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SYSTEMATIC REVIEW

Zirconia abutments in the anterior region: A systematic review of mechanical and esthetic outcomes

Adrien Naveau, DDS, PhD,[a] Christophe Rignon-Bret, DDS, PhD,[b] and Claudine Wulfman, DDS, PhD[c]

ABSTRACT

Statement of problem. The success of single, anterior, implant-supported restorations relies on mechanical and esthetic outcomes. Titanium has been the most commonly used material for abutments, but zirconia is increasingly chosen for its appearance despite its unclear mechanical performance. Today, manufacturers market prefabricated, computer-aided design and computer-aided manufacturing (CAD-CAM) custom and zirconia abutments with titanium connections.

Purpose. The purpose of this study was to systematically review the mechanical and esthetic outcomes of implant zirconia abutments used in the anterior region, considering the design changes of the past 5 years.

Material and methods. An electronic search was conducted in Medline (PubMed) for studies on zirconia abutments. All clinical studies with at least a 1-year follow-up and case series (>5 abutments) published after 2013 were included. Mechanical and esthetic outcomes were collected.

Results. Of the 231 retrieved studies, 20 remained for quantitative analysis. Twelve described mechanical outcomes, and 15 focused on esthetics, using mainly the pink esthetic score. Five articles reported abutment fractures and no chipping. No difference was found between prefabricated and custom abutments or internal and external implant connections regarding fractures or screw loosening. All authors reported "good to excellent" esthetic integration in terms of restorations and soft-tissue color and the presence and height of papillae. The most difficult esthetic parameters to achieve were root convexity, soft-tissue color, and texture and level of mucosa.

Conclusions. Esthetics remain the major advantage of zirconia abutment when compared with titanium, despite reservations concerning the risk of mechanical complications. Data are lacking for zirconia abutments with titanium inserts, although the prospects for this design are promising. (J Prosthet Dent 2019;121:775-81)

Replacing a missing maxillary anterior tooth with an implant-supported crown is a challenge because success relies on different mechanical and esthetic considerations. Esthetics has been considered as important as the quality of osseointegration and the survival of the restoration.[1] In an esthetic evaluation, the color, shape, and surface quality of the restoration and of the peri-implant soft tissues are all considered. Titanium (Ti) has been considered the standard abutment material, but ceramic abutments were introduced to address concerns about the grayish aspect of peri-implant mucosa. Among them, zirconia (Zir) has been more popular than other ceramics, such as alumina, because of its better mechanical properties.[2] Today, many zirconia abutments are commercially available for all implant diameters, connections, implant-abutment interfaces, and platforms. The 3 main current options are stock or prefabricated abutments (that usually can be adjusted or veneered), computer-aided design and computer-aided manufacturing (CAD-CAM) custom abutments, and abutments with titanium inserts called Ti base abutments or 2-piece abutments. These abutments were developed to receive cemented crowns,[3] but screw-retained crowns can also be used.[4]

In the most recent systematic review, published in 2013, Bidra and Rungruanganunt[5] compared the survival, mechanical, biological, and esthetic outcomes of implant

[a]Associate Professor, Prosthodontics Department, University of Bordeaux, Bordeaux, France; Saint Andre Hospital, Bordeaux University Hospital, Bordeaux, France.
[b]Associate Professor, Prosthodontics Department, Paris Descartes University – Sorbonne Paris Cité, Paris, France; Dental Department, Henri Mondor Hospital-University Group, AP-HP (Public Assistance-Paris hospital), Creteil, France.
[c]Associate Professor, Prosthodontics Department, Paris Descartes University – Sorbonne Paris Cité, Paris, France; Dental Department, Henri Mondor Hospital-University Group, AP-HP (Public Assistance-Paris Hospital), Creteil, France.

Clinical Implications

Zirconia abutments provide the best color matching and soft-tissue texture when peri-implant soft tissues are thinner than 2 mm. To prevent fracture risk, anodized or nitrided titanium abutments should be preferred if the angulation is greater than 20 degrees.

abutments (Ti and Zir) used in the anterior region. They concluded that Zir abutments were recommended from the esthetic point of view, especially for patients with thin mucosal tissues, because of better color integration. A recent review of their esthetic outcomes confirmed their improved gingival color and reported that Zir had similar soft-tissue recession, probing depths, bleeding on probing, marginal bone level, and patient-reported outcomes as Ti.[6] However, Zir abutments had more mechanical complications than Ti abutments.[5] The lack of mechanical strength is thus the principal limitation for the wider adoption of Zir abutments.

In the 5 years since Bidra and Rungruanganunt's review, the use of zirconia abutments has increased worldwide. The limitations of abutment angulation and the minimal Zir thickness are now better known.[7,8] Furthermore, the use of custom and zirconia abutments with titanium inserts has expanded. These abutments are composed of a prefabricated Ti prosthetic component supporting a custom Zir abutment. After fabrication and refinement, the abutment is adhesively cemented to the titanium base, and the resulting restoration is screw-retained on the implant.[9,10] The titanium base has been reported to reinforce the abutment in vitro.[3,11-14] Clinical studies on the esthetic outcomes of these designs are lacking.

Therefore, the purpose of this systematic review was to assess the mechanical and esthetic outcomes of implant zirconia abutments used in the anterior region, considering the design evolution of the past 5 years.

MATERIAL AND METHODS

The main question of this systematic review in the patient-intervention-control-outcome format was "In patients requiring a single, anterior implant, what are zirconia abutments' survival, mechanical, and esthetic outcomes?" The outcomes were divided into 2 sections: mechanical and esthetic. Abutment fracture, screw loosening, and abutment chipping were assigned to the mechanical section, whereas patient-reported satisfaction and objective esthetic indices were selected as esthetic outcomes.

The search strategy in Medline (PubMed) is presented in Supplemental Table 1. The references cited in the included articles were also verified. Inclusion criteria included clinical studies using zirconia abutments and reporting at least one of the outcome measures (mechanical or esthetic). All studies were published in English in a peer-reviewed journal after 2013. Pilot studies and case series were included when they reported follow-ups of at least 5 abutments with a minimum follow-up time of 1 year. Literature reviews, abstracts, articles that described the abutments solely for interim use, and technique articles without associated clinical trials and data were excluded.

Two reviewers (C.W., A.N.) carried out the literature search independently until May 2018. All titles and abstracts of articles found were analyzed and selected in accordance with the eligibility criteria. Papers that appeared to meet the inclusion criteria or in which there were insufficient data in the title and the abstract to make a decision were selected for full analysis. The 2 reviewers assessed the full-text articles independently. Any disagreement on the eligibility of studies included was resolved through discussion and consensus. One review author (C.W.) extracted the data, and the second author (A.N.) checked it. The reviewers tabulated the following data from the included articles: study design, follow-up, number of abutments, type of zirconia abutments, and type of control abutments.

Because of the high degree of heterogeneity in terms of the studied materials and methodologies, a meta-analysis was considered inappropriate.

RESULTS

After database screening and the removal of duplicates, 231 studies were identified (Fig. 1). After title screening, 93 studies remained, and this number was reduced to 25 after examination of the abstracts. The full texts of those 25 studies were further assessed for eligibility. Four were excluded because they reported clinical biological and esthetic measurements when zirconia abutments were placed but did not investigate those outcomes over time.[15-18] Another reported mechanical and esthetic outcomes for posterior teeth and only 2 canines.[19] This led to a total of 20 new studies published after 2013 (Supplemental Table 2). The key research question allowed the selection of pertinent studies for anterior, single restorations on incisors, canines, and sometimes first premolars. Fixed partial dentures were excluded.

Six retrospective studies,[20-25] 6 prospective studies,[26-31] and 8 randomized controlled trials (RCTs) were included.[4,32-38] Among those, 11 studies specifically focused on the outcome of zirconia abutments.[19,20,24,26,28,29,31-33,37,38] In the remaining 9 studies, the focus was on distinct surgical issues, and either esthetic outcomes or mechanical complications with Zir abutments

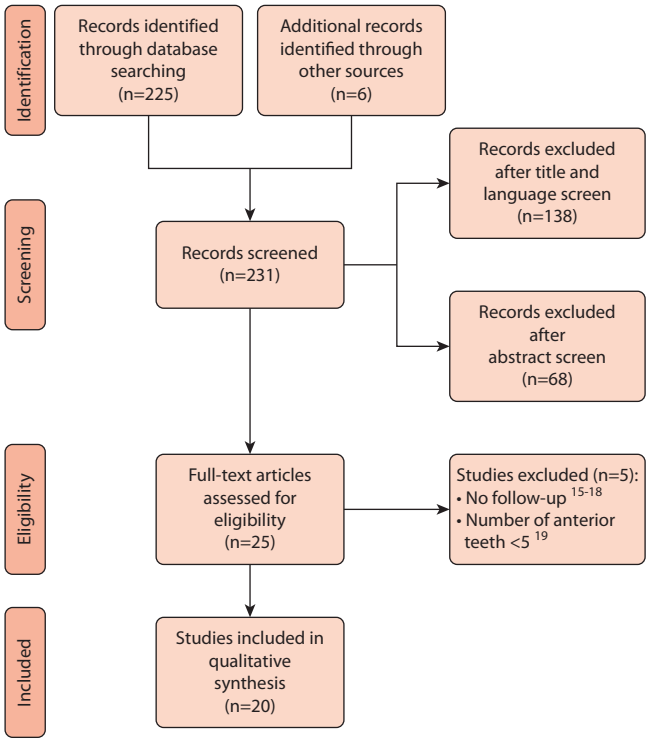

Figure 1. Flow diagram of study identification.

were reported. Six studies compared the performances of Zir abutments with Ti, Au, or Al_2O_3 abutments.[20,24,26,29,31,32]

The randomization in 3 RCTs was not related to Ti or Zir abutment but rather to the implant surface, implant-abutment interface, or treatment timing.[4,34,35] Only the Carrillo et al[32] study compared Ti and Zir abutments. Paolantoni et al[33] investigated 2 zirconia abutment designs, Thoma et al[37] studied pink veneering, and Wittneben et al[38] compared prefabricated with CAD-CAM custom abutments.

All types of Zir abutments were used in the included studies: prefabricated abutments with or without specified adjustments or veneering fabricated by the technician providing the definitive crown (8/19), custom abutments fabricated with CAD-CAM technology (11/19); and abutments with titanium insert (2/19). In 3 studies, the type of zirconia abutment was not specified.[23,25,36]

The included studies considered screw abutment loosening to be a minor mechanical complication, whereas an abutment fracture was considered a major mechanical complication (when requiring the replacement of the prosthetic component). Chipping of the abutment was not always investigated in the material and methods section of the included studies.

Twelve studies described the mechanical behavior of zirconia abutments (Table 1), and mechanical complications distribution varied among them. Only 5 studies[21,26,32,33,37] reported fractures, with fracture percentage varying from 1.2% to 8%. In a total of 659 abutments, 15 fractures were reported. A few fractures were reported around screw access holes with thin walls for implantation with external connection (9%)[21] and at the implant neck in implants with internal connections.[21,37] Implant diameter did not influence the investigated outcomes; fractures occurred with both narrow diameter implants (3.5 mm)[32] and with regular diameter implants (4 mm).[21,26] The remaining 2 studies[33,37] reporting fractures did not detail implant diameter and did not refer to narrow implant diameter as an explanation for fracture.

No specific time frame could be defined because one study reported fracturing during tightening of the abutment to the specified torque,[32] whereas others described fracture occurrence within the first year.[21,26,37] The 2 studies[21,33] that reported 4% and 6.7% of zirconia abutment fractures considered longer follow-up periods, 4 years and up to 12 years, respectively. In the retrospective study by Passos et al,[21] 1 fracture occurred each year between baseline and the sixth year for a maximum follow-up of 12 years.

The highest rate of abutment screw loosening was 6%.[26] No abutment chipping was reported. No mechanical outcomes were presented in either of the 2 studies using zirconia abutments with titanium inserts.[4,35]

Esthetic outcomes were mostly reported through soft-tissue-contour indices and patient satisfaction questionnaires (Table 2). The pink esthetic score (PES) was established by a comparison with a reference tooth (adjacent to the premolar region or contralateral to the anterior region).[39] This scale (scoring of 0, 1, or 2) describes 7 peri-implant mucosal components (shape of mesial and distal papillae, level of soft-tissue margin, soft-tissue contour, alveolar process, and soft-tissue color and texture), resulting in a maximum score of 14. Belser et al[40] completed the PES with a white esthetic score (WES) that evaluated the esthetics of the clinical crown of the implant restoration as well (tooth form, volume, color, surface texture, and translucency). This PES/WES considered both mucosal and dental components, with 10 points for both the parts. The PES was used in 3 studies,[30,34,35] and PES/WES was used in 6 studies.[4,23-25,27,38] With PES, a score >10 is considered good and that >12 is considered excellent. With PES/WES, the acceptability threshold is 6.

Several studies focused on the presence and height of papillae, with direct measurements or by using the Papilla Index[20,36] described by Jemt.[41] Borges et al[29] applied PES scoring to describe papillae. Carrillo de Albornoz et al[32] and Santing et al[27] used the Implant Crown Aesthetic Index, the last group comparing PES/WES and the Implant Crown Aesthetic Index. Branzen et al[20] used patient qualitative satisfaction questionnaires

Table 1. Mechanical outcomes

Study	Follow-up (Year)	Number of Patients (Abutments)	Zirconia Abutment Type	Abutment Fracture	Abutment Loosening
Borges et al. (2014)[29]	1	36	Custom	0	0
Carrillo de Albornoz et al. (2014)[32]	1	25	Prefabricated	2	0
Hosseini et al. (2013)[31]	3	59 (98)	52 prefabricated	0	0
Lops et al. (2015)[26]	2	77	14 prefabricated+20 custom	1	1 (prefabricated) and 1 (custom)
Paolantoni et al. (2016)[33]	4	65 (74)	29 prefabricated (cemented)+35 prefabricated (screw-retained)	3 (2 pieces)+2 (1 piece)	0
Passos et al. (2016)[21]	Up to 12	150	Prefabricated+custom	6	1
Rinke et al. (2015)[22]	>5	27 (42)	Prefabricated	0	2
Santing et al. (2013)[27]	1.4	60	Custom	0	0
Takeshita et al. (2015)[23]	1.5	18 (21)	Not specified	0	0
Thoma et al. (2016)[37]	1	20	Custom	1	0
Wittneben et al. (2017)[38]	1	40	20 prefabricated+20 custom	0	0
Zembic et al. (2015)[28]	11	16 (31)	Custom	0	2

to assess esthetic outcomes, specifically focusing on the indication to replace the restoration. Patients' opinions were also used to supplement objective evaluation.[24,27] Hosseini et al[31] used the Copenhagen Index Score and complemented it with questions from the Oral Health Impact Profile-49 questionnaire.

All indices considered that authors reported "very good to excellent" esthetic results and patient satisfaction, even if no significant correlation between objective scores and patient questionnaires was found.[24] According to PES scoring, the most difficult esthetic parameters to achieve were root convexity, soft-tissue color and texture,[24,35] and level of mucosa.[4,27,30]

DISCUSSION

The goal of the review was to update knowledge on the esthetic and mechanical outcomes of zirconia abutments in the anterior region. Until now, their main interest lay in very good esthetic integration, whereas mechanical complications represented 1.15%, according to Bidra and Rungruanganunt.[5]

Concerning mechanical behavior, complications reported in the included studies were in accordance with the review of Bidra and Rungruanganunt,[5] showing no change over the past 5 years. Thin screw walls, for external implant-abutment connections, and implant neck, for internal implant-abutment connections, were identified as weak parts susceptible to fracture, whereas no specific failure time scheme was defined. However, most examined studies included follow-up times of up to 1 year.

Heterogeneity in the study designs limited a comparison of the mechanical results. The data extraction from the included studies was challenging because of the number and types of Zir abutments, which were not always clearly identified. Furthermore, the heterogeneity among zirconia abutment designs—prefabricated, custom, and with titanium insert—made comparisons unreliable. Most studies focusing on surgical protocols and using zirconia abutments did not give any details regarding the prosthetic issues. Thus, whether any complications occurred or were not considered relevant in view of the primary objectives was difficult to infer. In those situations, the study was not considered for analysis in the mechanical section.

During the past 5 years, studies have mainly used implants with internal connections. In the only 2 retrospective studies that analyzed the mechanical and esthetic outcomes of zirconia abutments with external connection, Zembic et al[28] reported only 2 screw-loosening events, and Branzen et al[20] did not report any complications at all. The hypothesis made by Bidra and Rungruanganunt[5,42] about a possible trend toward abutment screw loosening with external connections was not supported in the present review, although it has been supported by in vitro findings.

The number of studies examining CAD-CAM abutments has increased in the past 5 years, but only 2 new studies[4,35] have been published reporting zirconia abutments with titanium insert outcomes in the anterior region, neither detailed mechanical complications. The effect of mechanical reinforcement due to the titanium component could not be assessed.

To limit mechanical complications, manufacturers have restricted the indications for Zir abutments to limited angulation. Indeed, stock abutments provide a maximum angulation of 15 to 20 degrees, whereas Atlantis CAD-CAM custom abutments, for example, are not recommended for angulation over 30 degrees. This concern was often reported by investigators who chose the abutment design based on clinical parameters (such as implant angulation[26,31] or soft-tissue thickness)[24,26] rather than through a randomization process, thus seemingly acting in the best interest of the patients. Angulation of 20 to 30 degrees seems to be the generally accepted maximum limit of indication for zirconia

Table 2. Esthetic outcomes

Study	Zirconia Abutment Type	Control Abutment Type	Indices	Outcomes
Barwacz et al. (2016)[34]	Custom, Atlantis		PES	Group Conical Interface subjects' median sum PES values ranged from 8.0 to 10.4. Group Flat-to-flat Interface subjects' median sum PES values ranged from 7.0 to 10.0. Group Platform Switch Interface subjects' median sum PES values ranged from 7.4 to 10.4. No statistical difference
Bashutski et al. (2013)[36]	Not specified		PPI and patients' satisfaction	PPI values for the flap control group and flapless test group were 2.38 (0.51) versus 2.31 (0.48) at crown placement and 2.52 (0.52) versus 2.64 (0.54) at 15 months (P=.42), Not significant.
Borges et al. (2014)[29]	Custom, Atlantis	Custom, Ti-Ni and Au-Ti	Papilla score from PES	No significant difference for papilla presence
Branzén et al. (2015)[20]	36 custom	8 custom Ti, 10 prefabricated Al_2O_3 CeraOne	PI and satisfaction questionnaire	Eight questions concerning the form, color, and appearance of the restorations, where satisfaction/importance was to be rated from 1 (not at all) to 5 (completely/very). The last question dealt with the possible desire to have the crown replaced (yes/no). Mean: 21.08.
Carrillo de Albornoz et al. (2014)[32]	11 prefabricated, SPY-ART	14 prefabricated, Ti SPY EASY	ICAI-mucosa	A subanalysis of the ICAI-mucosa index items showed a better integration of the color and surface of the mucosa with zirconia abutments
Den Hartog et al, (2013)[4]	Custom, Procera+Ti insert		PES WES	PES 6.1, 6.3, 6 and WES 7.2, 7.4, 7.2, with machined, rough with grooves, and scalloped rough implant necks respectively.
Fürhauser et al. (2017)[30]	Custom, Procera		PES	12.6
Hosseini et al. (2013)[31]	52 prefabricated	46 prefabricated, Ti and Au	CIS et OHIP-49	
Kolerman et al. (2017)[25]	Not specified		PES WES	15.5
Rieder et al. (2016)[35]	Ti insert, Straumann CARES		PES	8.47, 7.93, 6.62, and 8.10; significant differences between immediate/immediate and early/immediate and between early/immediate and early/early (implant placement/prosthetic restoration)
Santing et al. (2013)[27]	Custom, Straumann CARES		PES WES ICAI	6.9 7.5
Takeshita et al. (2015)[23]	Not specified		PES WES	PES 10.52 (/14) (baseline) and 10.24 (1.5 y) WES 8.05 (baseline) and 8.29 (1.5 y)
Thoma et al. (2016)[37]	Custom, Atlantis, pink veneered and nonveneered		PI	No significant difference after 1 year
Vanlioglu et al. (2014)[24]	10 prefabricated, IPS e-max Straumann	45 Ti Anatomic Straumann	PES WES patient satisfaction questionnaire	15.33 baseline and 15.71 after 4 years. No difference with or without veneering
Wittneben et al. (2017)[38]	20 prefabricated, IPS e-max (A)+20 Custom, Straumann CARES (B)		PES WES	PES 7 (A) and 7.65 (B) WES 8.28 (A) and 8.50 (B). No difference between prefabricated and custom abutments

CI, Conical interface; CIS, Copenhagen index score; FI, flat-to-flat interface; ICAI, Implant crown aesthetic index; OHIP, oral health impact profile; PES, pink esthetic score; PPI, papillary index; PS, platform switch interface.

abutments, whether in regard to mechanical issues or for esthetic reasons.

Narrow diameter implants and abutments have been hypothesized to be more susceptible to fracture because of the thinness of the zirconia components. Carrillo et al[32] reported that all fractures occurred with narrow implants, but Lops et al[26] and Passos et al[21] reported fractures with 4-mm-diameter implants and none with narrow implants. Thus, the influence of implant diameter on fracture was not established.

Analyzing esthetic outcomes of Zir abutments was the other objective of this systematic review. Linkevicius and Vaitelis[6] stated that Zir abutments provided better color integration. In their RCTs comparing Ti and Zir materials, Carrillo et al[32] also showed the advantage of Zir for mucosal surface. Otherwise, all authors claimed "good to excellent" esthetic results with prefabricated and custom zirconia abutments. Yet, this success cannot be attributed solely to the choice of zirconia material because in all studies, bone and soft tissue defects were either corrected with a graft or constituted an exclusion criterion.

Because zirconia abutments with titanium inserts were used in only 2 studies, it is difficult to know whether this alternative is validated from the viewpoint of esthetics, but prospects are encouraging. Den Hartog et al[4] used those abutments because no zirconia abutments were available with the specific implant neck required for their study; yet, they found no differences after 1 year in the PES/WES scores

when compared with those of zirconia abutments. Rieder et al[35] chose abutments with titanium inserts and obtained the same results (mean PES ranging from 6.6 to 8.4, according to implant placement and restoration protocol).

Coloring is the new trend toward improved esthetic integration. It can be obtained through veneering of a zirconia abutment or by anodization of titanium. Clinical spectrophotometric studies showed a statistically significant improvement in color with pink anodization of Ti abutments or Ti implant necks compared with the gray titanium, yet still inferior to Zir abutments.[16,43] Pink veneering of zirconia is more promising according to spectrophotometric measurement, without significant biological or technical alteration.[18,37] Zirconia veneering with a fluorescent ceramic was also validated by spectrophotometry,[17] although the benefits of fluorescent veneering of a Ti-base abutment was not conclusive.[44] Only Borges et al[29] reported nitriding of titanium to obtain a gold aspect for improved color integration. The choice of the zirconia material for the abutment is only 1 parameter of esthetic success for anterior, single-tooth implant restorations along with the choice of crown material and soft-tissue quality, color, and contour.

CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. Zirconia abutments provide better matching and integration of the color and surface of soft tissues than titanium abutments.
2. Zirconia abutments are particularly indicated in patients with thin peri-implant mucosa because discoloration does not depend on tissue thickness, whereas thick tissues are necessary to mask the gray color of titanium.
3. No difference was demonstrated between zirconia and titanium regarding papilla presence and height.
4. Some authors reported less marginal bone loss with zirconia abutments than with metal abutments.
5. Fractures of zirconia abutments are still regularly reported. Indications should be restricted to <20 to 30 degrees to prevent them. No influence of implant diameter was found.
6. CAD-CAM custom abutments may provide better soft-tissue stability, but this question should be better documented later with currently ongoing studies. There is no difference between custom and prefabricated abutments in mechanical outcomes after 1 year and up to 12 years.
7. Sparse information is available concerning the mechanical and esthetic outcomes of zirconia abutments with titanium inserts in the anterior region.

REFERENCES

1. Papaspyridakos P, Chen C-J, Singh M, Weber H-P, Gallucci GO. Success criteria in implant dentistry: a systematic review. J Dent Res 2012;91:242-8.
2. Glauser R, Sailer I, Wohlwend A, Studer S, Schibli M, Schärer P. Experimental zirconia abutments for implant-supported single-tooth restorations in esthetically demanding regions: 4-year results of a prospective clinical study. Int J Prosthodont 2004;17:285-90.
3. Gehrke P, Johannson D, Fischer C, Stawarczyk B, Beuer F. In vitro fatigue and fracture resistance of one- and two-piece CAD/CAM zirconia implant abutments. Int J Oral Maxillofac Implants 2015;30:546-54.
4. Den Hartog L, Raghoebar GM, Slater JJH, Stellingsma K, Vissink A, Meijer HJA. Single-tooth implants with different neck designs: a randomized clinical trial evaluating the aesthetic outcome. Clin Implant Dent Relat Res 2013;15:311-21.
5. Bidra AS, Rungruanganunt P. Clinical outcomes of implant abutments in the anterior region: a systematic review. J Esthet Restor Dent 2013;25:159-76.
6. Linkevicius T, Vaitelis J. The effect of zirconia or titanium as abutment material on soft peri-implant tissues: a systematic review and meta-analysis. Clin Oral Implants Res 2015;26 Suppl 11:139-47.
7. Zandparsa R, Albosefi A. An in vitro comparison of fracture load of zirconia custom abutments with internal connection and different angulations and thicknesses: part II. J Prosthodont 2016;25:151-5.
8. Ellakwa A, Raj T, Deeb S, Ronaghi G, Martin FE, Klineberg I. Influence of implant abutment angulations on the fracture resistance of overlaying CAM-milled zirconia single crowns. Aust Dent J 2011;56:132-40.
9. Mehl C, Zhang Q, Lehmann F, Kern M. Retention of zirconia on titanium in two-piece abutments with self-adhesive resin cements. J Prosthet Dent 2018 Apr 5.
10. Fadanelli MA, Amaral FLB, Basting RT, Turssi CP, Sotto-Maior BS, França FMG. Effect of steam autoclaving on the tensile strength of resin cements used for bonding two-piece zirconia abutments. J Oral Implantol 2017;43:87-93.
11. Kim JS, Raigrodski AJ, Flinn BD, Rubenstein JE, Chung K-H, Mancl LA. In vitro assessment of three types of zirconia implant abutments under static load. J Prosthet Dent 2013;109:255-63.
12. Truninger TC, Stawarczyk B, Leutert CR, Sailer TR, Hämmerle CHF, Sailer I. Bending moments of zirconia and titanium abutments with internal and external implant-abutment connections after aging and chewing simulation. Clin Oral Implants Res 2012;23:12-8.
13. Gehrke P, Alius J, Fischer C, Erdelt KJ, Beuer F. Retentive strength of two-piece CAD/CAM zirconia implant abutments. Clin Implant Dent Relat Res 2014;16:920-5.
14. Alsahhaf A, Spies BC, Vach K, Kohal R-J. Fracture resistance of zirconia-based implant abutments after artificial long-term aging. J Mech Behav Biomed Mater 2017;66:224-32.
15. Kajiwara N, Masaki C, Mukaibo T, Kondo Y, Nakamoto T, Hosokawa R. Soft tissue biological response to zirconia and metal implant abutments compared with natural tooth: microcirculation monitoring as a novel bioindicator. Implant Dent 2015;24:37-41.
16. Martínez-Rus F, Prieto M, Salido MP, Madrigal C, Özcan M, Pradíes G. A clinical study assessing the influence of anodized titanium and zirconium dioxide abutments and peri-implant soft tissue thickness on the optical outcome of implant-supported lithium disilicate single crowns. Int J Oral Maxillofac Implants 2017;32:156-63.
17. Happe A, Schulte-Mattler V, Fickl S, Naumann M, Zöller JE, Rothamel D. Spectrophotometric assessment of peri-implant mucosa after restoration with zirconia abutments veneered with fluorescent ceramic: a controlled, retrospective clinical study. Clin Oral Implants Res 2013;24 Suppl A100:28-33.
18. Thoma DS, Brandenberg F, Fehmer V, Knechtle N, Hämmerle CH, Sailer I. The esthetic effect of veneered zirconia abutments for single-tooth implant reconstructions: a randomized controlled clinical trial. Clin Implant Dent Relat Res 2016;18:1210-7.
19. Zembic A, Bösch A, Jung RE, Hämmerle CHF, Sailer I. Five-year results of a randomized controlled clinical trial comparing zirconia and titanium abutments supporting single-implant crowns in canine and posterior regions. Clin Oral Implants Res 2013;24:384-90.
20. Branzén M, Eliasson A, Arnrup K, Bazargani F. Implant-supported single crowns replacing congenitally missing maxillary lateral incisors: a 5-year follow-up. Clin Implant Dent Relat Res 2015;17:1134-40.
21. Passos SP, Linke B, Larjava H, French D. Performance of zirconia abutments for implant-supported single-tooth crowns in esthetic areas: a retrospective study up to 12-year follow-up. Clin Oral Implants Res 2016;27:47-54.
22. Rinke S, Lattke A, Eickholz P, Kramer K, Ziebolz D. Practice-based clinical evaluation of zirconia abutments for anterior single-tooth restorations. Quintessence Int 2015;46:19-29.
23. Takeshita K, Vandeweghe S, Vervack V, Sumi T, De Bruyn H, Jimbo R. Immediate implant placement and loading of single implants in the esthetic zone: clinical outcome and esthetic evaluation in a Japanese population. Int J Periodontics Restorative Dent 2015;35:715-23.

24. Vanlıoğlu BA, Kahramanoğlu E, Yıldız C, Ozkan Y, Kulak-Özkan Y. Esthetic outcome evaluation of maxillary anterior single-tooth bone-level implants with metal or ceramic abutments and ceramic crowns. Int J Oral Maxillofac Implants 2014;29:1130-6.
25. Kolerman R, Mijiritsky E, Barnea E, Dabaja A, Nissan J, Tal H. Esthetic assessment of implants placed into fresh extraction sockets for single-tooth replacements using a flapless approach. Clin Implant Dent Relat Res 2017;19:351-64.
26. Lops D, Bressan E, Parpaiola A, Sbricoli L, Cecchinato D, Romeo E. Soft tissues stability of cad-cam and stock abutments in anterior regions: 2-year prospective multicentric cohort study. Clin Oral Implants Res 2015;26:1436-42.
27. Santing HJ, Raghoebar GM, Vissink A, den Hartog L, Meijer HJA. Performance of the Straumann Bone Level Implant system for anterior single-tooth replacements in augmented and nonaugmented sites: a prospective cohort study with 60 consecutive patients. Clin Oral Implants Res 2013;24:941-8.
28. Zembic A, Philipp AOH, Hämmerle CHF, Wohlwend A, Sailer I. Eleven-year follow-up of a prospective study of zirconia implant abutments supporting single all-ceramic crowns in anterior and premolar regions. Clin Implant Dent Relat Res 2015;17 Suppl 2:e417-26.
29. Borges T, Lima T, Carvalho A, Dourado C, Carvalho V. The influence of customized abutments and custom metal abutments on the presence of the interproximal papilla at implants inserted in single-unit gaps: a 1-year prospective clinical study. Clin Oral Implants Res 2014;25:1222-7.
30. Fürhauser R, Mailath-Pokorny G, Haas R, Busenlechner D, Watzek G, Pommer B. Immediate restoration of immediate implants in the esthetic zone of the maxilla via the copy-abutment technique: 5-year follow-up of Pink Esthetic Scores. Clin Implant Dent Relat Res 2017;19:28-37.
31. Hosseini M, Worsaae N, Schiødt M, Gotfredsen K. A 3-year prospective study of implant-supported, single-tooth restorations of all-ceramic and metal-ceramic materials in patients with tooth agenesis. Clin Oral Implants Res 2013;24:1078-87.
32. Carrillo de Albornoz A, Vignoletti F, Ferrantino L, Cárdenas E, De Sanctis M, Sanz M. A randomized trial on the aesthetic outcomes of implant-supported restorations with zirconia or titanium abutments. J Clin Periodontol 2014;41:1161-9.
33. Paolantoni G, Marenzi G, Blasi A, Mignogna J, Sammartino G. Findings of a four-year randomized controlled clinical trial comparing two-piece and one-piece zirconia abutments supporting single prosthetic restorations in maxillary anterior region. Biomed Res Int 2016;2016:8767845.
34. Barwacz CA, Stanford CM, Diehl UA, Qian F, Cooper LF, Feine J, et al. Electronic assessment of peri-implant mucosal esthetics around three implant-abutment configurations: a randomized clinical trial. Clin Oral Implants Res 2016;27:707-15.
35. Rieder D, Eggert J, Krafft T, Weber H-P, Wichmann MG, Heckmann SM. Impact of placement and restoration timing on single-implant esthetic outcome - a randomized clinical trial. Clin Oral Implants Res 2016;27:e80-6.
36. Bashutski JD, Wang H-L, Rudek I, Moreno I, Koticha T, Oh T-J. Effect of flapless surgery on single-tooth implants in the esthetic zone: a randomized clinical trial. J Periodontol 2013;84:1747-54.
37. Thoma DS, Brandenberg F, Fehmer V, Büchi DLE, Hämmerle CHF, Sailer I. Randomized controlled clinical trial of all-ceramic single tooth implant reconstructions using modified zirconia abutments: radiographic and prosthetic results at 1 year of loading. Clin Implant Dent Relat Res 2016;18:462-72.
38. Wittneben JG, Gavric J, Belser UC, Bornstein MM, Joda T, Chappuis V, et al. Esthetic and clinical performance of implant-supported all-ceramic crowns made with prefabricated or CAD/CAM zirconia abutments: a randomized, multicenter clinical trial. J Dent Res 2017;96:163-70.
39. Fürhauser R, Florescu D, Benesch T, Haas R, Mailath G, Watzek G. Evaluation of soft tissue around single-tooth implant crowns: the pink esthetic score. Clin Oral Implants Res 2005;16:639-44.
40. Belser UC, Grütter L, Vailati F, Bornstein MM, Weber H-P, Buser D. Outcome evaluation of early placed maxillary anterior single-tooth implants using objective esthetic criteria: a cross-sectional, retrospective study in 45 patients with a 2- to 4-year follow-up using pink and white esthetic scores. J Periodontol 2009;80:140-51.
41. Jemt T. Regeneration of gingival papillae after single-implant treatment. Int J Periodontics Restorative Dent 1997;17:326-33.
42. Pardal-Peláez B, Montero J. Preload loss of abutment screws after dynamic fatigue in single implant-supported restorations. A systematic review. J Clin Exp Dent 2017;9:e1355-61.
43. Gil MS, Ishikawa-Nagai S, Elani HW, Da Silva JD, Kim DM, Tarnow D, et al. A prospective clinical trial to assess the optical efficacy of pink neck implants and pink abutments on soft tissue esthetics. J Esthet Restor Dent 2017;29:409-15.
44. Thoma DS, Gamper FB, Sapata VM, Voce G, Hämmerle CHF, Sailer I. Spectrophotometric analysis of fluorescent zirconia abutments compared to "conventional" zirconia abutments: a within subject controlled clinical trial. Clin Implant Dent Relat Res 2017;19:760-6.

Corresponding author:
Dr Claudine Wulfman
EA442
Faculty of Dentistry
1 rue Maurice Arnoux
92120 Montrouge
FRANCE
Email: claudine.wulfman@parisdescartes.fr

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Supplemental Table 1. Research strategy (PubMed/Medline, May 2018)

#1	#2	#3	#4
Anterior teeth OR canine OR incisor	Zirconia abutment OR hybrid abutment OR zirconium abutment OR alumina abutment OR ceramic abutment OR porcelain abutment OR esthetic abutment OR cad-cam abutment OR computer-aided design* OR metal free abutment OR custom abutment OR dental porcelain/therapeutic use* OR titanium based abutment OR dental implant-abutment design* OR dental abutments* OR dental implant-abutment design/methods* OR dental implants, single-tooth* OR dental prosthesis design* OR zirconium* OR zirconium/therapeutic use* OR dental prosthesis, implant-supported*	Success rate OR survival rate OR fracture OR chipping OR mechanical properties OR esthetic OR esthetic outcomes OR retention OR screw loosening OR screw fracture OR spectrophotometric analysis OR discoloration OR color change OR esthetics, dental* OR dental prosthesis repair* OR dental restoration failure OR prosthesis failure/adverse effects*	Longitudinal study OR cohort study OR clinical study OR controlled study OR retrospective study OR randomized study OR follow-up studies OR multicenter study OR randomized controlled trial OR comparative study

#1 AND #2 AND #3 AND #4.

Supplemental Table 2. Summary of included studies

	Study Design	Follow-up (year)	Number of Patients (Abutments)	Zirconia Abutment Types	Types
Barwacz et al. (2016)[34]	RCT	5	141	Custom, Atlantis	
Bashutski et al. (2013)[36]	RCT	1.25	24	Not specified	
Borges et al. (2014)[29]	Prospective	1	36	Custom, Atlantis	Custom, Ti-Ni, and Au-Ti
Branzén et al. (2015)[20]	Retrospective	5	36 (54)	36 custom	8 custom Ti, 10 prefabricated Al_2O_3 CeraOne
Carrillo de Albornoz et al. (2014)[32]	RCT	1	25	11 prefabricated, SPY-ART	14 prefabricated, Ti SPY EASY
Den Hartog et al. (2013)[4]	RCT	1	93	Custom, Procera+Ti insert	
Fürhauser et al. (2017)[30]	Prospective	5	77	Custom, Procera	
Hosseini et al. (2017)[31]	Prospective	3	59 (98)	52 prefabricated	46 prefabricated, Ti and Au
Kolerman et al. (2017)[25]	Retrospective	1	38	Not specified	
Lops et al. (2015)[26]	Prospective	2	77	13 prefabricated, Zir Design+20 Custom, Atlantis	23 prefabricated, Ti design+16 Ti prefabricated, Atlantis
Paolantoni et al. (2016)[33]	RCT	4	65 (74)	29 prefabricated, SPY-ART (cemented)+45 prefabricated, SPY-ART (screw-retained)	
Passos et al. (2016)[21]	Retrospective	Up to 12	150	Prefabricated, 3i+custom, Nobel, Astra, and Straumann	
Rieder et al. (2016)[35]	RCT	1	48	Ti insert, Straumann CARES	
Rinke et al. (2015)[22]	Retrospective	>5	27 (42)	Prefabricated, Cercon	
Santing et al. (2013)[27]	Prospective	1.5	60	Custom, Straumann CARES	
Takeshita et al. (2015)[23]	Retrospective	1.5	18 (21)	Not specified	
Thoma et al. (2016)[37]	RCT	1	20	Custom, Atlantis, pink veneered and non-veneered	
Vanlioglu et al. (2014)[24]	Retrospective	2 to 4	55 (47)	10 prefabricated, IPS e-max Straumann	
Wittneben et al. (2017)[38]	RCT	1	40	20 prefabricated, IPS e-max+20 Custom, Straumann CARES	45 Ti Anatomic Straumann
Zembic et al. (2015)[28]	Prospective	11	16 (31)	Custom, Metoxit	

RCT, randomized controlled trial.