CLINICAL ORAL IMPLANTS RESEARCH

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The effect of zirconia or titanium as abutment material on soft peri-implant tissues: a systematic review and meta-analysis

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Abstract

Aim: The objective of this review was to analyze research with regard to the effect of zirconia or titanium as abutment material on soft peri-implant tissues.

Methods: Clinical studies were selected via electronic and hand searches in English language journals until December 1, 2014. Only randomized clinical trials (RCTs) and prospective controlled clinical trials (CCTs) showing direct comparison between zirconia (Zr) and titanium (Ti) abutments in the same patient were considered. The outcome measures were (1) soft tissue color, (2) soft tissue recession, (3) peri-implant probing, (4) bleeding on probing, (5) esthetic indexes, (6) patient-reported outcome, (7) marginal bone level, and (8) biological complications.

Results: Nine relevant studies (11 papers) were identified: 4 RCTs and 5 CCTs. Due to heterogeneity in the study design, statistical methods, and reported results, a meta-analysis of the data was feasible only for soft tissue color. The outcome was found to be significantly superior for Zr abutments. For the other outcome measures, a qualitative analysis of the selected articles was performed. The studies did not show any statistically significant differences between Zr and Ti abutments on soft tissue recession, probing depths, bleeding on probing, marginal bone level, and patient-reported outcome. One study reported significantly higher pink esthetic score (PES) scores at Zr implants with Zr abutments, compared to metal implants and Ti abutments.

Conclusion: Overall, the research does not support any obvious advantage of Ti or Zr abutments over each other. However, there is a significant tendency in Zr abutments evoking better color response of peri-implant mucosa and superior esthetic outcome measured by PES score.

Prescription of prosthetic abutments has always been a critical part of implant treatment. For many years, standard stock abutments provided by implant manufacturers were the only option available for the clinician. Eventually, doctors had to accept all shortcomings of these products, including predetermined cement line position and lack of emergency profile. Currently, there has been growing evidence in the literature that the use of standard stock abutments for cementation is no longer justifiable, due to compelling proof of improper cement remnants removal (Linkevicius et al. 2011, 2013a,b; Wadhwani et al. 2012; Vindasiute et al. 2013; Korsch et al. 2014; Korsch & Walther 2014). Therefore, modern prosthetic implant dentistry cannot be imagined without the use of customized implant abutments. Such abutments have an individual shape, which follows the peri-implant soft tissue line of the implant site, giving two major advantages, namely (1) support of soft tissues and (2) a favorable location of the cementation margin for cleaning cement excess (Dumbrigue et al. 2002). Currently, various materials are used for fabrication of individually customized prosthetic abutments, such as metals, ceramics, and composites. For a long time, cast gold individual abutments were considered as the state of the art in customized prosthetic solutions; however, recently, their use has been rapidly decreasing due to lack of biocompatibility and higher pricing. It has been shown in animal studies that peri-implant soft tissues do not form a sufficient seal with gold abutments; therefore, soft tissue recession and crestal bone loss can be expected (Abrahamsson et al. 1998). Similarly, dental porcelain appeared not to be a proper material for the establishment of reliable soft tissue adherence. In fact, the outcome with feld-

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spathic ceramics was least favorable, as soft tissue recession and bone loss were the highest extent along this material (Abrahamsson et al. 1998). Composite resin abutments have been suggested as an alternative to restoring dental implants and have proved to be as strong, as zirconium ones in several *in vitro* tests (Magne et al. 2011). However, the reaction of soft peri-implant tissues to composite is a major concern. A randomized clinical trial showed that composite resin surfaces harbored a marked plaque accumulation, which produced mucosal inflammation in many cases, in comparison with titanium (Kanao et al. 2013). Therefore, the use of resin composite abutments remains limited.

Recent advances in milling technology recommend two materials to be selected for fabrication of patient-specific abutments – zirconium and titanium. Titanium for decades was the preferred material due to material strength, resistance to distortion, and possibility to produce the abutment as one-piece. Systematic reviews have shown excellent results promoting titanium abutments as highly reliable (Sailer et al. 2009b; Zembic et al. 2014a). However, the major drawback of these abutments is that their dark color can shine through soft peri-implant tissues, creating a grayish appearance of the peri-implant mucosa, which is esthetically unacceptable (Park et al. 2007). In contrast, zirconium abutments offer a much better esthetic outcome, especially in thinner peri-implant mucosa cases (Jung et al. 2008). In addition, some studies claim zirconium to be the most biocompatible material with lower adhesion of bacteria (Scarano et al. 2004; Degidi et al. 2006). Nevertheless, its brittleness is viewed as a shortcoming of zirconium abutments (Belser et al. 2004). Technical complications are highly dependent on the zirconia abutment design. Fractures of one-piece zirconia abutments with internal connection were reported in short-term studies (de Alboroz et al. 2014) and in longer follow-up observations (Passos et al. 2014). Conversely, other reports of increased loading situations showed 100% success (Glauser et al. 2004; Canullo 2007). It is interesting to note that these excellent outcome studies used zirconia abutments with an external connection or an internal hexagon two-piece construction, where zirconium abutment-like coping is cemented on a titanium base. Finally, Zembic et al. (2014b) showed no zirconium abutment fractures in an 11-year prospective clinical trial.

Although doubts about zirconium strength and its pertinence to successfully withstand loading are diminishing, clinicians often face the dilemma of choosing between zirconium and titanium abutments when having the soft tissues in mind. The influence of these materials on the status of soft peri-implant mucosa is still not clear, and the question that material offers a better outcome remains unanswered.

Several factors must be considered to answer this question properly. Firstly, there are many prospective clinical studies, which evaluate zirconium and titanium abutments; however, they are often performed without proper control (Bragger et al. 2005; Vanlioglu et al. 2012; Cionca et al. 2015). Further, biological outcome measures, such as pocket probing depth, bleeding on probing, plaque accumulation, and others, must be assessed. Finally, the impact of Zr or a Ti abutment on the esthetic result of the treatment in terms of soft tissue color, objective esthetic indexes, and patient-reported viewpoint to the outcome needs evaluation as well. Therefore, the topic would greatly benefit from a systematic review and meta-analysis of the literature on direct comparison between zirconia and titanium in the same patient.

The objective of this review was to analyze the research, pertaining to the effect of zirconia and titanium as abutment materials on soft peri-implant tissues. The secondary goal was to recommend further research methodologies to obtain an in-depth understanding of the subject matter.

Material and Methods

Focused question

The key research question of this review was to define the effect of zirconia and titanium as abutment materials on soft peri-implant tissues. The topic was divided into 2 parts: (a) biology and (b) esthetics. Pocket probing depth (PPD), bleeding on probing (BOP), soft tissue recession (REC), marginal bone level (MBL), and biological complications were attributed to the biological section. Soft tissue color, patient-reported outcome, and objective esthetic indexes were selected to define the effect of Zr and Ti on the esthetic outcome.

Search strategy

A MEDLINE search (PubMed) was performed to find articles published in the English language up to and including December 2014. The following combination of search terms was used: "Dental Implants"[Mesh] AND" abutments" AND "titanium" AND "zirconia" AND "peri-implant health" AND "esthetics," "implant abutments" AND "ceramic" AND "clinical study" AND "clinical trial." Furthermore, the manual search included all full-text articles and other related reviews selected from the electronic search in the following journals: *Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, European Journal of Oral Implants, Implant Dentistry, International Journal of Oral and Maxillofacial Implants, International Journal of Periodontics and Restorative Dentistry, Journal of Oral and Maxillofacial Surgery, Journal of Clinical Periodontology, Journal of Periodontal Research, Journal of Periodontology*, and *European Journal of Oral Implantology*. The electronic search was complemented by manual searching in the bibliographies of the most recent systematic reviews, and all references of the included publications (Fig. 1).

Inclusion criteria

The criteria for the study inclusion were as follows:

- Clinical studies with direct comparison of Ti to Zr abutments in the same patient,
- Studies with at least 10 patients,
- Studies with a mean follow-up of at least 1 year, and
- Studies reporting on at least one of the outcome measures.

Exclusion criteria

Studies from which data on selected outcome variables could not directly be retrieved or calculated were not considered. Prospective uncontrolled clinical studies, retrospective clinical studies, RCTs with teeth as control, and systematic reviews were excluded. The list of excluded studies and the reason for exclusion are provided in Table 1.

Data extraction

Two reviewers (TL and JV) extracted relevant data from the selected articles independently, using a specially designed date extraction methodology. Any disagreement was resolved through discussion, leading to consensus. Meta-analysis was performed only if at least three papers on any outcome measure were similar enough to analyze.

Results

After application of the inclusion criteria, nine studies, which produced 11 papers (Sailer et al. 2009a; Zembic et al. 2009; Bressan et al. 2011; Hosseini et al. 2011; Hosseini et al. 2013; Lops et al. 2013; Zembic et al. 2013; de Alboroz

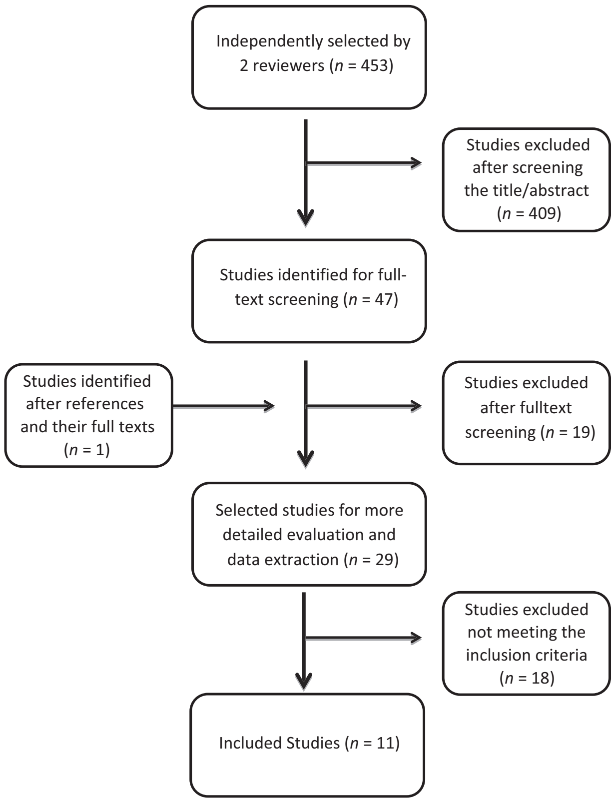

Fig. 1. Overview of the search strategy.

Table 1. **Studies excluded from this review**

Author (year)	Reasons of exclusion
van Brakel et al. (2011a,b)	3-month follow-up
van Brakel et al. (2014)	3-month follow-up
Sailer et al. (2009b)	Systematic review
Zembic et al. (2014b)	Systematic review
Glauser et al. (2004)	Teeth as control group
Zembic et al. (2014a)	Teeth as control group
Canullo (2007)	Teeth as control group
Passos et al. (2014)	No control titanium abutments, retrospective study
Ekfeldt et al. (2011)	No control titanium abutments, retrospective study
Vanlioglu et al. (2012)	No control titanium abutments
Payer et al. (2013)	No control titanium abutments
Happe et al. (2013)	No control titanium abutments
Cionca et al. (2015)	No control titanium abutments
Buchi et al. (2014)	No control titanium abutments
van Brakel et al. (2012)	No requested outcome measures
Nakamura et al. (2010)	Narrative review
Bollen et al. (1996)	Less than 10 patients

et al. 2014; Cosgarea et al. 2015; Lops et al. 2014; Payer et al. 2015), were selected for comprehensive review (Tables 2–4). All studies reported on customized Ti and Zr abutments, and one study also provided data on stock Zr and Ti abutments (Lops et al. 2014). Due to marked heterogeneity in the study design and quality of reported data, statistical meta-analysis was only feasible for peri-implant soft tissue color outcome measure. Hence, the report on other outcome measures is limited to an overall description in relation to the effect of zirconia and titanium as abutment materials on soft peri-implant tissues.

The effect of zirconia or titanium as abutment material on soft peri-implant tissues. Biology

Pocket probing depth

Pocket probing depth was recorded in three studies (five papers). Four papers measured PPD at four sites, while Albornoz et al. used six PPD sites. At 1-year follow-up, the mean PPD around Zr abutments ranged from 2.9 to 3.5 mm, while the mean PPD around Ti abutments was recorded to be exactly 3.3 mm (Sailer et al. 2009a; de Alboroz et al. 2014). In addition, an increase of 0.2 mm from baseline to 1-year follow-up around Zr abutments was recorded, while PPD around Ti abutments remained unchanged (de Alboroz et al. 2014). At 3-year follow-up, PPD around Zr abutments remained 3.2 ± 1.0 mm vs. 3.4 ± 0.5 mm at Ti sites (Zembic et al. 2009). Results after 5 years of service were provided by two studies. Zembic et al. (2013) showed a mean PPD around Zr abutments of 3.3 ± 0.6 mm with an increase of 0.4 mm from the baseline, while Ti abutments had 3.6 ± 1.1 mm with an increase of 0.5 mm from the baseline. Lops et al. (2013) reported 2.6 ± 0.5 mm at Zr abutments and 2.7 ± 0.4 mm at Ti sites. All included studies reported no significant differences between Zr and Ti abutments.

Bleeding on Probing

Five studies (seven papers) examined the bleeding on probing around Zr and Ti abutments. Three papers registered sulcus bleeding index (mBI), reporting mean values from 0 to 0.5 at Zr abutments and 0 to 0.4 at Ti abutments, with no significant differences between them (Hosseini et al. 2011; Hosseini et al. 2013; Lops et al. 2013). Four other papers scored BOP, assessed at four sites (mesial, buccal, distal, and oral) of the implants. Payer et al. (2015) evaluated two-piece zirconium implants with Zr abutments and titanium implants with Ti abutments. BOP was 9.1% ± 4.3 for Zr abutments and 7.4% ± 3.4 for titanium implants and abutments after 24 months, with no statistical difference. Similarly, BOP was found to be slightly higher at crowns supported by zirconia abutments than at those supported by titanium abutments after 1-year follow-up: Zr 60 ± 30% and Ti 30 ± 40%, however, without significant difference (Sailer et al. 2009a). Other papers showed no statistical differences on BOP around Ti and Zr abutments after 3-year (Zembic et al. 2009) and 5-year (Zembic et al. 2013) follow-up.

Marginal bone level

Six studies (7 papers: Zembic et al. 2009, Hosseini et al. 2011; Hosseini et al. 2013; Lops et al. 2013; Zembic et al. 2013; de Alboroz et al. 2014; Payer et al. 2015) reported on interproximal marginal bone-level changes. The bone loss was reported as absolute values and as the change. Mean marginal bone loss around Zr abutments was reported to vary from 0.4 ± 0.2 mm to 1.48 ± 1.05 mm and 0.5 ± 0.3 mm to 1.43 ± 0.67 mm at Ti abutments. Some of the papers presented separate mesial and distal values of bone loss. In every case, there was no significant statistical difference. Marginal bone loss data can be seen in Table 3.

Table 2. **The effect of zirconia and titanium on peri-implant tissues. Biology**

Author (Year) Study design	Patient N	Follow up	Zr abutment N	Ti abutment N	Pocket probing depth mean (SD)		Sulcus bleeding index Bleeding index mean (SD)			Recesion index Recesion mean (SD)			Biological complication	
					Zr	Ti		Zr	Ti		Zr	Ti	Zr	Ti
Hosseini et al. (2011) RCT	31	1 year	38	35			mBI	median 0	median 0				6	3
Sailer et al. (2009a) RCT	20	1 year	19	12	3.5 (0.7)	3.3 (0.6)	Bleeding on probing (BOP)	0.6 (0.3)	0.3 (0.4)					
Hosseini et al. (2013) CCT	59	3 years	52	21			mBI	median 0	median 0				3	0
Zembic et al. (2013) RCT	18	5 years	18	10	3.3 (0.6)	3.6 (1.1)	BOP	0.5 (0.3)	0.6 (0.3)	REC	0.1 (1)	0.3 (0.7)	2	1
Cosgarea et al. (2015) RCT	11		11	11										
Bressan et al. (2011) CCT	20		20	20										
Lops et al. (2014) CCT	72	2 years	33	39						REC	0.1 (0.3)	−0.3 (0.4)		
Zembic et al. (2009) RCT	22	3 years	18	10	3.2 (1)	3.4 (0.5)	BOP	0.4 (0.4)	0.2 (0.3)					
Payer et al. (2015) RCT	30	2 years	15	15			BOP	9.10% (4.34)	7.40% (3 .39)				1	0
Lops et al. (2013) CCT	81	5 years	36	45	2.6 (0.5)	2.7 (0.4)	mBI	0.5 (0.3)	0.4 (0.2)				0	1
de Alboroz et al. (2014) CCT	25	1 year	11	14	2.9 (0.5)	3.3 (0.8)				REC	0 (0)	0.04 (0.1)		

Biological complications

Biological complications were reported in five included studies. Hosseini et al. (2011) reported six biological incidents around Zr abutments (6/38) and three biological complications at Ti abutments (3/35) after 1-year follow-up, giving a 15.7% complication rate for Zr and 8.6% for Ti, respectively. Incidents at Zr sites consisted of one case of buccal marginal fistula, swelling, pain, and suppuration; three suppurations at probing; and three PPD more than 5 mm. The Ti group had three suppuration at probing with PPD > 5 mm.

Lops et al. (2013) registered 1 incidence of mucositis around Ti abutments, which was successfully treated with anti-inflammatory measures.

Hosseini et al. (2013) reported three fistulae at Zr abutments (3/52), making a 1.7% complication rate, while all Ti abutments were complication free after 3-year follow-up. Zembic et al. (2013) reported the loss of three implants in a 5-year follow-up study. Two implants were lost with Zr abutments (2/18, 88%) and one failed implant had a Ti abutment (1/10, 90%). Payer et al. (2015) reported the loss of 1 zirconia implant 8 months after placement (1/15), while no biological complications were registered in the titanium implant/abutment group.

In total, from 145 Zr abutments, 12 experienced biological incidents, and from 110 Ti abutments, five had biological complications. No significant differences were recorded.

Soft tissue recession

Peri-implant mucosa recession was registered in three studies. Zembic et al. (2013) evaluated the mean distance from the mucosal margin to the crown margin of restorations on zirconia and titanium abutments. Both the crown margins were located slightly submucosally after 5 years in service (0.1 mm for Zr and 0.3 mm for Ti); therefore, no significant difference was recorded.

Lops et al. (2014) looked at recession around stock and customized CAD/CAM Ti and Zr abutments. Authors determined buccal gingival margin modification at baseline and after 1- and 2-year follow-up by measuring calibrated photographs. After 2 years, the following results were obtained: Stock Zr abutments had 0.3 ± 0.3 mm, stock Ti 0.3 ± 0.4 mm, and CAD/CAM Zr 0.1 ± 0.3 mm of soft tissue recession. The CAD/CAM Ti group registered a soft tissue gain of 0.3 ± 0.4 mm. No significant differences were observed.

de Alboroz et al. (2014) studied 14 Ti abutments (control) and 11 Zr (test) for 1 year. The position of the gingival/mucosal margin was recorded with a periodontal probe from the incisal edge to the margin at the mesial, zenith, and distal sites. Data were recorded at baseline, and 1 month, and 12 months after delivery of restorations. At 1-year follow-up,

Table 3. **The effect of zirconia and titanium on peri-implant tissues. Esthetics**

Author (Year) Study design	Patient N	Follow-up	Zr abutment N	Ti abutment N	Aesthetic index Aesthetic index mean (SD)			Gingiva discoloration index Gingiva discoloration mean (SD)			Papilla index Papilla index mean (SD)	Mesially		Distally		Patient-reported esthetic outcome mean (SD)		
						Zr	Ti		Zr	Ti		Zr	Ti	Zr	Ti		Zr	Ti
Hosseini et al. (2011) RCT	31	1 year	38	34	Copenhagen Index Score (CIS)	9.3 (1.9)	9.1 (1.4)	Score (1–4)			Score (1–4)					Visual analog scale (VAS)	84.9 (18.4)	83.1 (18.8)
Sailer et al. (2009a) RCT	20	1 year	19	12				Spectrophotometric ΔE	8.1 (3.9)	7.8 (4.3)	Jemt papilla index	2.1	2.1	1.8	1.8			
Hosseini et al. (2013) CCT	59	3 years	52	21	CIS			Score (1–4)			Score (1–4)							
Zembic et al. (2013) RCT	18	5 years	18	10							Papilla height	2.3 (0.6)	2.2 (0.8)	2.1 (0.8)	1.9 (0.9)			
Cosgarea et al. (2015) RCT	11		11	11				Colorimeter ΔE	7.53* (2.39)	8.37* (2.76)								
Bressan et al. (2011) CCT	20		20	20				Spectrophotometer ΔE	8.5 (0.4)	11 (0.4)								
Lops et al. (2014) CCT	72	2 years	33	39														
Zembic et al. (2009) RCT	22	3 years	18	10				Spectrophotometric ΔE	9.3 (3.8)	6.8 (3.8)	Papilla height	2.4 (0.9)	2 (1.1)	1.6 (1.2)	1.5 (1)			
Payer et al. (2015) RCT	30	24 months	15	15	Pink esthetic score	11.22 (1.56)	10.75 (0.71)											
Lops et al. (2013) CCT	81	5 years	36	45														
de Alboroz et al. (2014) CCT	25	1 year	11	14	Implant Crown Aesthetic Index mucosa	5.4 (3)	6.7 (3.2)									VAS	8.5	8.5

Zr abutments had a gain of soft tissue equal to 0.2 mm in the marginal position at mesial sites and a recession of 0.3 mm at distal sites, while Ti abutments experienced a gain of 0.2 mm of soft tissue mesially and a loss of 0.4 mm of soft tissues distally. The changes were not relevant, and there were no statistically significant differences between the groups.

The effect of zirconia or titanium as abutment material on peri-implant soft tissues. Esthetics

Soft tissue color

Peri-implant mucosa color characteristics were evaluated in six papers, derived from five studies. Three studies were included into a meta-analysis (Zembic et al. 2009; Bressan et al. 2011; Cosgarea et al. 2015), while three reports were analyzed descriptively (Sailer et al. 2009a; Hosseini et al. 2011; Hosseini et al. 2013).

Cosgarea et al. (2015) evaluated the peri-implant soft tissues buccally around 11 Zr and 11 Ti abutments in 11 patients. Eleven teeth were used as additional controls for color matching. Zr–Ti implant tooth soft tissues were evaluated at three places: 1, 2, and 3 mm away from the gingival margin. The peri-implant soft tissue around zirconia demonstrated a better color match to the soft tissue at natural teeth than titanium. Bressan et al. (2011) reported an ΔE values of 11 ± 0.4 for Ti abutments, while for Zr value was 8.5 ± 0.4, and this difference was statistically significant. In contrast, a 3-year follow-up study did not find any statistical differences between both materials in resembling natural soft tissue color (Zembic et al. 2009).

A meta-analysis showed that the overall value for Zr abutments was 8.48; SE 0.39, 95% confidence interval ranged from 7.71 to 9.24, while Ti showed 10.88; SE 0.39, 95% confidence interval from 10.11 to 11.64. The difference was statistically significant.

Hosseini et al. (2011) used a mucosal discoloration score to evaluate the optical outcome of Zr and Ti abutments, where score 1 means "no discoloration," score 2, "light greyish discoloration"; score 3, "distinct greyish discoloration"; and score 4, "metal (zirconia) visible." At 1-year follow-up, 76.3% of Zr and 70.3% of Ti abutment restorations scored 1; 18.4% of Zr and 27% of Ti abutments were evaluated as score 2; 5.3% of Zr and 2.7% of Ti had score 3, while none of the abutments were evaluated as score 4. No statistically significant changes were recorded.

Another study used the same scoring index and evaluated 52 Zr and 21 Ti abutments

Table 4. **Marginal bone levels in included studies**

Author (year) Study design	Patient N	Follow up	Zr abutment N	Ti abutment N	Marginal bone-level loss measuring method	Method standardization	Baseline marginal bone-level mean (SD) mm: Zr	Zr Mesially	Zr Distally	Ti	Ti Mesially	Ti Distally	Examined marginal bone level mean (SD) mm: Zr	Zr Mesially	Zr Distally	Ti	Ti Mesially	Ti Distally	Marginal bone loss mean (SD) mm: Zr	Ti
Hosseini et al. (2011) RCT	31	1 year	38	34	Periapical	Digital Holders	0.58 (0.62)			0.33 (0.33)			0.66 (0.68)			0.43 (0.36)			0.08 (0.25)	0.1 (0.17)
Sailer et al. (2009a) RCT	20	1 year	19	12	Orthoradial Ro															
Hosseini et al. (2013) CCT	59	3 years	52	21	Periapical Ro	Parallel Holders							0.6 (0.7)			0.36 (0.35)			0.15 (0.25)	0.18 (0.29)
Zembic et al. (2013) RCT	18	5 years	18	10	Orthoradial Ro			1.5 (0.7)	1.5 (0.9)		2 (0.7)	2 (0.7)		1.8 (0.5)	2 (0.8)		2 (0.8)	1.9 (0.8)		
Cosgarea et al. (2015) RCT	11		11	11																
Bressan et al. (2011) CCT	20		20	20																
Lops et al. (2014) CCT	72	2 years	33	39																
Zembic et al. (2009) RCT	22	3 years	18	10	Periapical Ro	Parallel		1.5 (0.7)	1.5 (0.9)		2 (0.7)	2 (0.7)		1.7 (1)	1.6 (1)		2 (1)	2.1 (1)		
Payer et al. (2015) RCT	30	24 months	15	15	Periapical Ro	Digital	0.1 (0.19)			0.16 (0.24)			1.48 (1.05)			1.43 (0.67)				
Lops et al. (2013) CCT	81	5 years	36	45	Periapical Ro		0.1 (0.1)			0.2 (0.1)			0.4 (0.2)			0.5 (0.3)				
de Alboroz et al. (2014) CCT	25	1 year	11	14	Periapical Ro	Parallel Individualized tooth positioner	1.6 (0.11)			1.52 (0.21)									0.06 (0.07)	0.45 (0.02)

after 3 years in service. Zirconia abutments scored following marks: 1 (67%), 2 (20%), 3 (13%), and 4 (0%). Titanium abutments were evaluated as 1 (52%), 2 (43%), 3 (5%), and 4 (0%). No statistically relevant differences were recorded (Hosseini et al. 2013). Sailer et al. (2009a) reported ΔE values of 8.1 ± 3.9 for Zr and 7.8 ± 4.3 for Ti abutments with no significance.

Patient-reported outcome

The patient-reported outcome of Zr and Ti abutments was available in two studies. The outcome was assessed on a visual analog scale (VAS), benchmarked at "very bad esthetic" on the left and "very good esthetic" on the right. Hosseini et al. (2011) reported VAS scores for Zr and Ti restorations (Zr: mean 84.9, SD 18.4; Ti: mean 83.1, SD 18.8; $P = 0.92$). Another study reported VAS to be 8.5 of 10 points for both Zr and Ti abutment restorations (de Alboroz et al. 2014). Again no statistical differences were observed.

Esthetic indexes (PES, CIS, ICAI, and PI)

Various objective esthetic indexes were used to report on the outcome of a treatment with Zr or Ti abutments. In two studies, the professional-reported esthetic outcome of the restorations was evaluated using the Copenhagen Index Score (CIS) (Hosseini et al. 2011, 2013). According to this index, the score ranged from one for the best to four for the poorest esthetic outcome. Five variables were used in this study: crown morphology score, crown color match score, mucosal discoloration score, papilla index score mesially, and papilla index score distally. The overall professional-reported esthetic outcome was not significantly different between the Zr abutment- and Ti abutment-based restorations after 1 year (Zr: mean 9.3, SD 1.9; Ti: mean 9.1, SD 1.4; $P = 0.705$). Hosseini et al. (2013) reported no significant difference in overall professional-reported esthetic between Zr abutment-based restorations (Zr, $n = 52$, mean 8.0, SD 1.8) and Ti abutment-based restorations (Ti, $n = 34$, mean 8.2, SD 1.8). Payer et al. 2015 used the pink esthetic score (PES) for an objective evaluation of Zr and Ti abutments. The mean PESs for zirconia implants were 11.0 ± 2.0 after 12 months and 11.22 ± 1.56 after 24 months. For titanium implants, the clinical evaluations revealed 9.0 ± 3.54 after 12 months and 10.75 ± 0.71 after 24 months showing a significant difference ($P = 0.004$) between zirconia and titanium implants. The other included study used the Implant Crown Aesthetic Index (ICAI) for evaluation of the esthetic outcome. Using the ICAI, the scoring at baseline and 1 year was 7.9 and 7.6 for the test group and 10.6 and 11.3 for the control group, respectively. It was concluded that there was no difference between both abutments (de Alboroz et al. 2014).

Papilla index (PI) by Jemt (1977) was elegantly measured in a randomized controlled clinical trial with the same patient cohort. After 1-year the mean papilla height around Zr abutments was 2.1 mesially and 1.8 mm distally, and Ti abutments scored the same (Sailer et al. 2009a). After 3 years, Zr scored 2.3 ± 0.6 mm mesially and 2.1 ± 0.8 mm distally, while Ti showed 2.2 ± 0.8 mm mesially and 1.9 ± 0.9 mm distally (Zembic et al. 2009). Five-year results were as follows: Zr 2.4 ± 0.9 mm mesially and 1.6 ± 1.2 mm distally, and Ti 2.0 ± 1.1 mm mesially and 1.5 ± 1.1 mm distally. No significant differences were reported (Zembic et al. 2013).

Discussion

The aim of this review was to thoroughly evaluate the influence of zirconium and titanium abutments on the condition of the peri-implant mucosa. The researchers focused on biology and esthetics in their analysis. The authors made a decision to exclude studies in which both types of abutments were not compared in one and the same patient. As a result, some well-designed prospective clinical studies with the follow-up from 4 to 11 years were excluded (Glauser et al. 2004, Zembic et al. 2014b). This choice can be debated; however, uncontrolled prospective clinical trials harbor unavoidable patient bias. As a consequence, the longest follow-up studies included into this review were 5 years long (Zembic et al. 2013; Lops et al. 2014). In general, the results have demonstrated only minor statistically significant differences between both materials. A similar conclusion was drawn in a preceding evidence-based review, which evaluated the effect of both materials on crestal bone stability (Linkevicius & Apse 2008). It was stated that based on animal, human histological, and clinical studies, Zr and Ti abutments showed no difference in effect on bone levels.

This systematic review and meta-analysis clearly demonstrate that zirconia is significantly more favorable material to soft tissue appearance that titanium. However, it is well known in the literature that vestibular soft tissue thickness is a cofounding factor in the appearance. It has been established that if tissue thickness is 3 mm, human eye can no longer detect the differences between both materials (Jung et al. 2007). It can be concluded that zirconium abutments create a better color impression, than titanium abutments; however, the difference can be appreciated only in thin soft tissue biotype.

This current systematic review shows no significant differences in effect of zirconium and titanium as abutment materials on pocket probing depths. However, it is interesting to note that one of the excluded studies (due to a short 3-month observation period) by van Brakel et al. (2011a,b) showed significantly lower PPD around Zr abutments, compared to Ti ones. This study provided detailed description of the surface roughness of both types of abutments (Ra-values 210–236 nm). Recent *in vitro* studies have shown that the roughness of the material is very important in the behavior of cells on Zr or Ti. It was found that polished Zr surfaces provide better adhesion for epithelial cells, compared to Ti (Nothdurft et al. 2014). It could be speculated that better adherence of the cells to the abutments might reduce PPD around implants; however, this hypothesis needs to be tested. Consequently, the reports of abutment surface roughness in the studies would be very useful.

Some of the included trials used subgingival position of the cementation margin, which could be considered as a setback in the study design. It is clear that if the restoration margin extended deeper subgingivally, peri-implant tissues at the gingival perimeter would contact material of the restoration, usually feldspathic ceramics, instead of the material of the abutment. This, in turn, may influence PPD, accumulation of the plaque, and other biological parameters. Pocket probing depths more than 5 mm were registered in both studies, which had cement line location 1–1.5 mm below gingival line (Hosseini et al. 2011, 2013). This means that the peri-implant sulcus was intruded by dental porcelain at least 1 mm or more. Therefore, future studies may consider avoiding subgingival margins of the abutments, when testing the material's effect on peri-implant mucosa.

The review did not include assessment of plaque accumulation between Zr and Ti abutments, although plaque index is a common parameter to reflect peri-implant health. This decision was made because abutments were not exposed to oral environment in the selected studies. It means that plaque accumulation is rather related to patients' brushing activities than to restoration material. However, it should be mentioned that Scarano et al. (2004) showed significantly increased accumulation of plaque on titanium disks, compared to zirconium ones, placed in oral cavities of 10 patients. Significantly higher levels of bacterial loads around healing cap-like Ti abutments were reported, when compared to same design Zr abutments after 3 months as well (van Brakel et al. 2014). The influence of abutment material on plaque accumulation could be better evaluated if titanium or zirconium would be exposed to oral cavity.

Biological complications were not frequent in the included studies. The most robust number of biological incidents was recorded in two studies (Hosseini et al. 2011, 2013). Interestingly, the highest amount of biological complications was fistulas, which are commonly caused by cement excess (Gapski et al. 2008; Wilson 2009). The design of the abutments explains this finding., The crown margins were located 1–1.5 mm submucosally at the visible regions and <1 mm submucosally at nonvisible regions. Restorations on Zr abutments were cemented with resin luting agent. It can be speculated that biological complications were due to cement remnants. It has been shown that subgingival margins 1–1.5 mm preclude complete removal of cement remnants even with customized abutments (Linkevicius et al. 2011). In addition, resin cement is the most difficult to remove from abutments (Agar et al. 1997). Therefore, it is safe to assume that these complications are abutment design and cementation agent dependent, and not related to the abutment material. Undetected cement remnants were identified as a possible reason for implant loss in one of the included reports (Zembic et al. 2013). The study revealed those all-ceramic crowns were cemented on zirconium abutments with resin cement, whose poor cleansability features have already been stated. Again, the supragingival or epigingival margins of abutments are advocated, especially if implant restorations are to be cemented with resin luting agent.

Soft tissue recession was not influenced by the selection of the abutment material. It seems that there are more important factors, such as the 3D position of the implant and the presence/absence of attached mucosa, which influence the risk for of recessions. Interestingly, recession scores were lower around implants, compared to teeth.

The esthetic outcome was reported by different indexes: PES, CIS, ICAI, and PI. This demonstrates the complexity of the esthetic assessment, making the meta-analysis of the data impossible. The PES was originally proposed by Furhauser et al. (2005). It is comprised of five factors, namely mesial papilla, distal papilla, curvature of the facial mucosa, level of the facial mucosa, and root convexity/ soft tissue color and texture at the facial aspect of the implant site. This index, used by Payer et al. (2015), is considered an objective outcome measure of peri-implant soft tissue treatment. Interestingly, this study showed that PES around Zr abutments was significantly higher compared to Ti abutments at 2-year follow-up. It is important to note here that two-piece Zr and Ti implants were compared. Other indexes (CIS and ICAI) used in other studies included evaluation of laboratory parameters of the restoration, such as matching color, shape, and texture, which can influence the overall final score. This might be the reason, why these indexes did not report any significant differences in the esthetic outcome between Zr and Ti abutments. The PES index should be used for the evaluation of the final esthetic outcome, because it reflects the soft tissue condition better.

Future research should focus on improving study methodology in this field of implant dentistry. Researchers should report the surface roughness of abutments, because this might be the key factor in the change of probing depths. In addition, if supracrestal cementation margins were used, it would ensure the soft tissues sole contact with abutment, without cement and crown material interference with soft peri-implant tissues.

Conclusions

It can be concluded that the up-to-date research on the direct comparison in the same patient does not give a clear preference for the use of zirconia or titanium as abutment materials in relation to soft peri-implant tissue response. A meta-analysis showed statistically significant superiority of Zr abutments over Ti abutments in developing natural soft tissue color. Consequently, zirconium might be preferable in case of thin buccal soft tissues. Qualitative analysis of the data showed that superior esthetic outcome of Zr abutment over Ti measured by PES score.

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