JOURNAL OF OSSEOINTEGRATION
periodontics and prosthodontics

The biological complication of implant abutment materials. A systematic review and meta-analysis

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TO CITE THIS ARTICLE
Mokhtar MA, Elnagar G, Saleh M, Radwan MM. The biological complication of implant abutment materials. A systematic review and meta-analysis. J Osseointegr 2018;10(1):23-30.

DOI 10.23805 /JO.2018.10.01.04

KEYWORDS Implant abutments, Pocket depth, Recession, Crestal bone loss, Titanium, Zirconia.

ABSTRACT

Aim The goal of this review was to identify the biological complication of implant abutment materials in relation to alveolar bone around implant-supported superstructure.

Methodology An electronic database search and a further manual search were directed to select RCTs, and cohort studies that give evidence about different abutment materials complication. Pocket depth, amount of rescission and crestal bone loss were attributed to alveolar bone loss.

Results Fourteen clinical studies were selected from an initial search of 107 studies and the extraction of the analysis data were tabled according to complication output. Pocket probing depth were documented in eight studies, PPD around Zirconium implant abutments was 3.2 mm versus 3.4 mm for Titanium abutments. Five studies examined the recession index for Zirconium and Titanium implant abutments. The RI ranged from 0 to 0.4 at Titanium implant abutments and 0 to 0.3 at Zirconium implant abutments. Alveolar bone loss around Zirconia abutments was reported to differ from 0.2-1.48 mm and 0.3-1.43mm at Titanium abutments.

Conclusion The data reported in this systematic review did not give an evidence for the complication regarding all ceramic versus metallic implant abutment. However, it can be concluded that the assessment of the randomized clinical trials did not provide an absolute decision for the choice of ceramic or metallic as implant abutment material in relation to alveolar bone response. The meta-analysis presented a statistically significant difference between abutment material with superiority for the all ceramic abutments over metallic abutment providing a favorable response of Marginal Bone Loss, but non-statistically significant regarding Pocket Probing Depth and Recession Index of soft tissue.

INTRODUCTION

Implant supported restorations are presently an expectable method, which, in some cases is chosen to more conventional substitutes to removable or fixed prostheses (1). Polycrystalline ceramics alumina or zirconia abutment were used in high esthetic region as an ancillary for metallic abutment (2). In a recent clinical study, in different esthetic situations the zirconium abutment showed high documented performance over titanium abutments (3). Brittleness is still the limitation of ceramic materials (4). This property decreases the resistance to tensile forces. The all ceramic material has high tensile forces which increase the fracture risk of the material during function. Whether the fracture toughness of the ceramic is the main cause of fracture (5), zirconia shows the uppermost fracture toughness among all dental ceramics (1). Clinical studies show that supported prosthesis either on teeth supported or on implants supported can be constructed from zirconium frameworks, given its high clinical performance on function. In the esthetic area after four years of follow up, zirconium implant abutments show no evidence of fractures (6,7). On the other side, the alumina abutments after 1 year shows 7% fracture of the alumina abutment (8).

Peri-implant alveolar bone loss is determined through routine radiographs and is defined as a localized inflammatory lesion relating to alveolar bone loss around a completely osseointegrated implant-supported restoration (9). After at least 10 years of functional loading, many studies have been published (2000–2017) observing survival rates of implant supported restorations and concluded that the mean survival rate ranged from 87% to 96%. Implant supported restoration are overwhelmed with biological

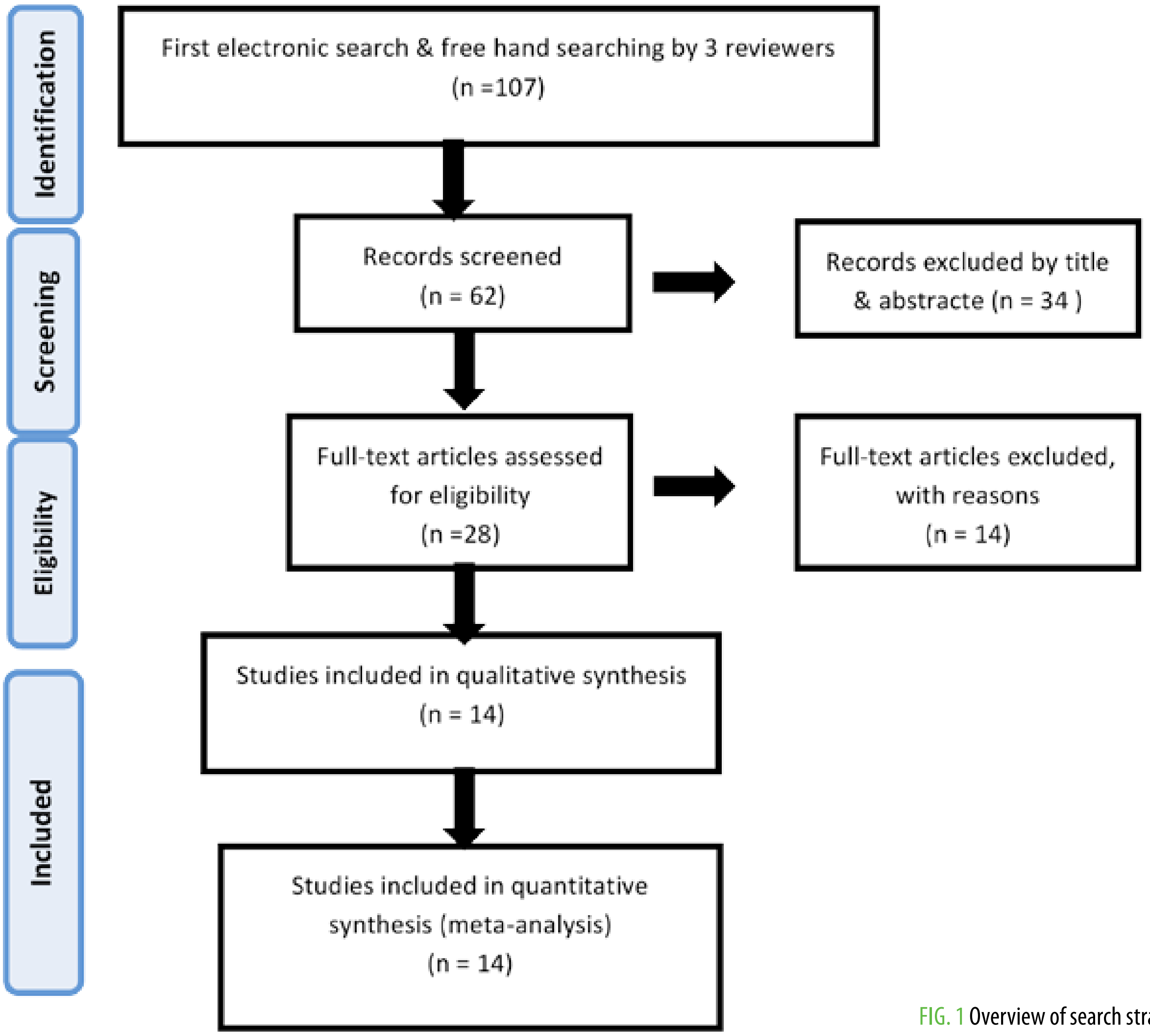

FIG. 1 Overview of search strategy.

and mechanical complications despite having high long-term survival rates (10). The cause of crestal bone loss may be due to mechanical or biological factors. The common mechanical complications result from poor prosthetic design, insufficient number of implants, size and position of implant fixture and parafunctional habits of patients such as occlusal overloading (11). The clinical drawbacks of inaccurate implant supported restoration range from fractures of abutment screws, prostheses losing, implant fracture and periimplant "marginal bone loss". The main biological cause of alveolar bone loss is microbial pathogens in dental plaque (12).

AIM OF RESEARCH

The goal of this review was to detect the complication of different abutment (all ceramic and metallic) materials of the implant supported restoration regarding biological complication.

METHODS

Criteria of studies

1 Article types

All randomized controlled trials (RCTs) and cohort studies estimating the effect of different types of implant abutment (metallic or all ceramic) on alveolar bone loss of implant-supported superstructure.

2 The participants

People having implant-supported restoration affected by bone loss.

3 The interventions

All types of implant abutment (metallic or all ceramic abutments).

4 Outcomes

Alveolar bone loss, signs attributing for alveolar bone loss

- Radiographic by intraoral radiographs.
- Pocket depth (PD).
- Soft tissue recession (REC).

Search methods for identification of studies

Electronic databases searched

The resulting inclusion criteria (Table 1) were obligatory to: complication of implant supported restoration (biological complication), articles published in English. Case report, case study, in vitro study, article in press and animal studies articles were excluded (Table 2).

In order to identify the research question, the PubMed database, the Cochrane and Ovid databases were searched electronically. Databases were searched for articles from 2000 through October 2017 using the next (MeSH) terms: (a) dental abutment (b) implants abutment (c) zirconia abutment (d) all ceramic abutment (e) metallic abutment (f) titanium abutment (g) periodontal loss (h) periodontal pocket (i) periodontal pocket index (j) alveolar bone loss (k) rescission and the combinations. Other applicable non-MeSH words were used in the search to recognize articles showing periodontal inflammatory parameters. These included "yttria-stabilized zirconia abutment" "zirconia implant abutment" "inflammation implant abutment" "bleeding index implant abutment" and "peri-implant pocket" and "clinical attachment loss around implant abutment". The studies collected after the described protocol (Fig. 1) were assessed by 3 authors (MM, JE, MA). The studies full texts were read by authors (MM, MS, JE) and independently assessed according to the inclusion criteria. For more deep knowledge hand search was done in the reference lists studies included during primary research. The contents of some nominated journals were independently searched by 2 authors (MM, JE) for related studies available up to october 2017. This was performed to detect any studies which may be lost in the earlier step. The included studies were checked among the all authors for any divergence.

Inclusion criteria
Clinical studies compare all ceramic to metallic abutments
Studies of 10 sample size at least
Studies at least show one of the outcome.
Studies in English

TABLE 1 Inclusion criteria.

Exclusion criteria
Uncontrolled randomized clinical trial
Studies of retrospective clinical trial
Randomized clinical trial using teeth as control group
Review (systematic or ordinary)
Experimental (animal) studies
Case-reports
Unpublished articles

TABLE 2 Exclusion criteria.

Author /year	Reason for exclusion
Belser et al. 2004	Review article
Bragger et al.2005	Titanium abutment only
Buchi et al. 2014	Zirconia abutment only
Canullo et al.2007	Zirconia abutment only
De boever et al 2006	Titanium abutment only
Ekfeldt et al.2011	Zirconia abutment only
Glauser et al. 2004	Zirconia abutment only
Muche et al.2003	Titanium abutment only
Nakamura et al. 2010	Zirconia abutment only
Passos et al.2014	Zirconia abutment only
Pjetursson, et al 2004	Systematic review
Sailer et al. 2009	Systematic review
Vigolo et al. 2006	Metallic abutment only
Zembic et al. (2014a)	Teeth as control group

TABLE 3 Studies excluded from this review.

Data collection and analysis

1 Study selection

The 107 articles were screened independently by two reviewers (MM, JE) through titles and abstracts. In case articles met the inclusion criteria and had no sufficient data to take optimum choice, the full text was gotten. The full reports that were collected from the different electronic and hand searches were checked independently by two authors (MM, MA) to get an absolute decision on whether these articles met the inclusion criteria or not.

Disagreements were resolved among authors by open discussion; a third review author (MS) was consulted when firmness was not possible; 14 studies meet the inclusion criteria, data extraction were done under constant protocol. Studies rejected at this stage or following stages were collected. A table for the excluded studies and the reasons for exclusion was reported (Table 3).

2 Data extraction

Independently using constant designed data extraction forms, fourteen studies underwent data extraction by two review authors (MM, JE). Data extraction were shown and modified on several papers before agreement to use. Any disagreements among authors were debated in open discussion and a review author (MS) was consulted. Data of disagreement were excluded until clarification was presented.

For each study, the extracted data were listed as follows (Table 4).

- Year of publication.
- The participants (No., Gender, Age).
- The type of intervention (No., Types).

• The outcomes reported (No., Assessment method).

3 Missing data protocol

Efforts was done to regain missing data from trials authors and if cross-sectional data were accessible. Change data could be done, the standard deviation "SD" of the changes was to be assessed using the no. within patient correlation, which would give information to the conservative estimate of the SD for change. This technique was described by Follmann (13). To guess the standard error of the difference for split mouth studies, when the proper data were not accessible and could not be found.

4 Heterogeneity assessment

Cochran's test for heterogeneity was used to assess the significance of any differences. Heterogeneity would have been considered significant if P <0.1. All 14 included studies results were pooled using the random model effect as statistical heterogeneity among studies was significant where I4 = 93% (P <0.00001).

RESULTS

After inclusion criteria regulation, fourteen studies were selected, including studies testing customized metallic and all ceramic abutments and also provided data on standard all ceramic and metallic abutments (14-17). All included studies reported a well-defined period of follow-up.

Meta-analysis

Results of the outcome of all ceramic and metallic abutments on radiographic marginal bone loss (MBL)

Marginal bone level 14 studies (Table 4) reported on interproximal marginal bone-loss. Mean bone loss differ from 0.2-0.4 mm to 1.05-1.48 mm for zirconia abutments and 0.3-0.5 mm to 0.67-1.43 mm for titanium abutments. Distal and mesial marginal bone loss was stated by some papers. The meta-analysis was done to evaluate the same intervention and outcomes for the fourteen included studies. The mean difference for the unceasing outcome (MBL) was used, using a software program of random effect model (RevMan 5.3, 2014).

Assessment of heterogeneity

Any discrepancies in the treatment effects estimation from the different RCTs were evaluated by means of Cochrans test for heterogeneity, which were considered significant if P < 0.1. The 14 statistics, which describes the percentage of the total difference across the trials that is due to heterogeneity other than chance, will

Study	Year	Study design	No.of patient	Follow up	Total no. of abutment	Titanium abutment	All ceramic abutment	"bone loss mean (SD)mm"
Andersson et al.	2001	RCT	15	1y-3y	69	35	34	NA
Andersson et al.	2003	RCT	32	5y	103	50	53	0.3 (0.2)mm ceramic and 0.4 (0.3)mm titanium
Zembic et al.	2009	RCT	22	3y	28	10	18	NA
Sailer et al	2009	RCT	20	1y	31	12	19	NA
Ralph et al.	2010	RCT	20	3m	40	20	20	1.7 (0.7)mm ceramic and 2.2 (0.8) mm titanium
Hosseini et al.	2011	RCT	31	1y	72	34	38	0.08 (0.17) mm ceramic and (0.25)0.1 mm titanium
Zembic et al.	2013	RCT	18	5y	28	10	18	0.5 (0.5) mm ceramic and 0.8 (0.7) mm titanium
Hosseini et al.	2013	CCT	59	3y	73	21	52	0.15 (0.25) mm ceramic and 0.18(0.29) mm titanium
Lops et al.	2013	CCT	81	5y	81	45	36	0.4 (0.1) mm ceramic and 0.5(0.1) mm titanium
de Alboroz et al.	2014	CCT	25	1y	25	14	11	0.06 (0.07) mm ceramic and 0.45(0.02)mm titanium
Lops et al.	2015	PCT	72	2y	72	39	33	0.1 (0.1) mm ceramic and 0.3(0.2)mm titanium
Payer et al.	2015	RCT	30	2Y	30	15	15	0.1 (0.19) mm ceramic and 0.16 (0.24) mm titanium
Nascimento et al.	2016	RCT	20	6m	20	10	10	0.92 (0.36) mm ceramic and 1.25(0.27)mm titanium
Yogesh et al.	2017	RCT	12	1y	12	12	12	0.5 (0.50) mm ceramic and 1.53(0.53)mm titanium

TABLE 4 Effect of bone loss in the included stydies.

Study	Year	Follow up	Total no. of abutment	Titanium abutment	All ceramic abutment	Bone level loss measuring method	Recession index		Pocket depth	
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Andersson et al.	2001	1y-3y	69	35	34	periapical	0.3	0.4		
Andersson et al.	2003	5y	103	50	53	Periodontal probe				
Zembic et al.	2009	3y	28	10	18	Periapical			3.2 (1)	3.4 (0.5)
Sailer etal	2009	1y	31	12	19	Orthoradial Ro			3.5 (0.7)	3.3 (0.6)
Ralph et al.	2010	3m	40	20	20	Periodontal probe	2.7 (0.6)	2.6 (1)	1.7 (0.7)	2.2 (0.8)
Hosseini et al.	2011	1y	72	34	38	Periapical				
Zembic et al.	2013	5y	28	10	18	Orthoradial Ro	0.1 (1)	0.3 (0.7)	3.3 (0.6)	3.6 (1.1)
Hosseini et al.	2013	3y	73	21	52	periapical				
Lops et al.	2013	5y	81	45	36	Periapical			2.6 (0.5)	2.7 (0.4)
de Alboroz et al.	2014	1y	25	14	11	Periapical	REC 0 (0	0.04 (0.1	2.9 (0.5	3.3 (0.8)
Lops et al.	2014	2y	72	39	33	Periapical	0.1 (0.3)	0.3 (0.4)		
Payer et al.	2015	2Y	30	15	15	Periapical				
Nascimento et al.	2016	6m	RCT	10	10	Periodontal probe	0.16 ± 0.42	0.27± 0.60	2.12 ±0.70	2.05± 0.87
Yogesh et al.	2017	1y	RPS	12		periapical			3.29 ±0.50	3.38 ±0.53

TABLE 5 The effect of zirconia and titanium on biological complication.

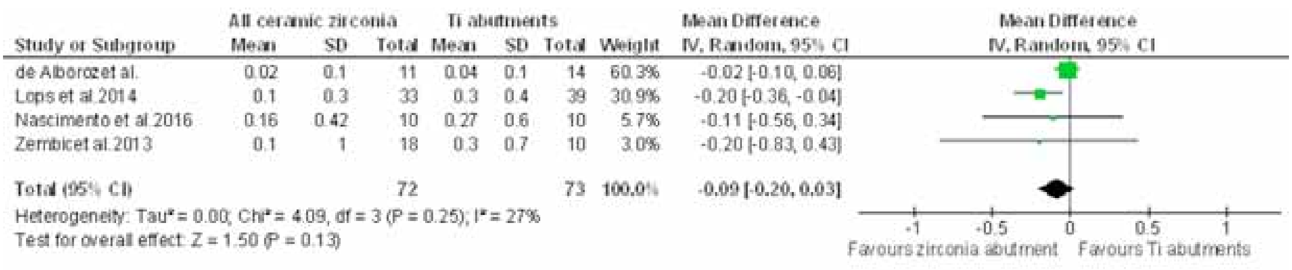

FIG. 2 Forest plot of comparison implants all ceramic zirconia abutments versus Ti abutments, outcome: Marginal BoneLoss (mm)

be used to compute heterogeneity with 14 over 50% being considered moderate to high heterogeneity. All 10 included studies results were pooled using the random model effect as statistical heterogeneity among studies was significance where (I4 = 93% P <0.00001). The mean difference of MBL which used in this meta-analysis the mean difference of marginal bone loss between all ceramic and titanium abutments for all pooled results were -0.20 (–0.32-0.08) with 95% confidence interval. This overall estimate is statistically significant with P < 0.0009. The meta-analysis was done for the continuous outcome with random effect model (Fig. 2).

Results of the effect of metallic and nonmetallic implant abutment on Pocket Probing Depth (PPD)

Eight studies recorded the pocket probing depth. Albornoz et al. (12) measured pPPD at six sites while the other seven papers measured it at four sites. After one-year follow-up (12, 15) the mean pocket depth around Titanium abutments was 3.3 mm while mean pocket depth around all ceramic zirconia abutments ranged from 2.90 to 3.50 mm. De Alboroz et al. (12) reported that after one-year of follow-up an increase of 0.2 mm from baseline was recorded around Zirconia abutments, while pocket probing depth around Titanium abutments

Study or Subgroup	All ceramic zirconia Mean	SD	Total	Ti abutments Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Andersson et al.2003	0.3	0.2	53	0.4	0.3	50	11.9%	-0.10 [-0.20, -0.00]
de Alborozet al.	0.06	0.07	11	0.45	0.02	14	12.8%	-0.39 [-0.43, -0.35]
Hosseiniet al.2011	0.08	0.17	38	0.1	0.25	34	11.9%	-0.02 [-0.12, 0.08]
Hosseiniet al.2013	0.15	0.25	52	0.18	0.29	21	11.0%	-0.03 [-0.17, 0.11]
Lops et al.2013	0.4	0.1	36	0.5	0.1	45	12.8%	-0.10 [-0.14, -0.06]
Lops et al.2014	0.1	0.1	33	0.3	0.2	39	12.4%	-0.20 [-0.27, -0.13]
Nascimento et al.2016	0.92	0.36	10	1.25	0.27	10	7.6%	-0.33 [-0.61, -0.05]
Payer et al.2015	0.1	0.19	15	0.16	0.24	15	10.6%	-0.06 [-0.21, 0.09]
Yogesh et al.2017	0.5	0.5	12	1.53	0.53	12	5.1%	-1.03 [-1.44, -0.62]
Zembicet al.2013	0.5	0.5	18	0.8	0.7	10	4.0%	-0.30 [-0.79, 0.19]
Total (95% CI)			**278**			**250**	**100.0%**	**-0.20 [-0.32, -0.08]**

Heterogeneity: Tau² = 0.03; Chi² = 137.11, df = 9 (P < 0.00001); I² = 93%
Test for overall effect: Z = 3.31 (P = 0.0009)

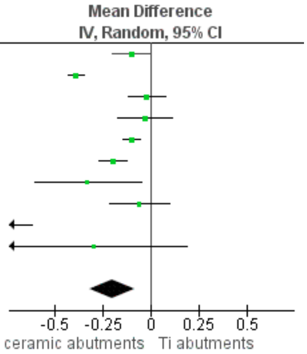

FIG. 3 Forest plot of comparison implants all ceramic zirconia abutments versus Titanium abutments, outcome: Pocket Probing Depth (mm).

Study or Subgroup	All ceramic abutments Mean	SD	Total	Ti abutments Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
de Alborozet al.	2.9	0.5	11	3.3	0.8	14	8.2%	-0.40 [-0.91, 0.11]
Lops et al.2013	2.6	0.5	36	2.7	0.4	45	53.5%	-0.10 [-0.30, 0.10]
Nascimento et al.2016	2.12	0.7	10	2.05	0.87	10	4.5%	0.07 [-0.62, 0.76]
Sailer et al 2009	3.5	0.7	19	3.3	0.6	12	10.1%	0.20 [-0.26, 0.66]
Yogesh et al.2017	3.29	0.5	12	3.38	0.53	12	12.7%	-0.09 [-0.50, 0.32]
Zembicet al.2009	3.2	1	18	3.4	0.5	10	7.0%	-0.20 [-0.76, 0.36]
Zembicet al.2013	3.3	0.6	18	3.6	1.1	10	4.0%	-0.30 [-1.04, 0.44]
Total (95% CI)			**124**			**113**	**100.0%**	**-0.10 [-0.25, 0.05]**

Heterogeneity: Tau² = 0.00; Chi² = 3.57, df = 6 (P = 0.73); I² = 0%
Test for overall effect: Z = 1.34 (P = 0.18)

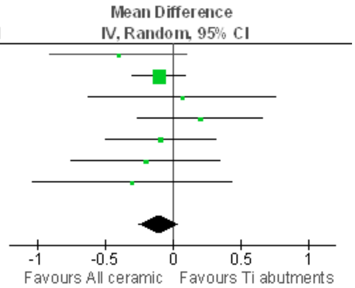

FIG. 4 Forest plot of comparison implants all ceramic zirconia abutments versus Titanium abutments, outcome: Recession Index (mm).

remained unaffected. Recently (16) the mean pocket depth around Zirconia abutments was 3.38 mm, while the mean pocket depth around metallic abutments was 3.3 mm (16). After 3-year follow-up, zirconia abutment showed pocket probing depth of 3.2 mm versus 3.4 mm at the sites of titanium abutment (18). The survival rate after 5 years was applied by two studies. Zembic et al. (19) stated that the mean pocket a probing depth around Zirconia abutments of 3.3 mm with an upsurge of 0.4 mm from the baseline, while Titanium abutments had 3.6 mm with an upsurge of 0.5 mm from the baseline. Lops et al. (10) reported 2.6 mm for Zirconia abutments and 2.7 mm for Titanium sites. All included studies informed no significant differences between Zirconia and Titanium abutments. The pocket probing depth mean difference used in this meta-analysis were -0.10 (-0.25-0.05) with 95% confidence interval. This overall evaluation is statistically non-significant with P = 0.18. The meta-analysis with random effect model was made for the continuous outcome (Fig. 3).

Results of the effect of metallic and non metallic implant abutment on rescission index

Examination of rescission index around Zirconia and Titanium abutments was reported in four studies. showing mean values ranging from 0 to 0.3 at Zirconia abutments and 0 to 0.4 at Titanium abutments, after 6 months the mean of recession index around Zirconia abutment was 0.16 while for titanium abutment was 0.27 (15). At the 1 year follow up the mean of recession index around Zirconia abutments was 0 while for titanium abutment was 0.04 (12), furthermore increasing recession was reported after 2 year follow up for Zirconia, range from 0.3, and was 0.4 for titanium abutments (10); additionally the mean of recession index around Zirconia abutments ranged from 0.1-0.3 whereas for titanium abutment was from 0.3- 0.4 after 3 and 5 years of follow up (8, 11) with no significant differences.

The mean difference of rescission index was -0.09 (-0.20-0.03) with 95% confidence interval. This overall estimate is statistically non-significant with P = 0.13. The meta-analysis with random effect model was made for the continuous outcome of rescission index (Fig. 4).

DISCUSSION

The purpose of this review was to systematically assess the biological complication all ceramic and metallic abutments. The authors in their investigation focused on the biological outcome (pocket depth and recession). The authors plan was to exclude studies in which abutments were compared to tooth born restoration or any restoration other than implant abutment. So, some studies with follow-up from 4 to 11 years were omitted (6, 11). This action can be claimed; though, patient bias is avoidable through uncontrolled prospective clinical trials. Therefore, the longest follow-up included was 5 years (10, 11). In general, the results of both abutment materials showed only minor statistically significant differences. Evidence-based review assessed the outcome of abutment materials on alveolar bone loss, was drawn in the same decision as previously (27). Based on visceral, human biology and different clinical studies, abutments materials (zirconia and titanium) showed no difference in effect on alveolar bone stability. The present systematic review shows no significant differences on pocket probing depths between the different abutment materials. On the other hand, it is inspiring to note that van Brakel et al. (21) showed significantly lower pocket probing depth around Zirconium abutments compared to Titanium abutments. This study showed a complete picture of the surface roughness zirconia and titanium implant abutments (Ra-val. 210 Zirconia–236 Titanium nm). New in vitro studies (15) showed that the surface roughness of the different abutment materials has a significant role in the performance of cells on Zirconia or Titanium abutment. It was stated that polished Zirconia surfaces give better adhesion media for epithelial cells, in comparison to Titanium surface (22). It could be speculated that decreased pocket probing depth around implant abutment is in deep relation with adherence of the gingival cells to the abutments. It is hard to evaluate the influence of abutment material on plaque accumulation due to abutment not showing in the oral cavity. The included studies did not notice biological or mechanical complications. The most noticeable complication was reported in two studies (23, 24). Remarkably, a fistula triggered by excess cement was documented as one of biological complications (25, 26), so this result was explained by the abutment design. The margin of the superstructure is located subgingivally about 1-1.5 mm below the gingival crest; implant-supported fixed partial dentures were cemented using dual cured resin cement on zirconia abutments. Therefore, due to removal of excess cement which is extremely difficult to be removed, as a result biological complication was speculated. So, it is concluded that full removal of excess resin cement is necessary, even with customized implant abutment (27). As it is very difficult to remove an excess of resin cement from the implant abutment (28), the idea of this complication is not related to abutment material (titanium or zirconia), but as deep dependent to abutment design and cementation agent. Resin cement remnants were documented to be a likely reason for implant loss (11). The microbial variety and microorganisms number in oral biofilm in relation to different abutment materials reported that titanium abutments have a high concentration of microorganisms numbers and also biofilm mass. Due to roughness of titanium surfaces which play an important role in microbial adhesion; oppositely, zirconia abutments show the free surface which lead to lower susceptibility for bacterial adhesion. Supporting the idea of biomaterial property's playing an important role in stress distribution around implant abutments, which in sequence affect the alveolar bone loss (15), it was suggested that higher elastic modulus for the implant supported superstructure material allowed for a more uniform stress distribution within the implant supported framework, thus providing a more effective and reliable load transfer to the implant fixture. This could clarify why the all ceramic restorations (high modulus of elasticity) could redistribute the stresses more evenly to the implant fixture when compared to the other restorations (29).

One of the important approach on clinical practice to preserve the soft tissue integrity and improving peri-implantitis treatment is decreasing bacterial adhesion and consequently biofilm formation on implant abutment surface. However, different types of implant abutment materials showed different opinion for biofilm formation. Titanium and zirconium abutments show hydrophobic activity due to thick peptidoglycan layer that attract immediately the gram-positive bacteria. On the other hand, gram-negative bacteria will be fended off. Although the hydrophobicity of titanium and zirconium abutment play an important role for bacterial adhesion but the bioactive dioxide layer titanium shows semi-conductor structures, and this may explain debated results in the systematic literature (22).

CONCLUSIONS

Although until now all evidence-based researches does not give an absolute-cut decision for the use of ceramic or metallic as abutment materials in relative to alveolar bone response, some studies show better mechanical and biological performance of zirconia abutment over titanium abutment. The meta-analysis presented statistically significant advantage of zirconia abutments over titanium one in developing favorable response of alveolar bone

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