bone loss (MBL) and probing depth. peri-implant disease (PPD) and aesthetic outcomes, most commonly assessed by the Pink Esthetic Score. (PES). Secondary outcomes included implant survival rates, biological and technical complications, and patient-reported outcome measures (PROMs). The main characteristics of the included studies are summarized in Table 1.

The assessment of overall risk of bias, carried out using the Cochrane RoB 2 tool, is summarized in Figure 2, while the judgments by domain for each included study are presented in Table S2. Most trials were classified as having a low risk of bias or some concerns, mainly related to deviations from the intended interventions and regarding outcome assessment. In particular, limitations were observed in the blinding of the evaluators. of outcomes for aesthetic parameters, which is often not feasible in clinical trials of implants. Notably, no consistent pattern of systematic bias was identified. favoring zirconia or titanium implants.

META-ANALYSIS

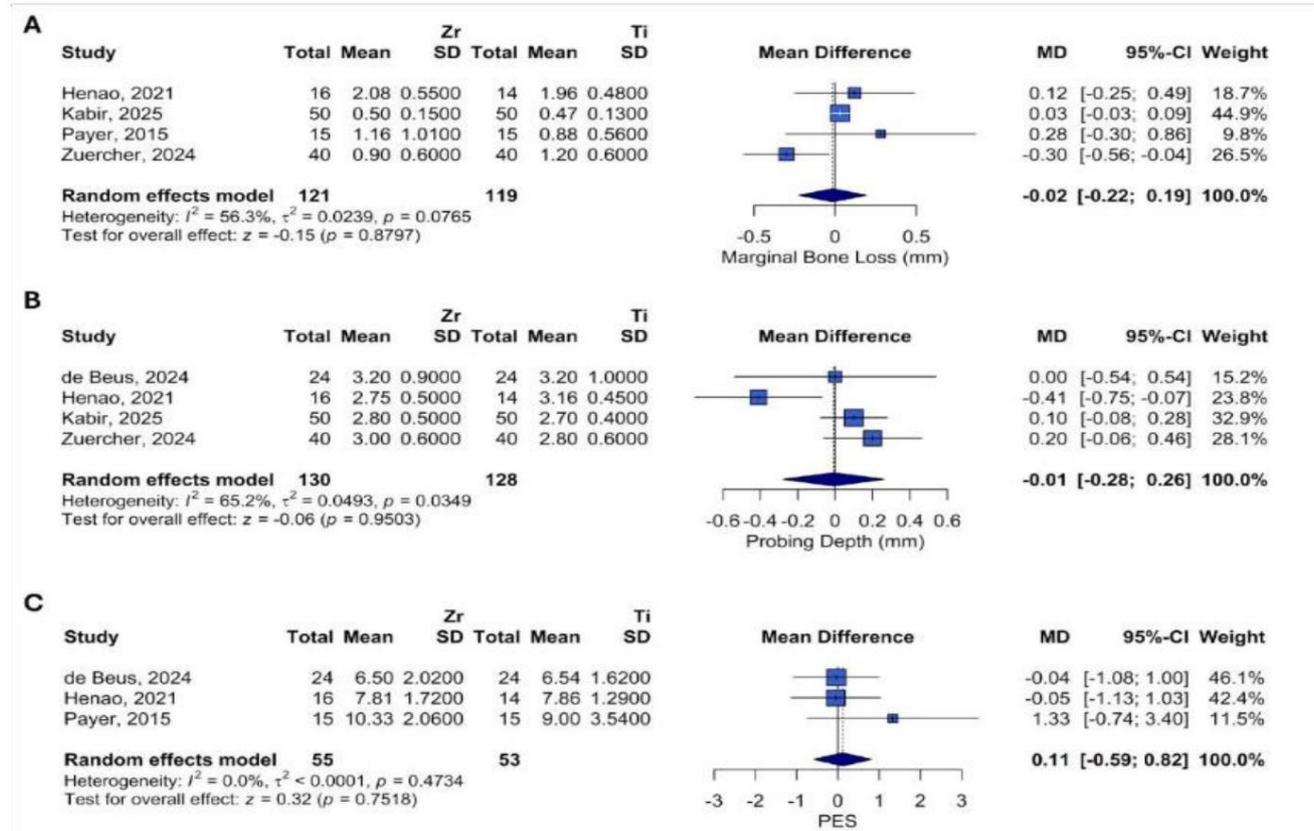
A total of four studies that reported marginal bone loss (MBL) were included in quantitative synthesis. (Henao, 2021 (26) ; Kabir, 2025 (27) ; Payer, 2015 (17) ; Zuercher, 2024 (28)) (Figure 3A). The combined analysis revealed no significant difference between the zirconia implants and Titanium (MD = -0.02 mm; 95% CI: -0.22 to 0.19; p = 0.88). Moderate heterogeneity was observed. ($I^2 = 56.3%$, p = 0.076).

Similarly, four studies provided data on drilling depth. peri-implant (PPD). (de Beus, 2024 (29) ; Henao, 2021 (26) ; Kabir, 2025 (27) ; Zuercher, 2024 (28) (Figure 3B). Consistent with the findings for MBL, the meta-analysis did not demonstrate a difference.

Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

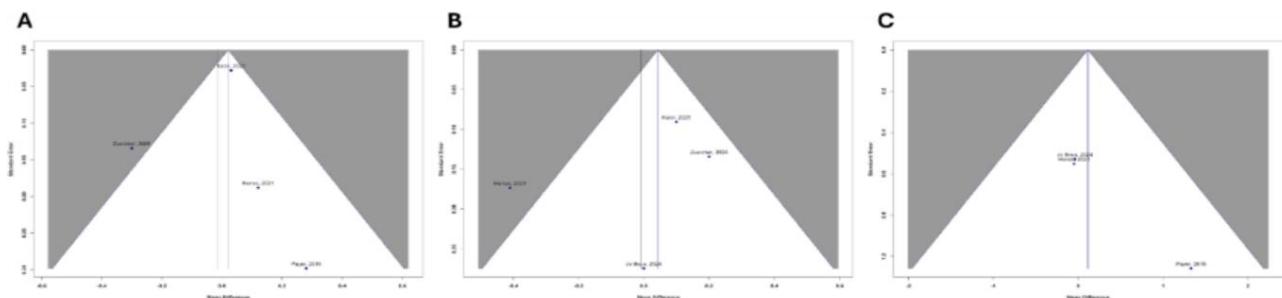
Significant difference between zirconia and titanium implants (MD = -0.01 mm; 95% CI: -0.28 to 0.26; $p = 0.95$). In this case, however, substantial heterogeneity was detected ($I^2 = 65.2\%$, $p = 0.035$).

Figure 3. Forest plots comparing zirconia (Zr) and titanium (Ti) implants. (A) Marginal bone loss (MBL); (B) peri-implant probing depth (PPD); (C) Pink Aesthetic Score (PES). SD: standard deviation; DM: mean difference; 95% CI: 95% confidence interval.



In addition, three studies evaluated the *Pink Esthetic Score* (PES) (de Beus, 2024 (29); Henao, 2021 (26); Payer, 2015 (17)) (Figure 3C). The joint estimate showed, once again, that there were no A significant difference was found between the groups (MD = 0.11; 95% CI: -0.59 to 0.82; $p = 0.75$), and, in contrast Compared to previous results, no heterogeneity was detected ($I^2 = 0\%$, $p = 0.47$).

Figure 4. Funnel plots evaluating publication bias for the included studies. A Marginal bone loss, B peri-implant probing depth, and C Pink Esthetic Score. The distribution of the presented studies was symmetrical, but without evidence of publication bias.



The *funnel plots* for MBL, PPD, and PES (Figure 4A–C) showed a symmetrical distribution.

The studies indicated an absence of evidence of publication bias. Some dispersion was observed.

for MBL and PPD, consistent with the heterogeneity detected.

In these outcomes, while the PES graph appeared homogeneous, in line with the absence of heterogeneity.

CERTAINTY OF EVIDENCE

Finally, the certainty of the evidence was assessed using the GRADE approach (Figure 5).

According to the *Pink Esthetic Score* (PES), the overall certainty of the evidence was rated as high. However, for Based on marginal bone loss (MBL) and peri-implant probing depth (PPD), certainty was considered moderate due to the inconsistency evidenced by the heterogeneity of the data.

In the included randomized clinical trials, no other serious concerns were identified.

due to the risk of bias, indirectness, or imprecision. Consequently, confidence in the estimated effects

The impact ranged from moderate to robust, and the outcomes were graded as important for decision-making. clinical decision.

Figure 5. Summary of conclusions and certainty of evidence assessed using the GRADE approach. The outcomes assessed included marginal bone loss (MBL), peri-implant probing depth (PPD), and Pink Aesthetic Score (PES). All outcomes were classified as high-certainty evidence and considered important for clinical decision-making.

Certainty assessment							N of patients		Effect		Certainty	Importance
No of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Zr dental implants	Ti dental implants	Relative (95% CI)	Absolute (95% CI)		
MBL												
4	randomized trials	not serious	not serious	not serious	not serious	none	121	119	-	MD 0.02 mm (0.22 to 0.19)	⊕⊕⊕⊕ High	IMPORTANT
PPD												
4	randomized trials	not serious	not serious	not serious	not serious	none	130	125	-	MD 0.01 mm (0.28 to 0.26)	⊕⊕⊕⊕ High	IMPORTANT
PES												
3	randomized trials	not serious	not serious	not serious	not serious	none	55	53	-	MD 0.11 PES (0.59 to 0.82)	⊕⊕⊕⊕ High	IMPORTANT

4. DISCUSSION

This systematic review and meta-analysis, which included exclusively clinical trials

Randomized trials comparing zirconia and titanium implants found no differences.

statistically significant differences were observed in the primary outcomes assessed. The pooled analysis demonstrated...

Minimum variation in marginal bone loss (MD = \bar{y} 0.02 mm; 95% CI \bar{y} 0.22 to 0.19; p = 0.88; I² =

56.3%), peri-implant probing depth (MD = \bar{y} 0.01 mm; 95% CI \bar{y} 0.28 to 0.26; p = 0.95;

I² = 65.2%) and aesthetic score (PES; MD = 0.11; 95% CI -0.59 to 0.82; p = 0.75; I² = 0%). The assessment

The quality of the evidence (GRADE) indicated high certainty for these outcomes, reinforcing that, in

In the short to medium term, zirconia implants offer excellent clinical, radiographic, and aesthetic performance.



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

comparable to that of titanium implants. These findings contrast in part with some Previous reviews reported a higher risk of failure and greater bone loss for zirconia. probably due to the inclusion of early generation implants and non-existent studies. randomized, with heterogeneous methodologies.

Survival rates were high in all included studies, ranging from 92% and 100% after 12 months of follow-up (27–29)28,29,30. In contrast, the Longer follow-up studies suggest less predictable behavior of the zirconia. Ruiz Henao et al. (2024) (30) observed that, after 5 years, survival was 86% for implants of Zirconia versus 100% titanium, with fractures representing the main cause of failure. Similarly, in the pilot study by Payer et al. (2015)17, which followed two-piece implants by Losses related to fractures in zirconia, even up to 80 months old, have also been reported, although without significant difference compared to titanium. The study by Sterzenbach et al. (2025) (31) also revealed that the non-inferiority of the zirconia group could not be confirmed, with a cumulative survival was 10.7% lower compared to the titanium group (100%) after 3 years. primarily due to early failures caused by insufficient osseointegration in zirconia implants. These findings suggest that, while short-term performance is comparable, the durability of Zirconia in the medium and long term still represents a point of clinical uncertainty, especially in with regard to initial osseointegration and fracture resistance.

However, some differences arose when considering the biological and technical complications. Zirconia implants showed a higher incidence of fractures or mechanical failures in several studies. studies, particularly in single-piece studies and longer accompaniments17,32. In Kabir et al. (2025) (27), a slightly higher incidence of peri-implantitis was observed, although without difference statistics. The study by Sterzenbach et al. (2025) (31) also noted that although the rate of While overall technical complications were low and statistically insignificant, there was a tendency towards more. Cases of loss of retention of the PEKK abutment and loosening of the screw in the zirconia group. By On the other hand, titanium implants have presented some prosthetic complications, such as failures of components or cementation, also reported in Kabir et al. (2025) (27). This pattern suggests that the choice of material can influence the profile of complications in the medium term: zirconia can being more susceptible to mechanical failures and osseointegration problems, while titanium presents increased risk of prosthetic complications associated with metal components.

Regarding the maintenance of the alveolar crest, all included RCTs reported loss values. similar marginal bone between the groups. In the study by de Beus et al. (2024) (29), there were no significant differences in MBL after 12 months. Zuercher et al. (2024) (28), evaluating the region Subsequently, they found an average marginal bone loss of 0.7 ± 0.6 mm for zirconia, comparable to titanium. Similar results were observed in Kabir et al. (2025) (27), where the loss was of



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

0.50 ± 0.15 mm for zirconia and 0.47 ± 0.13 mm for titanium. Both in the accompanying parts intermediate (24 months in Payer et al., 2015 (17)) as well as longer (5 years in Ruiz Henao et al., 2021 (26)), marginal bone stability did not show statistical differences between the materials. This finding is consistent with the evolution of zirconia implant surfaces, which They began to exhibit microstructured roughness capable of promoting osseointegration. similar to that of titanium. The high certainty of the evidence (GRADE) for MBL reinforces confidence that The actual effect is close to the estimated effect, indicating a robust equivalence between the materials. in the short and medium term.

With regard to soft tissues, clinical parameters such as probing depth (PPD), bleeding on probing (BOP), and plaque index were similar between zirconia and titanium. in all RCTs. Zuercher et al. (2024) (28) and Kabir et al. (2025) (27) reported depth of average borehole depth of approximately 2.7–2.8 mm in both groups, with percentages of bleeding on probing also comparable. The study by de Beus et al. (2024) (29) found Initial differences in PPD and BOP favor titanium 1 month after crown placement, but these The differences were no longer noticeable after 1 year, suggesting that any initial disparities may be due to the underlying causes. to be transient. Although preclinical studies have suggested less bacterial adhesion and less Inflammatory response on zirconia surfaces, translating these effects into clinical benefits. measurable results remain unclear. One possible explanation is that, in clinical trials, the Patients generally have good oral hygiene, which reduces the chance of observing [the condition]. significant clinical differences (32,33). The high certainty of the evidence (GRADE) for PPD also supports the equivalence between the materials in this outcome.

The aesthetic results also showed equivalence between the groups. The meta-analysis did not identified differences in PES, despite the theoretical expectation that zirconia would perform better. Performance is enhanced by its white color and lower risk of discoloration of the peri-implant mucosa. In tests carried out in aesthetic regions, such as those by de Beus et al. (2024) (29) and Ruiz Henao et al. (2021) (26), there was a trend towards better color scores and ICAI for zirconia, especially in patients with thin mucosa, but these findings did not reach statistical significance in the overall PES. However, de Beus et al. (2024) (29) identified significant differences in aesthetic criteria specific factors, such as root convexity/color and texture of soft tissues in favor of zirconia, and the level from the facial mucosa in favor of titanium, suggesting that the implant design and the implant-prosthesis interface They can be as important as the material. The study by Sterzenbach et al. (2025) (31) showed that PES improved significantly in both groups, with the zirconia group achieving... Aesthetic results comparable to titanium after 12 months, despite a lower baseline. Satisfaction Patients' self-reported PROMs were elevated in both groups in all studies. (26,27,29,31), indicating that both zirconia and titanium provide clinical results and



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

acceptable aesthetics for patients in the short and medium term. Kabir et al. (2025) (27) highlighted that Patients preferred zirconia implants because of the soft tissue color, with a difference significant in the perception among patients and clinicians, reinforcing the importance of perceived aesthetics. by the patient.

Compared to previous systematic reviews, our findings offer a broader perspective. more rigorous, since only randomized clinical trials were included. Previous reviews They frequently gathered data from different generations of zirconia implants, including studies non-randomized, retrospective, or with very short follow-up, which increased the heterogeneity and reduced the reliability of the conclusions (32,34). In contrast, this review confirms that, when evaluated under methodologically controlled conditions, zirconia implants They can achieve clinical and radiographic results equivalent to those of titanium, even though they remain doubts regarding long-term performance and mechanical resistance.

Among the limitations of this review, the restricted number of available RCTs stands out. the predominance of follow-ups lasting up to 12 months and the heterogeneity of the implants evaluated (one-piece versus two-piece, front versus back regions, distinct surfaces and connections). Furthermore, few studies have stratified the results according to relevant clinical variables. such as gingival biotype, functional load or parafunction. The study by Sterzenbach et al. (2025) (31) He also pointed to the loss of patients for follow-up as a limitation that affected the survival outcomes. These gaps reinforce the need for multicenter clinical trials. with longer follow-up periods, microbiological and inflammatory outcomes, and PROMs standardized methods, in order to provide more robust evidence on the clinical applicability of zirconia.

From a clinical standpoint, the findings of this review support the use of zirconia as a A viable alternative to titanium, especially in situations with high aesthetic demands or in patients. who exhibit hypersensitivity to metals. However, given the increased risk of mechanical failure observed in longer follow-up studies and the lower initial osseointegration rate in some studies (31) recommend caution in its use in areas of high masticatory load, in Patients with bruxism or when reduced-diameter implants are needed. Titanium, for example. In turn, it remains the gold standard, with excellent clinical longevity, but may present Aesthetic limitations and occasional prosthetic complications.

Future studies, well-designed and with follow-up periods exceeding 10 years, will be essential. to consolidate the scientific evidence on the durability of zirconia implants in clinical practice. It is crucial that future research focuses on optimizing the osseointegration of zirconia implants. Two-piece zirconia, in the evaluation of long-term complications, and in the investigation of implants. Zirconia with transmucosal designs similar to titanium to isolate the material's effect. The importance of a robust study design and rigorous follow-up to avoid losses.



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

Patients should also be highlighted.

CONCLUSION

This systematic review and meta-analysis, which included exclusively clinical trials
Randomized trials demonstrate that zirconia implants exhibit clinical performance.
Radiographic and aesthetic results are comparable to those of titanium implants in the short and medium term. They were not...
Statistically significant differences were found in marginal bone loss (MBL), depth
peri-implant probing (PPD) and aesthetic score (PES), with high certainty of evidence (GRADE)
for these outcomes. These findings are robust and suggest that both materials are equally effective.
effective in maintaining bone and peri-implant soft tissue health, as well as in obtaining
of satisfactory aesthetic results, contrasting with previous reviews that included studies with
more heterogeneous methodologies.

However, analysis of studies with longer follow-ups reveals that durability
The medium- and long-term future of zirconia still presents uncertainties. A trend towards lower returns has been observed.
survival rates and a higher incidence of mechanical failures, such as fractures, and problems with
Initial osseointegration in zirconia implants. From a clinical point of view, zirconia is a
A viable alternative to titanium, especially in aesthetic situations or for patients with
Hypersensitivity to metals. However, uncertainty remains regarding its long-term durability and the risk
Mechanical failures require caution when prescribing this product for areas of high masticatory load. Future studies,
Well-designed studies with follow-up periods exceeding 10 years are fundamental for consolidating the evidence.
Scientific research on the longevity and optimization of zirconia implants in clinical practice.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to the materials and devices.
or methods discussed in this study.

FINANCING

This study did not receive specific funding.

DATA AVAILABILITY

All data generated or analyzed during this study are included in this article.



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

published and in its supplementary material.

References

ANDREIOTELLI, M.; WENZ, H.J.; KOHAL, RJ Are ceramic implants a viable alternative to titanium implants? A systematic literature review. **Clinical Oral Implants Research**, [S. l.], v. 20, no. 4, p. 32–47, Sept. 2009. Available at: <https://pubmed.ncbi.nlm.nih.gov/19663947/>. Accessed on: December 19, 2025.

BORGONOVO, AE et al. Zirconia Implants in Esthetic Areas: 4-Year Follow-Up Evaluation Study. **International Journal of Dentistry**, [S. l.], v. 2015, 2015. Available at: <https://pubmed.ncbi.nlm.nih.gov/26124836/>. Accessed on: December 19, 2025.

BRÅNEMARK, PI et al. Intra-osseous anchorage of dental prostheses. I. Experimental studies. **Scandinavian Journal of Plastic and Reconstructive Surgery**, [S. l.], v. 3, no. 2, p. 81–100, 1969. Available at: <https://pubmed.ncbi.nlm.nih.gov/4924041/>. Accessed on: December 19, 2025.

BUSER, D. et al. 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: a retrospective study in 303 partially edentulous patients. **Clinical Implant Dentistry and Related Research**, [S. l.], v. 14, no. 6, p. 839–51, Dec. 2012. Available at: <https://pubmed.ncbi.nlm.nih.gov/22897683/>. Accessed on: December 19, 2025.

BUSER, D. et al. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. **Journal of Biomedical Materials Research**, [S. l.], v. 25, no. 7, p. 889–902, 1991. Available at: <https://pubmed.ncbi.nlm.nih.gov/1918105/>. Accessed on: December 19, 2025.

CAVALCANTI, AN et al. Y-TZP ceramics: key concepts for clinical application. **Operative Dentistry**, [S. l.], v. 34, pp 344–51, May 2009. Available at: <https://pubmed.ncbi.nlm.nih.gov/19544825/>. Accessed on: December 19, 2025.

CHRISTEL, P. et al. Mechanical properties and short-term in-vivo evaluation of yttrium-oxide-partially-stabilized zirconia. **Journal of Biomedical Materials Research**, [S. l.], v. 23, no. 1, p. 45–61, 1989. Available at: <https://pubmed.ncbi.nlm.nih.gov/2708404/>. Accessed on: December 19, 2025.

COCHRAN, DL et al. A 5-year prospective multicenter study of early loaded titanium implants with a sandblasted and acid-etched surface. **The International Journal of Oral & Maxillofacial Implants**, [S. l.], v. 26, no. 6, pp. 1324–34, Nov. 2011. Available at: www.researchgate.net/publication/51876518. Accessed on: January 16, 2026.

COCHRAN, DL et al. Evaluation of an endosseous titanium implant with a sandblasted and acid-etched surface in the canine mandible: radiographic results. **Clinical Oral Implants Research**, [S. l.], v. 7, no. 3, p. 240–52, 1996. Available at: <https://pubmed.ncbi.nlm.nih.gov/9151588/>. Accessed on: December 19, 2025.



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

COMISSO, I.; ARIAS-HERRERA, S.; GUPTA, S. Zirconium dioxide implants as an alternative to titanium: A systematic review.

Journal of Clinical and Experimental Dentistry, [S. l.], v. 13, no. 5, p. 511–9, May 2021. Available at: <https://pubmed.ncbi.nlm.nih.gov/33981400/>. Accessed on: December 19, 2025.

DA SILVA, LH et al. Dental ceramics: a review of new materials and processing methods.

Brazilian Oral Research, [S. l.], v. 31, n. 1, p. 133–46, Aug. 2017. Available at: <https://pubmed.ncbi.nlm.nih.gov/28902238/>. Accessed on: December 19, 2025.

DE BEUS, JHW et al. A randomized clinical trial on zirconia versus titanium implants in maxillary single tooth replacement.

Clinical Oral Implants Research, [S. l.], v. 35, no. 6, p. 630–40, jun. 2024.

Available at: <https://pubmed.ncbi.nlm.nih.gov/38567929/>. Accessed on: December 20, 2025.

ELNAYEF, B. et al. Zirconia Implants as an Alternative to Titanium: A Systematic Review and Meta-Analysis. **The**

International Journal of Oral & Maxillofacial Implants, [S. l.], v. 32, no. 3, p. e125–

34, May 2017. Available at: <https://pubmed.ncbi.nlm.nih.gov/28170450/>. Accessed on: December 20, 2025.

GAHLERT, M. et al. A prospective clinical study to evaluate the performance of zirconium dioxide dental implants in single-tooth gaps. **Clinical Oral Implants Research**, [S. l.], v. 27, no. 12, p. e176–

84, Dec. 2016. Available at: <https://pubmed.ncbi.nlm.nih.gov/25827600/>. Accessed on: December 19, 2025.

GAHLERT, M. et al. In vivo performance of zirconia and titanium implants: a histomorphometric study in mini pig maxillae.

Clinical Oral Implants Research, [S. l.], v. 23, no. 3, p. 281–6, mar. 2012.

Available at: <https://pubmed.ncbi.nlm.nih.gov/21806681/>. Accessed on: December 19, 2025.

GÜNGÖR, MB et al. An overview of zirconia dental implants: Basic properties and clinical application of three cases. **Journal of Oral Implantology**, [S. l.], v. 40, no. 4, p. 485–94, 2014.

HASHIM, D. et al. A systematic review of the clinical survival of zirconia implants. **Clinical Oral Investigations**, [S. l.], v. 20, no. 7, p. 1403–17, Sept. 2016. Available at: <https://pubmed.ncbi.nlm.nih.gov/27217032/>. Accessed on: December 20, 2025.

KABIR, N. Long-term Performance of Zirconium vs Titanium Dental Implant. **EAS Journal of Dentistry and Oral Medicine**, [S. l.], v. 7, no. 2, p. 105–10, apr. 2025.

KOHAL, RJ; FINKE, H. C.; KLAUS, G. Stability of prototype two-piece zirconia and titanium implants after artificial aging: an in vitro pilot study. **Clinical Implant Dentistry and Related Research**, [S. l.], v. 11, p. 323–9, Dec. 2009. Available at: <https://pubmed.ncbi.nlm.nih.gov/18783418/>. Accessed on: December 19, 2025.

KOLLER, M. et al. Two-piece zirconia versus titanium implants after 80 months: Clinical outcomes from a prospective randomized pilot trial. **Clinical Oral Implants Research**, [S. l.], v. 31, no. 4, p. 388–96, apr. 2020. Available at: <https://pubmed.ncbi.nlm.nih.gov/31944420/>. Accessed on: December 19, 2025.



Year VI, v.1 2026 | Submission: 03/14/2026 | Accepted: 03/16/2026 | Publication: 03/18/2026

MORENA, D. et al. Comparative Clinical Behavior of Zirconia versus Titanium Dental Implants: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. **Journal of Clinical Medicine**, [S. l.], 15, 2024. <https://pubmed.ncbi.nlm.nih.gov/39124755/>. Accessed on: December 19, 2025. 13, n. Aug. Available in:

PADHYE, NM et al. Survival and success of zirconia compared with titanium implants: a systematic review and meta-analysis. **Clinical Oral Investigations**, [S. l.], v. 27, no. 11, p. 6279–90, nov. 2023. Available at: <https://pubmed.ncbi.nlm.nih.gov/37740825/>. Accessed on: December 19, 2025.

PAYER, M. et al. All-ceramic restoration of zirconia two-piece implants--a randomized controlled clinical trial. **Clinical Oral Implants Research**, [S. l.], v. 26, no. 4, p. 371–6, apr. 2015. Available at: <https://pubmed.ncbi.nlm.nih.gov/24502675/>. Accessed on: December 19, 2025.

PICONI, C.; MACCAURO, G. Zirconia as a ceramic biomaterial. **Biomaterials**, [S. l.], v. 20, n. 1, p. 1–25, jan. 1999. Available at: <https://pubmed.ncbi.nlm.nih.gov/9916767/>. Accessed on: December 19, 2025.

PIERALLI, S. et al. Clinical Outcomes of Zirconia Dental Implants: A Systematic Review. **Journal of Dental Research**, [S. l.], v. 96, no. 1, p. 38–46, Jan. 2017. Available at: <https://pubmed.ncbi.nlm.nih.gov/27625355/>. Accessed on: December 20, 2025.

RIMONDINI, L. et al. Bacterial colonization of zirconia ceramic surfaces: an in vitro and in vivo study. **The International Journal of Oral & Maxillofacial Implants**, [S. l.], v. 17, no. 6, p. 793–8, nov. 2002. Available at: <https://pubmed.ncbi.nlm.nih.gov/12507238/>. Accessed on: December 19, 2025.

ROEHLING, S. et al. Performance and outcome of zirconia dental implants in clinical studies: A meta-analysis. **Clinical Oral Implants Research**, [S. l.], v. 29, no. 16, p. 135–53, Oct. 2018. Available at: <https://pubmed.ncbi.nlm.nih.gov/30328200/>. Accessed on: December 19, 2025.

RUIZ HENAO, PA et al. Single-piece zirconia versus single-piece titanium, narrow-diameter dental implants in the anterior maxilla: 5-year post-loading results of a randomized clinical trial. **Clinical Oral Implants Research**, [S. l.], v. 35, no. 10, p. 1310–23, Oct. 2024. Available at: <https://pubmed.ncbi.nlm.nih.gov/38940623/>. Accessed on: December 20, 2025.

RUIZ HENAO, PA et al. Titanium vs ceramic single dental implants in the anterior maxilla: A 12-month randomized clinical trial. **Clinical Oral Implants Research**, [S. l.], v. 32, no. 8, p. 951–61, Aug. 2021. Available at: <https://pubmed.ncbi.nlm.nih.gov/34061402/>. Accessed on: December 20, 2020.

SALES, PHH et al. Do zirconia dental implants present better clinical results than titanium dental implants? A systematic review and meta-analysis. **Journal of Stomatology, Oral and Maxillofacial Surgery**, [S. l.], v. 124, no. 1, Feb. 2023. Available at: <https://pubmed.ncbi.nlm.nih.gov/36330865/>. Accessed on: December 19, 2025.

SIDDIQI, A. et al. Titanium allergy: could it affect dental implant integration? **Clinical Oral Implants Research**, [S. l.], v. 22, no. 7, p. 673–80, Jul. 2011. Available at: <https://pubmed.ncbi.nlm.nih.gov/21251079/>. Accessed on: December 19, 2025.

STERZENBACH, G. et al. A Randomized Controlled Trial Evaluating 3-Year Survival Rates and Technical Complications of Screw-Retained Hybrid Abutment Crowns on Two-Piece Zirconia and Titanium Implants. **Clinical Oral Implants Research**, [S. l.], v. 36, no. 8, p. 965–77, Aug. 2025.

Available at: <https://pubmed.ncbi.nlm.nih.gov/40297919/>. Accessed on: December 20, 2025.

ZHOU, Z. et al. The unfavorable role of titanium particles released from dental implants.

Nanotheranostics, [S. 3, p. 321–32, 2021.5]. Available at: <https://pubmed.ncbi.nlm.nih.gov/33732603/>.

Accessed on: December 19, 2025.

ZUERCHER, AN et al. Clinical, radiographic and patient-reported outcomes of zirconia and titanium implants in the posterior zone after 1 year of loading-A randomized controlled trial. **Clinical Oral Implants Research**, [S. l.], v. 35, no. 11, p. 1428–39, nov. 2024. Available at: <https://pubmed.ncbi.nlm.nih.gov/39056305/>.

Accessed on: December 20, 2025.

APPENDIX

Electronic databases	Search data
PubMed	1. ("Dental implants"[MeSH] OR "Dental implants" OR "Dental Implant" OR "Surgical Dental Prostheses" OR "Surgical Dental Prosthesis" OR "Dental Implants, Single-Tooth"[MeSH] OR "Dental Implants, Single-Tooth" OR "Single Tooth Dental Implants" OR "Single-Tooth Implants" OR "Single-Tooth Implant" OR "Single Tooth Implants" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") 2. ("zirconia" OR "zirconium dioxide" OR "yttria-stabilized tetragonal zirconia" OR "Y-TZP ceramic" OR "Yttria-Stabilized Tetragonal Zirconia Polycrystals Ceramic" OR "zirconia" OR "ceramic implants") 3. #1 AND #2
Scopus	(("Dental implants" OR "Dental Implant" OR "Surgical Dental Prostheses" OR "Surgical Dental Prosthesis" OR "Dental Implants, Single-Tooth" OR "Single Tooth Dental Implants" OR "Single-Tooth Implants" OR "Single-Tooth Implant" OR "Single Tooth Implants" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") AND ("zirconia" OR "zirconium dioxide" OR "yttria-stabilized tetragonal zirconia" OR "Y-TZP ceramic" OR "Yttria-Stabilized Tetragonal Zirconia Polycrystals Ceramic" OR "zirconia" OR "ceramic implants"))

Web of Science	<ol style="list-style-type: none"> 1. TS=("Dental implants" OR "Dental Implant" OR "Surgical Dental Prostheses" OR "Surgical Dental Prosthesis" OR "Dental Implants, Single-Tooth" OR "Single Tooth Dental Implants" OR "Single-Tooth Implants" OR "Single-Tooth Implant" OR "Single Tooth Implants" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") 2. TS=("zirconia" OR "zirconium dioxide" OR "yttria-stabilized tetragonal zirconia" OR "Y-TZP ceramic" OR "Yttria-Stabilized Tetragonal Zirconia Polycrystals Ceramic" OR "zirconia" OR "ceramic implants") 3. #1 AND #2
Embase	<p>((("Dental implants" OR "Dental Implant" OR "Surgical Dental Prostheses" OR "Surgical Dental Prosthesis" OR "Dental Implants, Single-Tooth" OR "Single Tooth Dental Implants" OR "Single-Tooth Implants" OR "Single-Tooth Implant" OR "Single Tooth Implants" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") AND ("zirconia" OR "zirconium dioxide" OR "yttria-stabilized tetragonal zirconia" OR "Y-TZP ceramic" OR "Yttria-Stabilized Tetragonal Zirconia Polycrystals Ceramic" OR "zirconia" OR "ceramic implants"))</p>
Cochrane	<ol style="list-style-type: none"> 1. ("Dental implants" OR "Dental Implant" OR "Surgical Dental Prostheses" OR "Surgical Dental Prosthesis" OR "Dental Implants, Single-Tooth" OR "Single Tooth Dental Implants" OR "Single-Tooth Implants" OR "Single-Tooth Implant" OR "Single Tooth Implants" OR "Single-Tooth Dental Implant" OR "Single Tooth Dental Implant") 2. ("zirconia" OR "zirconium dioxide" OR "yttria-stabilized tetragonal zirconia" OR "Y-TZP ceramic" OR "Yttria-Stabilized Tetragonal Zirconia Polycrystals Ceramic" OR "zirconia" OR "ceramic implants") 3. #1 AND #2