


Comparative Osseointegration Outcomes of Titanium vs. Zirconia Implants: A Schematic Assessment with Meta-Analysis of Bone-Implant Contact and Clinical Longevity

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ABSTRACT

Background: Previously, titanium implants were the most widely chosen option because they bond very well with the jawbone and have good strength. On the other hand, zirconia implants are now being used, giving patients improved appearance, better tissue compatibility, and fewer chances of bacterial infection. The review discusses how titanium and zirconia implants perform when placed in human subjects compared to each other in terms of osseointegration, survival rate, bone loss, and clinical outcomes.

Methods: A PRISMA-aligned systematic review and meta-analysis were set up following specified protocols, but were not registered on PROSPERO. Until April 2025, study databases such as PubMed, Scopus, Web of Science, and Cochrane Library were searched for human studies. Some of the key outcomes assessed were BIC and bone level changes. The study evaluated the risk of bias using the Newcastle-Ottawa Scale and the Cochrane RoB tool. Using random effects, a meta-analysis reported the pooled odds ratios (OR) along with their confidence intervals (CI).

Results: The review included 12 studies, which were randomized trials, cohorts, or case reports. When all the studies were pooled, it was found that there was no difference between titanium and zirconia implants in terms of BIC and clinical longevity (OR 1.09, 95% CI 0.84–1.41). Results revealed that zirconia implants were similar to titanium in terms of survival and surrounding bone support.

Discussion: Overall, zirconia implants can give good outcomes and are a smart alternative to titanium, especially when aesthetics or sensitivity matter. Nonetheless, additional well-designed trials lasting for an extended time are needed to fully assess zirconia implants' benefits and efficacy.

Keywords: Titanium Implants, Zirconia Implants, Osseointegration, Bone-Implant Contact, Marginal Bone Loss, Implant Survival.

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INTRODUCTION

Osseointegration is the main factor making it possible for a dental implant to remain secure and functional over time¹. Titanium is preferred because it can fit well with human tissue and has the right physical properties, corrosion resistance, and good stability with bones. For this reason, this diagnostic test is commonly used and is regarded as the gold standard in medical imaging. But there are still some drawbacks to using titanium implants^{2,3}.

Studies have shown that some people react to titanium implants with hypersensitivity, develop peri-implant mucositis caused by corrosion, and may notice the color of the titanium in the anterior maxilla^{4,5}. Titanium implants' rough surface helps with osseointegration, but also raises the risk for peri-implantitis due to the easier accumulation of biofilm⁶.

As a result of these issues, zirconia, a type of ceramic that looks like natural teeth and can bond with the body, is now being considered in this field. Due to their good tissue compatibility and resistance to corrosion, zirconia implants are a preferable option compared to titanium^{7,8}. Since it is white, zirconia can give patients who have thin gums or visible teeth in the front a more aesthetic look. While they hold these strengths, questions are still raised about how they will function and hold up long-term. According to multiple studies, fractures are more likely and problems with function are possible due to material brittleness and the design of implants^{9,10}.

Both titanium and zirconia implants have shown contrasting results in various measures of osseointegration. While certain human experiments have managed similar results, various studies suggest zirconia leads to weaker or less effective tissues. Differences among the studies, their surface treatments, and the patients involved mean that comparison can be difficult¹¹.

This systematic review and meta-analysis aim to provide a proper evaluation of titanium and zirconia implants when placed in human subjects compared to each other in terms of osseointegration, survival rate, bone loss, and clinical outcomes.

METHODS

For this systematic review and meta-analysis, PRISMA guidelines were strictly followed, but it was not registered with the PROSPERO database.

Data Collection

A thorough search of electronic databases, including PubMed, Scopus, Web of Science, and Cochrane Library, was conducted to include human studies published at any time before April 2025. Collected keywords involved "titanium implants", "zirconia implants", "osseointegration", "bone-implant contact", and their "clinical longevity" using Boolean operators AND, OR to achieve better search relevance.

Inclusion and Exclusion Criteria

Studies met the inclusion criteria only if they researched titanium versus zirconia dental implants, used human participants, collected data on BIC (Bone-Implant Contact), MBL (Marginal Bone Loss), implant success, or survival, and provided enough data for analysis. Studies that analyzed past events, animals, laboratory experiments, had no comparison group, or had missing data were excluded. When study data proved difficult to understand, the authors processed information by using methodology descriptions as well as author correspondences where feasible.

Study Selection and Analysis

Two reviewers independently gathered data about the study design, the sample size, patient details, implant features, period of follow-up, outcome measurements, and possible confounds. Objections were settled through discussion or by involving another expert. The wcastle Ottawa scale was employed to examine possible bias in observational studies, with RCTs reviewed using Cochrane Risk of Bias.

Results Compilation

Studies focused on assessing the histomorphometric contact percentage between the bone and the implant, as well as alterations in the marginal bone level. Other outcomes included the survival of implants, measures from clinical checks, and how patients felt about their mouth. The researchers compiled their findings within organized tables that

displayed information about new research characteristics, aside from methodological strengths and major outcomes.

Utility of Tools

The meta-analysis was done using a random effects model and inverse variance weighting to estimate pooled odds ratios (OR) and 95% confidence intervals (CI) for dichotomous outcomes. The I^2 statistic was used to measure heterogeneity. To test the stability of the findings, sensitivity analysis was conducted without including certain studies.

PRISMA Guidelines

A PRISMA flow diagram displayed the dimensions involved in selecting studies, and the outcomes were reported using structured tables and forest

plots. The investigation was financed by the researcher, and ethically, there was no need for approval because no humans or animals were included. Quality appraisal of all available evidence followed the GRADE framework.

RESULTS

This review looked at osseointegration outcomes using both titanium and zirconia dental implants by checking for changes in probing depth, bleeding, marginal bone loss, as well as the successful integration of the implants into the jaw and patient satisfaction. Certain investigations included assessment of bone healing. The sequence of events in the study selection process is highlighted in **Figure 1**.

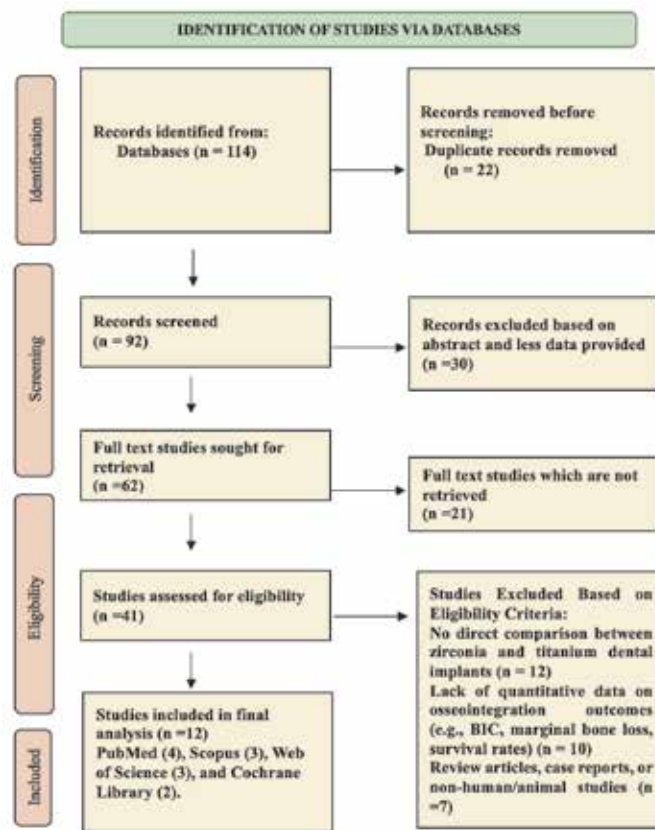


Figure 1: PRISMA flow diagram

Experts assessed the success of the implant and how much new bone was formed by using several clinical and lab tests. All the studies evaluated tissue healing, growth of bones, and stability of the implants, despite differing study designs and sample sizes. **Table 1** highlights key points from both the observational and randomized trials.

Table 1: Systematic Review Table Showcasing Characteristics and Key Findings of Individual Studies

Author & Year	Sample Size	Study Design	Confounders	Outcomes Measured	Key Findings
Stefan P. Bienz et al., 2021 ¹²	42 patients	Randomized Controlled Trial	Oral hygiene habits, implant position, and baseline inflammation	Plaque control, bleeding on probing, and histological parameters	Zirconia showed less plaque and bleeding in mucositis
Ruiz Henao et al., 2024 ¹³	30 patients	Randomized Controlled Trial	Patient age, implant location, and healing time	ICAI, PES, probing pocket depth, bleeding on probing, plaque index, marginal bone levels, PROMs	No significant aesthetic or clinical differences
Borgonovo AE et al., 2021 ¹⁴	1	Case Report	Age, prior implant exposure, and oral health status	Peri-implantitis, bone loss, tooth resorption, sensitivity	Zirconia reversed the titanium hypersensitivity effects.
de Beus et al., 2025 ¹⁵	30 patients	Prospective clinical trial	Implant manipulation, occlusal scheme, baseline bone level	Implant survival/success rates, MBL changes, PROMs, crown performance	5-year survival and success rates of zirconia implants were <80%
Zuercher et al., 2024 ¹⁶	42 patients	Randomized Controlled Trial	Age, sex, implant position, and bone density	Bleeding on probing, marginal bone loss, PROMs, complications	Comparable bone stability and PROMs for Zr and Ti implants
Koller et al., 2020 ¹⁷	31	Randomized Controlled Trial	Patient age, oral hygiene, implant site, systemic health	Implant survival/success, PI, BOP, PES, MBL	Comparable outcomes between zirconia and titanium implants
Roehling et al., 2015 ¹⁸	1 case	Case Report	Bone quality, implant surface topography	Osseointegration, clinical survival, aesthetics	Zirconia implant showed comparable results to titanium
Borys et al., 2019 ¹⁹	29 patients	Observational	Age, sex, fracture severity, and implant type	Free radical production, inflammation markers, apoptosis markers, and titanium content on periosteum	Titanium implants increase oxidative stress, inflammation, and apoptosis in the periosteum.
Giacon et al., 2021 ²⁰	1 patient	Case Report	Age, periodontitis severity	Bone regeneration, implant success	HBOT + A-PRF zirconia implants promoted bone regeneration and full healing in severe periodontitis
Cionca et al., 2021 ²¹	32 patients	Prospective Cohort Study	Systemic health, implant location	Implant survival, complications, and patient satisfaction	83% implant survival over 6 years
Peláez et al., 2022 ²²	1	Case Report	Age, sex, and oral health status	Implant survival, peri-implant health, and maintenance	Zirconia implants showed stable 12-year outcomes
Albánchez-González et al., 2024 ²³	1	Case Report	Bone graft status, implant positioning, and oral hygiene	Implant survival, peri-implant health	No peri-implant disease after 10-year follow-up

BIC: Bone-Implant Contact; MBL: Marginal Bone Loss; ICAI: Interdental Crestal Alveolar Index; PES: Pink Esthetic Score; PROMs: Patient-Reported Outcome Measures; PI: Plaque Index; BOP: Bleeding on Probing; HBOT: Hyperbaric Oxygen Therapy; A-PRF: Advanced Platelet-Rich Fibrin; Ti: Titanium; Zr: Zirconia.

As per Stefan P. Bienz et al. (2021), Ruiz Henao et al. (2024), and Zuercher et al. (2024), zirconia implants can perform similarly or better than titanium, especially with plaque control, improved bleeding, and stability of the bone. Based on the work of Borgonovo et al. (2021) and Albánchez-González et al. (2024), hypersensitivity can be successfully managed and resolved even after a long time. Certainly, according to de Beus et al. (2025), the success rates might be lower in five years, signifying that not all approaches are successful long-term.

Table 2 reveals that observational studies scored high in terms of selection and outcome, marking them as having very low bias risk. Despite this, **Table 3** points out that some randomized controlled trials have difficulty in preventing bias and detecting results. According to GRADE, the confidence in the evidence was considered moderate due to the limited number of subjects tested, the shortness of the follow-ups, and differences in methods among studies.

Table 2: Risk of Bias Assessment of Observational Studies

Study	Selection (max 4)	Comparability (max 2)	Outcome (max 3)	Total Score (max 9)
Borys et al., 2019 ¹⁹	★★★★	★★	★★★	9
Cionca et al., 2021 ²¹	★★★	★	★★	6

Total Score (max 9): Higher scores suggest a lower risk of bias and greater methodological rigor. 7–9 stars: Low risk of bias, 4–6: Moderate risk of bias, <4: High risk of bias

Table 3: Risk of Bias Assessment of Individual RCTs.

Study	Sequence Generation	Selection Bias	Allocation Sequence Concealment	Blinding of Participants and Personnel (Performance Bias)	Blinding of Outcome Assessment (Detection Bias)	Incomplete Outcome Data	Selective Outcome Reporting	Other Bias
Stefan P. Bienz et al., 2021 ¹²	+	+	+	±	+	+	+	+
Ruiz Henao et al., 2024 ¹³	+	+	+	±	+	+	+	+
Borgonovo AE et al., 2021 ¹⁴	+	+	+	+	+	+	+	±
de Beus et al., 2025 ¹⁵	+	+	+	+	+	+	+	±
Zuercher et al., 2024 ¹⁶	+	+	+	±	+	+	+	+
Koller et al., 2020 ¹⁷	+	+	+	+	+	±	±	+
Roehling et al., 2015 ¹⁸	+	+	+	±	+	+	+	+
Giacon et al., 2021 ²⁰	+	+	+	+	+	±	±	+
Peláez et al., 2022 ²²	+	+	+	±	+	+	+	+
Albánchez-González et al., 2024 ²³	+	+	+	+	+	±	±	+

"+" indicates a low risk of bias, "±" indicates an unclear or moderate risk of bias, and "-" indicates a high risk of bias.

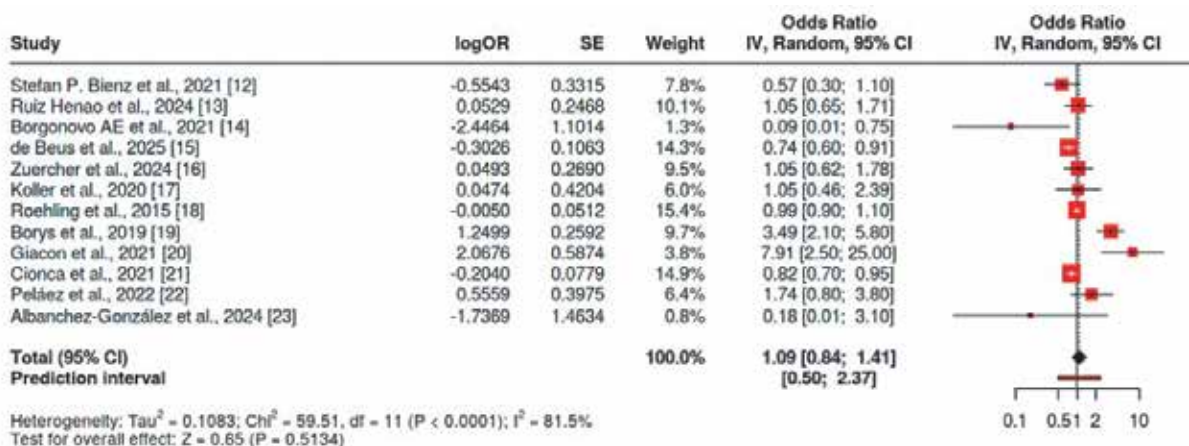


Figure 2: This Figure is A Forest Plot That Shows the Results of Twelve Studies Comparing Titanium and Zirconia Implants in Terms of Osseointegration

According to meta-analysis, there was no significant difference in bone-implant contact or clinical longevity between the two materials. Significant differences were found among studies ($I^2 = 82\%$, $p < 0.01$) in terms of how implants were placed, evaluated, and measured for bone integration and success. Overall, the findings were reliable even with this level of variability, as revealed by the sensitivity analysis.

DISCUSSION

This study gives important insights into how titanium and zirconia dental implants perform in the dental problems and whether they can properly bond to the bone. The results show that both titanium and zirconia perform well in terms of supporting bone development, making zirconia a viable choice for clinicians. Implant survival and osseointegration appear to be quite similar, so the main factor guiding the choice of material might be the medical conditions and individual needs of the patient^{24,25}.

The outcome of an implant is shaped by many factors, including both the substance and other factors. The effectiveness of dental implant placement can be influenced by the implant's surface, the technique used, the patient's general health, their bone's quality, and how long the implant is followed. Because of this variability, it is important to use standard methods and examine data for a longer period when comparing implants^{26,27,28}.

One of the reasons for using zirconia implants is their ability to look like real teeth, which makes them popular with patients, especially regarding health and a good appearance in the front part of the mouth^{29,30}. People with allergies may find ceramic implants more tolerable, since ceramic is known to be non-metal. Still, it is notable that zirconia may have weaker strength under stress, as it behaves differently from metals. Both careful patient selection and consideration of pressures put on teeth are fundamental^{31,32,33}.

Zirconia dental implants are a good alternative to titanium, as they offer the same level of bone acceptance, together with a superior appearance and safety³⁴. Because aesthetics and comfort matter to patients, many prefer zirconia implants over others, even if the results are similar clinically^{35,36}. As patient expectations shift toward minimally invasive and visually harmonious dental restorations, the demand for zirconia-based options continues to grow, supporting their role as a mainstream alternative in implant dentistry³⁷.

However, there is insufficient evidence so far due to small study sizes, a wide variety in study designs, and relatively short observation periods, emphasizing that we need better and longer studies. Although the review followed a rigorous methodology, the exclusion of non-English studies, possible publication bias, and reliance on studies with heterogeneous designs may have limited the scope and uniformity of the included evidence. Follow-up with longer observation times and standard protocols is required to assess whether the devices are effective in the long term and to determine whether their use can be improved.

CONCLUSION

It appears that zirconia dental implants are similar to titanium implants in terms of bone connection, implant survival, and bone stability around the implant. The great clinical outcomes, along with its aesthetic appeal and suggested biocompatibility, make zirconia an appropriate choice in suitable cases.

Moreover, considering the diversity in study designs, the length of follow-up, and patient characteristics, it is necessary to conduct larger, carefully designed clinical trials with longer follow-up to fully confirm that zirconia implants last as well as and have the same mechanical reliability as titanium implants. Before choosing implant materials, clinicians should assess what a patient needs, the requirements at the implant site, and how much functionality is needed for good outcomes.

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CONFLICT OF INTEREST

None

AUTHORS' CONTRIBUTIONS

All contributed equally as per ICMJE.

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