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Review Article

Zirconia abutments: Biological, mechanical, and esthetic considerations – An umbrella review of available systematic reviews and meta-analyses

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ABSTRACT

Zirconia abutments can enhance esthetics by providing a natural appearance due to their semitranslucency. Evidence for final outcomes of using zirconia abutments compared to other available materials are diverse. This study aims to review all available evidence from previous reviews to compare zirconia and titanium abutments regarding biological, mechanical, and esthetics indices and survival. An electronic search was conducted on six databases (PubMed, Scopus, Embase, Web of Science, ProQuest, and Cochrane) for systematic reviews/meta-analyses published until 2023. The relevant data were extracted and reviewed from the selected studies. Fourteen articles were included following a systematic application of the inclusion and exclusion criteria. These studies evaluated various factors, including soft tissue recession, width of keratinized mucosa, papilla index, plaque accumulation, Copenhagen Index Score, Implant Crown Aesthetic Index, gingival discoloration, pocket probing depth, marginal bone loss, bleeding on probing, Pink Esthetic Score, White Esthetic Score, survival rate, and patient's satisfaction. Zirconia abutments showed better or similar effects than titanium in biological, esthetic, and mechanical factors and survival.

Key Words: Biological complications, ceramic abutment, dental implant, esthetics, mechanical complications, metal abutment, survival

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INTRODUCTION

Implant-supported restorations are desirable for replacing missing teeth due to their high survival rates.[1,2] Implant abutment is an essential component of the implant systems that connects the implant body to the prosthetic part and provides support, retention, and an antirotation effect for the crown.[3] Furthermore, it transmits the masticatory forces to the implant body and protects it against oral cavity bacteria by adjusting to peri-implant soft tissue.[4] To obtain optimal biological, mechanical, and esthetic outcomes, several different biomaterials have been developed for implant components.[2] Apart from the clinician's preference, there are other factors influencing implant abutment material selection, including the biotype of mucosa around the implant (thick or thin), the choice of screw or cement-retained restorations, restorative accessibility, and the angulation of the implant.[5]

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Titanium (Ti) is widely regarded as the gold standard material for implant-supported constructions due to its excellent biocompatibility and resistance to distortiontt.[6] However, allergic reactions, cellular sensitization, and galvanic reactions[7] and gray discoloration due to the galvanic reactions can become problematic, especially in the esthetic zone.[8-10] Therefore, zirconia (Zr) abutments have been introduced to eliminate the esthetic issues of Ti. Zr provides a much better appearance due to its semitranslucency features,[9] especially in the areas with thin biotypes of peri-implant mucosa,[11] and might show less bacterial adhesion.[12]

Many systematic reviews and meta-analyses have been conducted to compare Zr and Ti abutments on different biological and clinical aspects. However, the results are controversial and debatable.[13-17] This umbrella review aimed to comprehensively review and compare the biological, mechanical, and esthetic features along with survival rates of Zr and Ti abutments using evidence from previously published systematic reviews/meta-analyses.

MATERIALS AND METHODS

After defining a well-focused keyword, searching for relevant studies was performed on six electronic databases (PubMed, Scopus, Embase, Web of Science, ProQuest, and Cochrane) to find the systematic reviews or meta-analyses investigating the use of "Zr abutment" compared to "other abutment materials" for "peri-implant soft tissue health and esthetic aspects." Table 1 shows the free-text and MeSH terms used as the keywords. The inclusion and exclusion criteria are presented in Table 2.

Two independent researchers (K.S. and A.D.) searched and screened the results that were obtained regarding the aim of the current umbrella review. The studies were chosen based on their title/abstract for relevance. The full texts of relevant studies were obtained and assessed using the inclusion criteria. Cohen's kappa was used to determine the authors' agreement with MedCalc software (MedCalc Software), and the kappa score was 0.90 and 0.93 in abstract and full-text screening stages, respectively. If there were any disagreements, a discussion was undertaken to reach an agreement between the two reviewers.

A manual search was performed to avoid missing data. Endnote software version 8 (Thomson Reuters) was used for reference management. The risk of bias in the selected studies was assessed with the AMSTAR checklist. This checklist comprises 16 questions, each of which can be scored as yes (2 scores), partial yes (1 score), or no (0 score). Systematic reviews with scores <14 and meta-analyses with scores <16 were considered a high risk of bias and were omitted [Table 3].

Table 1: Applied MeSH and non-MeSH keywords

PICO	Key Words
Population	(Systematic Review) OR (Meta-Analysis) OR (Review)
Intervention	(Zirconia Abutment) OR (Zirconia Dental Abutment) OR (Computer-Assisted Design Zirconia Abutment) OR (Computer-Aided Manufactured Zirconia Abutment) OR (CAD-CAM Zirconia Abutment)
Comparison	(Titanium Abutment) OR (Custom Abutment) OR (Dental Implants (Mesh Term)) OR (Dental Abutment (Mesh Term)) OR (Dental Implant-Abutment) OR (Custom Abutment) OR (Computer-Assisted Design Abutment) OR (Computer-Aided Manufactured Abutment) OR (CAD-CAM (Mesh Terms))
Outcome	(White Esthetic Index) OR (Pink Esthetic Index) OR (Papilla Index) OR (Dental Papilla (Mesh Terms)) OR (Soft Tissue Stability) OR (Gingival Recession (Mesh Terms)) OR (Peri-Implant Soft Tissue) OR (Soft Tissue Color) OR (Soft Tissue Recession) OR (Probing) OR (Bleeding) OR (Marginal Bone) OR (Pink Esthetic Score) OR (Peri-Implant Mucosa) OR (Soft Tissue Response) OR (Soft Tissue Level) OR (Keratinized Tissue Height) OR (Facial Keratinized Tissue) OR (Peri-Implant Tissue Health) OR (Esthetic Aspect) OR (Gingival Margin) OR (Gingival Discoloration) OR (Gingival Color Change) OR (Periodontal Health) OR (Periodontal Tissue) OR (Biological Complications) OR (Mechanical Complications) OR (abutment fracture) OR (screw loosening) OR (screw fracture) OR (veneer failure) OR (porcelain chipping) OR (survival)

Table 2: The inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
English language Investigated the effect of the Zr abutment on selected outcomes Assessed Zr abutments against Ti abutments	Narrative reviews Studies with missing data Studies in languages other than English Repeatedly published studies: The last version was included Studies with an AMSTAR score of <16 for meta-analysis and <14 for systematic reviews

Two reviewers reviewed the included studies for data extraction. The author's names and publication years, the number of reviewed articles, study designs, searched databases, the number of patients and implants, the regions of implant placement, the abutment details, the crown details, and the follow-up periods were extracted from each study [Table 4].

RESULTS

After eliminating duplicate studies, 457 titles remained for screening. The results of the search

Table 3: A measurement tool to assess systematic reviews checklist assessment of included studies

	Aljomar jose vechiato, 2016[15]	Thakare *et al*., 2023[10]	Davoudi *et al*., 2023[24]	Pesce *et al*., 2023[13]	Totou *et al*., 2021[23]	He Cai, Jung Chen 2018[16]	Adrien naveau 2018[20]
PICO components included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Review methods established before conduct?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Study designs explained?	Yes	Yes	Yes	Partial yes	Yes	Yes	Yes
Comprehensive literature search?	Partial yes	Yes	Yes	Yes	Yes	Yes	No
Study selection in duplicate?	Yes	Yes	Yes	Yes	No	Yes	Yes
Data extraction in duplicate?	Yes	Yes	Yes	Partial yes	Yes	Yes	Yes
Excluded studies listed and justified?	No	Yes	Partial yes	Yes	Yes	No	No
Included studies described in detail?	Yes	Yes	Partial yes	Yes	Yes	Yes	Yes
Good technique for risk of bias assessment?	Yes	Yes	Yes	Yes	Yes	Yes	No
Funding sources reported?	No	Yes	No	No	Yes	No	No
Appropriate methods for meta-analysis (if performed)?	Yes	Yes	No meta-analysis	Yes	No meta-analysis	Yes	No meta-analysis
Impact of risk of bias assessed?	Yes	Yes	No meta-analysis	Yes	No meta-analysis	Yes	No meta-analysis
Risk of bias accounted for in interpretation?	Yes	Yes	Yes	Yes	Yes	Yes	No
Heterogeneity explained and discussed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Publication bias investigated?	Yes	Yes	No	No	Yes	Yes	No
Potential conflicts of interest reported?	Yes	Yes	No	Yes	Yes	Yes	No
Total score	27	30	18	26	26	28	14

	Adrien naveau 2018[20]	Avinash S. Bidra 2013[5]	Menglonghu, 2019[18]	Ignacio Sanz-Martín, 2017[3]	Ignacio Sanz-Sánchez, 2018[22]	Tomas Linkevicius Julius Vaitelis, 2015[19]	Yubin Cao, 2019[17]	Mohamed A. Mokhtar, 2018[14]
PICO components included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Review methods established before conduct?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Study designs explained?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Comprehensive literature search?	No	No	Partial yes	Partial yes	Partial yes	No	Partial yes	Partial yes
Study selection in duplicate?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Data extraction in duplicate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Excluded studies listed and justified?	No	Yes	No	No	No	Yes	No	Yes
Included studies described in detail?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Good technique for risk of bias assessment?	No	No	Yes	Yes	Yes	No	Yes	No
Funding sources reported?	No	No	No	No	No	No	No	No
Appropriate methods for meta-analysis (if performed)?	No meta-analysis	No meta-analysis	Yes	Yes	Yes	Yes	Yes	Yes
Impact of risk of bias assessed?	No meta-analysis	No meta-analysis	Yes	Yes	Yes	No	Yes	No
Risk of bias accounted for in interpretation?	No	No	Yes	Yes	Yes	No	Yes	No
Heterogeneity explained and discussed?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Publication bias investigated?	No	No	Yes	Yes	Yes	No	Yes	No
Potential conflicts of interest reported?	No	Yes	Yes	Yes	Yes	No	Yes	No
Total score	14	18	27	27	27	16	27	17

The scoring scale is as follows: Yes=2; partial yes=1; no=0

Table 4: General information of reviewed articles

Author	Publication year	Included RCTs	Databases	Number of patients/ implants	Region of implant placement	Follow up period
Thakare *et al.** [10]	2023	15	Medline (PubMed), Cochrane Library (The Cochrane Central Register of Controlled Trials), SCOPUS, Embase, CINHAL, Web of Science, and Google Scholar	364 patients (320 patient with follow up) 362 abutments (Zr group=104, Ti group=115)	Anterior and posterior regions of the jaw	From 4 to 84 months
Davoudi *et al.* [24]	2023	6	PubMed, Web of Science, Scopus, ProQuest, and Embase	304 implants	Anterior	1–10 years
Pesce *et al.** [13]	2023	18	MEDLINE (PubMed), Cochrane Central Register of Controlled Trials, and Scopus	612 patients 848 abutments	-	6 months–7 years
Totou *et al.* [23]	2021	23	Medline, Embase, and Cochrane Central databases	693 patients and 1030 abutments	Anterior	6 months–5 years
Vechiato-Filhato *et al.** [15]	2016	6	PubMed, Cochrane	298 Zr abutments and 136 Ti abutments in 382 patients (mean age: 39.95 years)	Posterior region	1 year or more (Mean: 2.9 years)
Cai *et al.** [16]	2018	8	PubMed, Embase, CDSR, CENTRAL	141 Zr abutments and 128 Ti abutments, and 96 golden abutments	NR	NR
Naveau *et al.* [20]	2018	20	PubMed	593 Zr abutments	Anterior region	1 year or more
Bidra and Rungruanganunt [5]	2013	27	PubMed	1876 abutments in 1077 patients	Anterior region	0.08–13 years
M.Hu, *et al.** [18]	2019	23	PubMed, Embase, Web of Science, CENTRAL, Chinese biomedical literature database, CNKI	1006 abutments		Mean: 1.63 years
Sanz-Martín *et al.** [3]	2017	13	PubMed, Cochrane	608 implants in 372 patients		Mean: 36.69 months (12–86.4 months)
Sanz Sánchez *et al.** [22]	2018	29	PubMed, Cochrane	1354 implants in 1026 patients		Mean: 30.05 months (minimum: 6 months)
Linkevicius and Vaitelis*[19]	2015	11	PubMed	271 Zr and 232 Ti abutments in 389 patients		at least 1 year (Mean: 2.5 years)
Cao *et al.**[17]	2019	Part 1: 8 study in 10 publications Part 2: 10 study in 12 publications	PubMed, Embase, Chinese biomedical literature database	Part 1: 353 patients Part 2: 427 patients		Part 2: mean: 23.7 months
Mokhtar M.A. *et al.** [14]	2018	14	PubMed, Cochrane, Ovid databases	696 abutments (327 Ti and 369 all-ceramic abutments) in 457 patients	NR	3 months–5 years

*Indicates a meta-analysis was performed. Ti: Titanium; RCTs: Randomized controlled trials; NR: Not Reported ; CNKI: China National Knowledge Infrastructure; CDSR: Cochrane database of systematic reviews

process were as follows: PubMed, 19; Scopus, 356; Embase, 0; Web of Science, 2; ProQuest, 80; and Cochrane, 0. Following the abstract assessment, 16 studies were selected for full-text evaluation, which led to the exclusion of two more studies [Figure 1]. After the AMSTAR checklist assessment, 14 studies remained [Table 3].[5,10,13,14-24]

This systematic review pooled data from 14 systematic reviews and meta-analyses published until March 2023 on a total number of 6456 patients

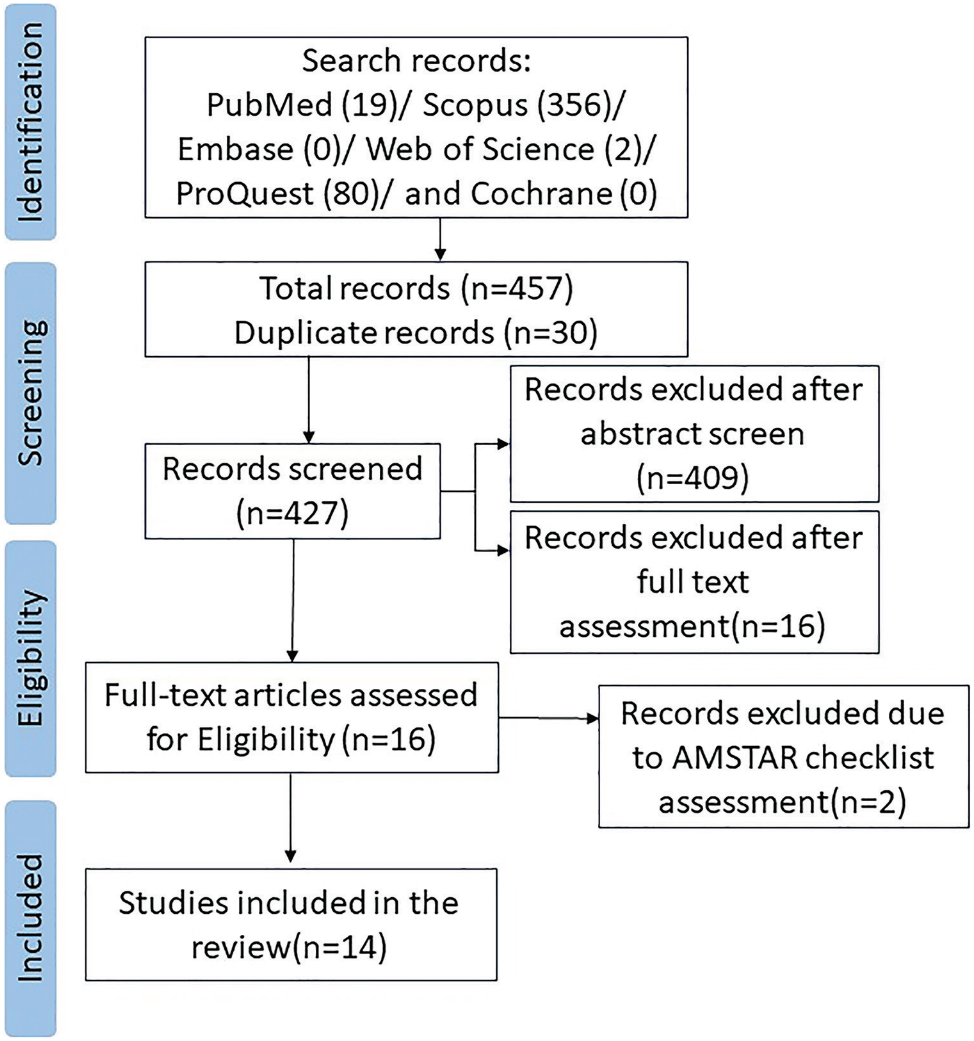

Figure 1: The flowchart of search strategy.

having 10,063 implants. The included studies were either systematic reviews[5,20,23,24] or systematic reviews and meta-analyses.[10,13-19,21,22] All studies investigated the abutment materials.[5,10,13-24] At the same time, four of them also considered the macroscopic design of abutment and its surface topography.[5,17,20,21] The general information of the studies we included in our umbrella review are shown in Table 4.

Table 5 represents the detailed evaluated factors and relative results of each included study. The most commonly evaluated parameters were plaque accumulation (PA),[15,21,22] pocket probing depth (PPD),[10,13,17,19,21,22] gingival discoloration,[5,10,16,18,19] bleeding on probing (BOP),[10,13,15,19,21,22] soft tissue recession (REC),[5,13,14,19,22,24] marginal bone loss (MBL),[5,10,14,15,17-22] papilla index (PI),[5,10,13,20,22] and White Esthetic Score and Pink Esthetic Score (WES and PES).[10,19,20,22,24]

Biological aspects

Marginal bone loss

Among the ten reviews comparing MBL in Zr and Ti abutments, six reviews did not find a statistically significant difference,[5,10,15,19,21,22] while the other four reviews favored Zr.[14,20,17,18]

PPD

Seven review studies analyzed the effect of abutment material on PPD.[10,13,14,17,19,21,22] The majority of the reviews found no statistical differences,[10,13,14,19,21] and one favored Zr[17] while the other showed better results for Ti.[22]

Recession

Seven reviews examined the evidence on REC,[5,13,14,19,21,22,24] Four of them showed no difference between Zr and Ti abutments.[14,19,21,22] Two of them also reviewed the width and thickness of keratinized mucosa around implants.[21,22] Minimal changes were

Table 5: The criteria and outcomes of the included studies

Author	Groups	Examined tests	Outcomes
Thakare *et al*.[10]	Group 1: Zr abutment Group 2: Ti abutment	MBL, PPD, BOP, PI, PES, WES, spectrophotometric evaluation of peri-implant mucosa, ICAI, color evaluation	The abutment survival rate, MBL, PPD, and PI showed no significant difference. For BOP (MD 95% CI 0.13 (−0.11, 0.38) P=0.04, I^2=69) did not show any significant difference. Zr group observed a slightly more favorable response for biological outcome In one study significant difference (P<0.01) for PES from baseline to 7 years for Zr group (6.33±1.41–8.25±1.03). WES showed a higher mean for Ti group (T1=7.00±1.17; T3=0.35±1.27; P<0.01). Thin gingival phenotype reported a higher mean (P=0.03) for Zr group. No significant difference of color evaluation was recorded between two groups. For ICAI observed no significant difference for both groups (ZA: 7.6+3.5, TA: 11.3+5.4), but the Zr group showed favorable esthetic. For ICAI score didn't mention the mean and SD. However, Zr group observed excellent esthetic (8 patients) as compared to Ti (1 patient, P=0.10)
Davoudi *et al*.[24]	Group 1: Zr CAD/CAM abutments Group 2: Other types of abutments	Soft tissue stability, REC, WES, PES, CPB, ITD, and papilla fill	CAD/CAM Zr abutments can enhance soft tissue stability and decrease the REC index. However, no difference is expected between CAD/CAM and stock abutments in WES, PES, CPB, ITD, and papilla fill
Pesce *et al*.[13]	Group 1: Any abutment material other than Ti Group 2: Ti abutments	Bone resorption, PPD, PI, Recession, SUCRA, BOP	Significant reduction in bone resorption in groups using Zr abutments than in those using Ti (0.20 mm; 95% CI (0.14–0.26), P<0.00001) After 1, 3, 5 and 7 years of follow-up, there was no significant difference in PPD and PI 3–7-year follow-up. Zr abutments showed SUCRA scores of 83.3% in PI, 87.0% in BOP, and 65.0% in PPD outcome, suggesting that Zr abutments performed better than Ti and alumina abutments
Totou *et al*.[23]	Zr; alumina; Ti; cast metal abutment	Esthetic, mechanical, biological, and survival outcomes	Abutment failure due to fracture was associated with ceramic abutments, and a mean rate was calculated at 4.26% Similar biological complications were noted for metallic and ceramic materials
Vechiato-Filhato *et al*.[15]	Group 1: Zr abutment Group 2: Ti abutment	MBL, BOP, PA	5-year success rate of single crowns in posterior areas: Zr<Ti Complication with Zr abutments (8.39%) <Ti abutments (9.56%) No significant differences (P>0.05) between the two varieties of abutments relating to the biological complications evaluated (MBL, BOP, PA) No significant differences of veneer failures (P=0.11) between Zr and Ti abutments
Cai *et al*.[16]	Group 1: Zr abutment Group 2: Ti abutment Group 3: Au abutment	Peri-implant soft tissue discoloration	Soft tissue discoloration around Group 1 < Group 2 (MD=−1.84; 95% CI=−3.62 to−0.07; P=0.04<0.05) or Group 3 (MD=−0.90; 95% CI=−1.60 to−0.20; P=0.01<0.05)
Naveau *et al*.[20]	Group 1: Zr abutment Group 2: Ti abutment Group 3: Zr CAD/CAM abutment Group 4: Zr stock abutment	MBL, PES, WES, PI, ICAI, OHIP, tissue discoloration	MBL in Group 1<Group 2 Better matching and integration of the color and texture of soft tissue in Zr rather than Ti abutments No difference between Group 1 and Group 2 regarding PI Zr abutments are indicated in patients with thin peri-implant mucosa
Bidra and Rungruanganunt[5]	Group 1: Ti abutment Group 2: Zr abutment Group 3: Metal abutment Group 4: Al abutment Group 5: Ceramic abutment	REC, Gingival discoloration, PI, MBL	11 fractures in ceramic abutments (1.15%): fractures in Al abutments (8) >Zr abutments (3). No abutment fractures were noted with Ti or cast metal abutments REC was higher in Ti abutments Lesser peri-implant mucosal discoloration with Zr abutments All other biological surrogate treatment outcomes such as PI MBL, and tissue health were unremarkable across all studies
M.Hu, *et al*.[18]	Group 1: Ti abutment Group 2: Zr abutment Group 3: Au abutment Group 4: Al abutment	Survival rate, MBL, Peri-implant soft tissue discoloration	No significant differences between Ti, Zr, Au, and Al abutments in survival rate (excluding Al<Ti [P<0.05], MBL excluding Zr < Ti [P<0.05] and Au > Zr [P<0.05]), or discoloration of peri-implant soft tissue The lowest peri-implant discoloration with Zr abutments (84.8%) It is most likely to be the best option in terms of survival rate: Ti (97.9%) > Zr (39.4%) > Al (12.7%). In terms of MBL: Al (81.4%) > Zr (79.3%) > Ti (34.9%) > Au (4.4%). In terms of peri-implant discoloration: Zr (84.8%) > Au (55.6%) > Ti (9.6%)

Contd...

Table 5: Contd...

Author	Groups	Examined tests	Outcomes
Sanz-Martín *et al.*[3]	Group 1: Zr abutment Group 2: Ti abutment Group 3: Au abutment Group 4: Al abutment	Survival rate, BOP, PA, MBL, PPD, CLI, KM, Thickness of the mucosa, Patient-reported satisfaction	Mean implant survival rate: 98.61% (minimum: 89%; maximum: 100%), no differences between test and control Groups (98.6% and 98.62%, respectively) BOP in Group 1 < Group 2 (*n*=3; WMD=−26.96; 95% CI [−45.00 to−8.92]; *P*=0.003) and less PA (*n*=1; MD=−20.00; 95% CI [−41.47 to 1.47]; *P*=0.068) PA in Group 2 > Group 1 (*n*=1; Mean difference=−20.00%; 95% CI [−41.47% to 1.47%]; *P*<0.068) Revealed no significant differences in assessment of PPD, neither for the global nor for the subgroup's comparisons Greater increase of CLI in Group 2 (0.86 mm vs. 0.19 mm); minimal changes (<0.4 mm) with no differences between other Groups Minimal changes of KM within Groups over time (0–0.7 mm), and no sig differences between test and control Groups (0–0.6 mm). Mean KM values: 2.85 mm (SD=0.37) to 5.4 mm (SD=1.7) No changes in mucosal thickness within Groups over time No significant differences in patient satisfaction when comparing Group 1 with Group 2
SANZ SÁNCHEZ *et al.*[22]	Group 1: Zr abutment Group 2: Ti abutment Group 3: Au abutment Group 4: Al abutment	Survival rate, MBL, BOP, PPD, REC, KM, Thickness of the mucosa, PI, PA, PES, WES, ICAI, CIS, PROM	Mean implant survival rate: 99.2% (minimum: 89%; maximum: 100%) No significant MBL differences between the different abutment materials compared to Ti (*n*=15; WMD=0.034; 95% CI [−0.04, 0.10]; *P*<0.339) BOP in Group 2 > Group 1 (*n*=3; WMD=−26.96%; 95% CI [−45.00% to−8.92%]; *P*=0.003) Significant increase in PPD around Zr abutments (*n*=12; WMD=0.35; 95% CI [0.09 to 0.61]; *P*=0.009) Even though no significant differences in the changes in PA were found when comparing the different abutment materials No significant differences in PA changes when comparing the different abutment materials, a trend toward a larger PA around Group 2 compared to Group 1 (*n*=1; mean difference=−20.00%; 95% CI [−41.47% to 1.47%]; *P*=0.068) Minimal or no changes in REC comparing different abutment materials over time, with a maximum REC of 0.6 (SD=0.7) Minimal changes of KM within Groups over time (0–0.8 mm), and no differences between the test and control Groups. Mean values: 3.04 mm (SD=1.15) to 5.4 mm (SD=1.7) No significant differences comparing WES and PES between Groups during 12 months No significant differences in ICAI between Groups No significant differences in CIS among Groups in the overall score, although there was a tendency for better outcomes in Zr abutments No differences in patient satisfaction between different abutment materials
Linkevicius and Vaitelis[19]	Group 1: Zr abutment Group 2: Ti abutment	Soft tissue color, REC, BOP, PROM, MBL, PES, PPD	PES at Zr implants with Zr abutments>metal implants with Ti abutments Mean PPD around Group 1 (3.3±0.6 mm with an increase of 0.4 mm) < Group 2 (3.6±1.1 mm with an increase of 0.5 mm) BOP was not significant between two groups Group 1 (9.1%±4.3) > Group 2 (7.4%±3.4) MBL in every case, there was no significant statistical difference
Cao *et al.*[17]	Group 1: Ti implants with Zr abutment Group 2: Ti implants with Ti abutment	Survival rate, MBL, PPD	Survival rate of implants with Zr abutments: 96% (CIs 94% to 98%, I^2=0%) Lower MBL in Group 1 < Group 2 (MD=−0.09, CIs−0.17 to 0.00, *P*=0.05, I2=40%; For PPD, MD =−0.18, CIs−0.32 to−0.05, *P*=0.008, I^2=0%)
Mokhtar M.A. *et al.*[14]	Group 1: All ceramic abutments Group 2: Ti abutment	PPD, REC, MBL	No significant differences in PPD between two Groups (PPD around Group 1: 3.2 mm and 3.4 mm for Group 2) REC: Group 2 (0–0.4) > Group 1 (0–0.3) MBL around Group 1: 0.2–1.48 mm and 0.3–1.43 mm in Group 2

Al: Alumina; BOP: Bleeding on probing; CAD-CAM: Computer-aided design and computer-aided manufacturing; CIS: Copenhagen Index Score; CLI: Crown length of the implant restoration; ICAI: Implant Crown Aesthetic Index; KM: Apico-coronal dimension of the keratinized mucosa on the midbuccal aspect of the implant crown; MBL: Marginal bone loss; OHIP: Oral health impact profile; PA: Plaque accumulation; PES: Pink Esthetic Score; PI: Papilla index; PPD: Pocket probing depth; PROM: Patient-reported outcome measures; REC: Recession; Ti: Titanium; WES: White Esthetic Score; Zr: Zirconia; CI: Confidence interval; SD: Standard deviation observed in either width or thickness of keratinized mucosa with no statistical difference between the two groups. However, Bidra and Rungruanganunt[5] and Davoudi *et al*.[24] favored Zr abutments. Pesce *et al*.[13] stated lower bone resorptions in the Zr abutment group, too.

Plaque accumulation and bleeding on probing

Six reviews[10,13,15,19,21,22] investigated PA and BOP, which two of them[21,22] showing statistically significant difference in BOP better PA results around Ti abutments. The other studies showed no difference between the two groups for BOP and PA.[10,13,15,19]

Other biological complications

Two reviews also studied mucositis and fistula as biological complications.[5,19] Although no meta-analysis was performed, the evidence from experimental studies suggested no difference between different abutment materials.

Esthetic aspects

Gingival discoloration

Eight reviews compared mucosal discoloration of the buccal soft tissue of Zr and Ti abutments.[5,10,16,18-22] Among them, two[5,20] reviews had not performed a meta-analysis and two[16,19] favored Zr. Four other reviews[10,18,21,22] showed no statistical difference.

Objective esthetics indices

Six different indices, namely PES, PES/WES, Copenhagen Index Score (CIS), Implant Crown Aesthetic Index (ICAI), and PI, were evaluated in seven reviews.[5,10,13,19-22,24] None of the studies had performed a meta-analysis on these indices, and the qualitative synthesis of the data was inconclusive.

Mechanical complications

Among the five studies reviewing mechanical complications,[5,15,20,22,23] two studies had done a meta-analysis.[15,22] The results of the meta-analyses showed no statistical difference between Zr and Ti with risk ratios of 0.87[22] and 0.52, respectively.[15] The prevalence of mechanical complications was reported to be <7.9%.[22]

Survival

There were five reviews elaborating survival rates of Zr and Ti abutments.[17,18,21-23] Three meta-analyses[17,21,22] and one network meta-analysis[18] showed that there was no statistically significant difference between the groups. However, Totou *et al*.[23] stated the superiority of Ti abutments in terms of abutment fracture. Two meta-analyses[21,22] reported the survival rates of Zr and Ti abutments as follows: 98.6%, 98.8% and 98.62%, 99.4%, respectively.

DISCUSSION

Summary of evidence

This umbrella review analyzed the available evidence by summarizing and critically appraising systematic reviews and meta-analyses evaluating the peri-implant tissue indices of Zr abutments. The examined factors can be divided into three subgroups: biological, esthetic, and mechanical outcomes. Biological indices included MBL, PPD, BOP, PA, and REC. Esthetic parameters contained PES, WES, CIS, ICAI, PI, gingival discoloration, and mechanical outcomes mainly related to prosthetic complications.

Zr abutment had preferred or resembled effects as other abutment materials in terms of biologic parameters.[15,17-22] However, some randomized controlled trials (RCTs), including Sanz-Sánchez *et al*.[22] and Linkevicius and Vaitelis,[19] showed different outcomes. Nevertheless, these opposing results were usually limited to one or two main studies in a review and were seldom statistically significant. Table 6 demonstrates these inconsistencies.

Marginal bone loss

The marginal bone level is an indicator of implant crestal support normally evaluated by periapical radiography. Compared to sequential follow-up sessions, the alterations in the bone level, which is mainly seen as bone loss, can be assessed. The MBL indicated the clinical situation known as peri-implantitis. The most common reasons for MBL are inflammation due to microbial adhesion and disproportionate masticatory forces. Ti abutments are more susceptible to bacterial colonization than Zr abutments, with a more polished surface impeding microbial biofilm formation.[11]

In one of the systematic reviews, different surface decontamination methods were used.[21] It was shown that only when plasma argon cleansing, a robust decontamination technique, was used, the Ti abutment surfaces showed enhanced marginal bone levels. One review demonstrated that MBL around Zr abutments was lower when implants with single crowns were evaluated and not fixed dental prostheses.[18] In another review, a subgroup analysis showed an even more prominent superiority for Zr in abutments bearing overdentures than single crowns.[17] This was explained by the fact that larger occlusal forces are

Table 6: Summary of the evidence reported for the included systematic reviews/meta-analyses included (*n*=14)

Evaluated parameters	Systematic reviews/ meta-analyses showing the superiority of Zr abutment over other materials	Systematic reviews/meta-analyses showing no difference between Zr abutment and other materials	Systematic reviews/meta-analyses showing the superiority of other materials over than Zr abutment
Survival rate		M.Hu *et al.*, 2019[18] Sanz-Martín *et al.*, 2017[3] Sanz-Sánchez *et al.*, 2018[22] Thakare *et al.*, 2023[10]	Totou *et al.*, 2021[23]
MBL	Naveau *et al.*, 2019[20] M.Hu, *et al.*, 2019[18] Cao *et al.*, 2019[17] Mokhtar M.A. *et al.*, 2018[14]	Sanz-Sánchez *et al.*, 2018[22] Vechiato-Filhato *et al.*, 2016[15] Sanz-Martín *et al.*, 2017[3] Thakare *et al.*, 2023[10] Bidra and Rungruanganunt, 2013[5] Linkevicius and Vaitelis, 2015[19]	
Soft tissue recession	Pesce *et al.*, 2023[13] Davoudi *et al.*, 2023[24] Bidra and Rungruanganunt, 2013 [5]	Linkevicius and Vaitelis, 2015[19] Mokhtar M.A. *et al.*, 2018[14] Sanz-Sánchez *et al.*, 2018[22]	
PPD	Cao *et al.*, 2019[17]	Mokhtar M.A. *et al.*, 2018[14] Thakare *et al.*, 2023[10] Pesce *et al.*, 2023[13] Sanz-Martín *et al.*, 2017[3] Linkevicius and Vaitelis, 2015[19]	Sanz-Sánchez *et al.*, 2018[22]
BOP	Sanz-Martín *et al.*, 2017[3] Sanz-Sánchez *et al.*, 2018[22]	Vechiato-Filhato *et al.*, 2016[15] Thakare *et al.*, 2023[10] Pesce *et al.*, 2023[13] Linkevicius and Vaitelis, 2015[19]	
PI		Naveau *et al.*, 2019[20] Pesce *et al.*, 2023[13] Thakare *et al.*, 2023[10] Bidra and Rungruanganunt *et al.*,2013[5] Sanz-Sánchez *et al.*, 2018[22]	
PA	Sanz-Martín *et al.*, 2017[3] Sanz-Sánchez *et al.*, 2018[22]	Vechiato-Filhato *et al.*, 2016[15]	
Gingival discoloration	Bidra and Rungruanganunt *et al.*,2013[5] Cai *et al.*, 2018[16] Linkevicius and Vaitelis, 2015[19] Naveau *et al.*, 2019 [20]	Sanz-Sánchez *et al.*, 2018[22] Sanz-Martín *et al.*, 2017[3] M.Hu, *et al.*, 2019[18] Thakare *et al.*, 2023[10]	
Color match	Naveau *et al.*, 2019 [20]		
WES, PES	Linkevicius and Vaitelis, 2015[19] Naveau *et al.*, 2019[20] Thakare *et al.*, 2023[10] (PES)	Sanz-Sánchez *et al.*, 2018[22] Davoudi *et al.*, 2023[24] (PES, WES)	Thakare *et al.*, 2023[10] (WES)
ICAI		Sanz-Sánchez *et al.*, 2018[22] Thakare *et al.*, 2023[10] Naveau *et al.*, 2019 [20]	
KM		Sanz-Martín *et al.*, 2017[3] Sanz-Sánchez *et al.*, 2018[22]	
CIS	Sanz-Sánchez *et al.*, 2018[22]		
Veneer failure		Vechiato-Filhato *et al.*, 2016[15] Totou *et al.*, 2021 [23]	
PROM		Sanz-Martín *et al.*, 2017[3] Sanz-Sánchez *et al.*, 2018[22]	

KM: Keratinized mucosa; PPD: Pocket probing depth; PROM: Patient-reported outcome measures; CIS: Copenhagen Index Score; BOP: Bleeding on probing; ICAI: Implant Crown Aesthetic Index; WES: White Esthetic Score; PES: Pink Esthetic Score; PA: Plaque accumulation; PI: Papilla index; MBL: Marginal bone loss

applied to implants beneath the overdentures. As the higher elastic modulus of implant superstructures leads to a more uniform distribution of occlusal loads in the framework, a more reliable load transfer to the osseointegrated implants is seen in Zr abutments.[14] Therefore, the protection effect of Zr is more apparent when overdentures are of concern.

Another major factor that influences the results of studies on MBL is the length of the follow-ups. It has been shown that, on average, it takes 3 years of function to see the signs of peri-implantitis onset.[22] However, most studies on MBL do not have adequate follow-up length. This also explains the results of those studies that despite having better soft tissue outcomes such as BOP in Zr groups, they fail to demonstrate any significant difference in terms of MBL.[22]

Finally, the limitations of measurement techniques should be considered. MBL is usually evaluated through repeated mesial, distal, or average crestal bone level radiographic measurements. The typical limitations of such dental radiology, such as distortion, elongation, superimposition, and different X-ray angles, all introduce errors in the measurement technique. The results of studies become unreliable when the difference between groups (even when supported by a significant *P* value) is smaller than the measurement error.[18,22]

PPD

The technique of probing around implant restorations is used mainly similarly to probing natural teeth to measure periodontal pockets. However, there are limitations in assessing peri-implant health using traditional probing methods. The restorations' design, contour, and splinting can restrict the probe's access to the depth of the pocket, leading to an underestimation of PPD values.[21] To form the attachment of mucosa around the suprarenal components of the implant, epithelial cells should first adhere to the abutment. It is shown that the roughness of the abutment surface is crucial in how cells behave. As the epithelial cell adhesion is much better to smooth surfaces, it is suggested that the polished Zr abutment surfaces should provide a better adhesion medium.[14,19] Second, Zr abutments have chemically stable surfaces and are corrosion resistant. Hence, the epithelial cells can grow better around such surfaces, producing better surface adhesion.[25]

Nevertheless, the results of only one review complied with this theory, while most showed comparable results for Zr and Ti. This contradiction can be partly explained by the fact that many experimental studies had a subgingival position of the cementation margin, meaning that the peri-implant mucosa was usually in contact with the feldspathic ceramic used on the restoration rather than the material of the abutment. In such situations, the subgingival portion of the restoration greatly influences PPD, making the comparison of the abutment material inconclusive.[19] Only one review showed better results for Ti, which contained a wide range of studies such as nonrandomized trials and case series included in their analysis and the randomized controlled clinical trials.[19] Hence, the different results might be due to a higher risk of bias in the included studies.

Recession

The incidence of the peri-implant REC appears to be influenced by several essential parameters, including 3D implant position, attached mucosa, and microbial activity in peri-implant mucosa.[19] The REC of peri-implant mucosa is usually assessed by measuring the distance from the mucosal level to a particular reference point on the restoration (e.g. the incisal edge). One approach to maintaining soft tissue integrity is to reduce bacterial adhesion and subsequent plaque formation on the surfaces of the implant restoration. The arrangement of biofilm around implants varies depending on the type of abutment material used. Both Ti and Zr provide hydrophobic surfaces where a thick peptidoglycan layer can form. This layer instantly attracts Gram-positive bacteria when repelling Gram-negative ones. However, the formation of a Ti dioxide layer can alter the surface properties of Ti structures toward a semiconductor medium, which can justify the debated results reported in the systematic reviews.[26]

All five reviews on REC showed similar results for Zr and Ti abutments.[5,14,19,21,22] The review by Mokhtar *et al*.[14] compared REC of Zr and Ti in different follow-up times from 6 months to 5 years. Similarly, no difference was found between the two materials. Linkevicius and Vaitelis[19] compared Zr and Ti in customized CAD/CAM and stock abutments. Once again, there were no different results for Zr and Ti. When comparing mesial and distal sites multiple times, they found an average increase of 0.2 mm of soft tissue in the mesial area. In contrast, the distal area had an average REC of 0.3–0.4 mm for both the Zr and Ti groups. However, no further explanation was presented for such a difference. Another review focused on the evidence of experimental concave-shaped abutments, suggesting more predictable results for peri-implant mucosa stability for both Zr and Ti abutments.[5]

The quality of the peri-implant soft tissue was assessed in two reviews by evaluating the width and thickness of the keratinized mucosa.[21,22] The Zr and Ti abutments were satisfactory and were not influenced by the choice of abutment material.

Bleeding on probing and plaque accumulation

The peri-implant soft tissue health is paramount to implant long-term success. Diagnosing primary alterations in soft tissue is challenging; however, BOP is a well-established method to identify inflammation in peri-implant mucosa.[21] Plague accumulation around the exposed parts of implant restoration provides a medium for microbial colonization. Consequently, the inflammatory processes start in the irritated mucosa, with the most prominent sign being a tendency to bleed easily. The restoration material may not directly affect PA, yet lower surface energy and higher stability in the restoration can decrease PA.[27,28]

The included reviews for PA had a small number of studies evaluating the parameter and failed to show any difference between Zr and Ti.[15,21,22] Theoretically, based on *in vitro* studies comparing Ti and Zr discs showing more significant PA for Ti, it is expected to observe more PA around Ti abutments.[19] However, many other factors influence PA and possibly reduce the effect of the choice of abutment material. These factors include oral hygiene and brushing effectiveness, the misfit between the prosthesis and the platform of the implant due to screw loosening or cement excess, and the contour and roughness of the prosthesis.[15,19,21]

The reviews evaluating BOP showed similar[15,19] or better[21,22] results for Zr. Apart from the plaque index, a better soft tissue attachment to Zr can improve the BOP scores. In *in vitro* studies, Zr demonstrated a higher degree of fibroblast proliferation, thereby promoting the quality of soft tissue attachment.[21,29]

Other biological complications

The most common biological complication was the presence of a fistula in buccal mucosa.[5,19] In cement-retained restorations, the remnant of cement causes a biological reaction in the form of fistula and suppuration. It is more prominent when resin cements are used because the complete removal of the excess cement is more challenging or when the crown margins are placed more than 1 mm submucosally.[5,19] Even in customized abutments, which are shown to facilitate the cement excess removal, the deep margin of the crowns hinders complete cement remnant removal.[19] Therefore, this can be attributed to the design of the abutment and the cementing agent rather than the abutment's material. Fistula formation is not exclusive to cement-retained restorations. In screw-retained restorations, complications were limited to cases with external hex implant platforms where ill-fitting abutments created a gap in the interface of the implant and the abutment penetrated by soft tissue invaginations.[5] Similarly, the choice of abutment material was not influential.

Mucosal discoloration

Esthetics of implant restorations are receiving increasingly more attention as they are becoming more reliable. Soft tissue color in the implant area is a key indicator of a natural appearance.[16] Based on the current evidence, Zr abutments provide similar[18,21,22] or better[16,19] mucosal color than Ti abutments. When compared to the gingival color of natural teeth as a control, spectrophotometry assessments showed mucosal discoloration for both abutment materials.[30] This discoloration is more visible when there is thin mucosa with a thickness of <2 mm. However, when the thickness of the mucosa is more than 2 mm, the abutment shadow beneath the mucosa becomes undetectable by human eyes. At the same time, the discoloration can still be recorded by spectrophotometry.[5,19,21] Therefore, the choice of abutment material between Zr and Ti, where there is adequate thickness of mucosa, may not have clinical significance for mucosal color.

Notably, all the included studies were on cases with either no defect or a repaired defect on the buccal site. There is insufficient evidence of the mucosal color of different abutment materials for cases with buccal defects, and our findings may not be applicable to these cases.[20] A newer technique that may improve the mucosal color in such situations involves coloring the abutment by veneering the Zr or anodizing the Ti.[20] There are currently very few studies on this technique, so it only remains a suggestion at this point, and much more evidence is needed to draw a concrete conclusion.

Objective esthetic indices

Different indices have been developed to evaluate the esthetics of soft tissue and crowns of implants.[31,32] Seven criteria shape the PES, including the papillae's shape to the crown's mesial and distal, contour of soft tissue, contour of alveolar process, level of the margin of soft tissue, and color and texture of soft tissue. The PES/WES index assesses the esthetic aspects of the crown and those estimated in PES. These aspects include the tooth form, the volume, the translucency, the surface texture, and the color of the implant-supported crown.[20] The ICAI is another index that examines the esthetics of soft tissue and crowns by comparing them to adjacent teeth. The other index for both esthetic aspects is CIS, which assesses the morphology and color matching of the crown along with the soft tissue esthetics. Finally, the PI only focuses on the papillae around the crown of implants.[22]

None of the included review studies had a meta-analysis on these indices. As these indices are fundamentally different, combining them into one another in a single meta-analysis was impossible. The high heterogeneity and inconsistency in the results, with only a few studies on each index, made doing a meta-analysis for each index separately impractical. In summary, the Pink Esthetic Score (PES) serves as a more focused and appropriate tool for comparing abutment materials, as it specifically evaluates peri-implant soft tissue esthetics, thereby excluding numerous aesthetic factors related to crown fabrication and laboratory procedures that do not directly reflect the influence of the abutment.[19]

The results for PI were inconsistent. Some studies showed a significant increase in PI during the 1st year of restoration placement with no difference between Zr and Ti abutments. When considering long-term follow-ups, the index remained stable or slightly increased between 3 and 5 years.[21]

Mechanical complications

The main mechanical complications reported in the reviewed studies were veneer failure and screw loosening as minor complications and fracture in different parts of the restoration as a major complication.[5,15,20-22] In the two meta-analyses comparing Zr and Ti abutments, similar mechanical complications were observed.[15,22]

Veneer failure indicates problems such as chipping, fracture, or debonding in the veneering layer, a typical mechanical complication for Zr abutments in both posterior and anterior regions.[5,15] Weak bonding between the Zr abutment and the veneering ceramic is the main reason for such a failure. Although veneer failure may not endanger implant survival, it can compromise the restoration's esthetics and function and the patient's satisfaction with the treatment. As occlusal interactions are crucial in veneer failure, patients with parafunctional habits or implant-supported restorations/ceramic restorations as antagonists are more prone to this complication because of higher stresses on the restoration from clenching or mastication.[15] Different strategies have been suggested to reduce veneer failure, including the use of monolithic restorations, an anatomical preparation design for the Zr framework to provide better mechanical support to the veneering layer, the use of Zr-Ti hybrid systems, using press-veneering as a substitute for hand-layer veneering technique, enhancing adhesion methods and finally, the advent of new ceramic materials.[15,22,33,34]

Abutment screw loosening is another common mechanical complication. There are unavoidable micromovements in the implant–abutment interface and between prosthetic components, which induce wear to these components. The wear is higher when the mechanical properties of materials are different, such as that seen in Zr abutments.[15] Irrespective of the material, the prevalence of screw loosening is higher in external hex implants and implants for single restorations.[5]

Fracture in prosthetic components is another issue of concern. The most susceptible parts to fracture are thin screw walls in external connection abutments and implant neck for internal connection abutments.[20] It has been shown that fractures on Zr abutments occur in the screw–abutment interface, which is believed to follow the other complication: screw loosening. Therefore, with proper preload applied to torque the prostheses, the rate of such fractures will decrease.[15] Another factor that can lower this complication is limiting the angulation of stock Zr abutments to 15°–20° and CAD/CAM Zr abutments to 30°.[20] While narrow diameters of abutments and implants have been speculated to increase fracture rates, there is currently no convincing evidence on this matter.[20]

Survival

The survival rate of implant-supported prostheses is a good estimate of the longevity of the treatment. In theory, the difference in fracture resistance of Ti and Zr (Ti = 1454 N, Zr = 443.6 N) and their flexural strength (Ti = 2000 MPa, Zr = 900–1200 MPa) gives the expectation of a higher survival rate for Ti abutments. However, the evidence in the literature shows similar survival rates for the two materials.[5,17,18,21,22]

The main challenge for the quantitative synthesis of data from different studies in a meta-analysis is the high heterogeneity of the studies. A broad range of follow-up durations (0.08–13 years) and lack of a life table survival analysis pose significant obstacles to calculating actual survival or cumulative survival rates. Instead, in one review, an unrefined mean survival estimate was used to indicate the survival of Zr and Ti abutments.[5] Further studies with long follow-ups (5 or 10 years) and the precise number of remaining implants at each evaluation stage can help estimate these abutments' actual and cumulative survival rates.

As for any review studies, our umbrella review of Zr and Ti abutments had certain limitations. Not all studies conducted meta-analyses on the outcomes of interest, and even among those that did, sufficient data for statistical analyses and forest plot generation were not always provided. Certain outcomes, including objective esthetic indices, some biological complications, and implant success rates, were considered secondary endpoints in the reviews and were not thoroughly addressed. Further research focusing on these outcomes is necessary to draw more definitive conclusions. Additionally, some meta-analyses were based on a limited number of studies, resulting in inadequate sample sizes to achieve the statistical power typically expected in meta-analytical approaches. More exhaustive search strategies enriched with manually searching the gray literature can enhance the quality of such reviews.

CONCLUSION

Based on the evidence from this umbrella review, it can be concluded that Zr abutments can provide similar or better soft tissue indices and esthetics without significantly compromising implants' mechanical features or survival, provided that excessive forces from occlusal interactions or improper angulations are avoided. Finally, clinicians should consider functional and esthetic performance when making decisions regarding abutment selection.

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Conflicts of interest

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