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Review article

Comparison of external and internal implant-abutment connections for implant supported prostheses. A systematic review and meta-analysis

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ABSTRACT

Objective: The systematic review and meta-analysis aimed to answer the PICO question: "Do patients that received external connection implants show similar marginal bone loss, implant survival and complication rates as internal connection implants?".

Data: Meta-analyses of marginal bone loss, survival rates of implants and complications rates were performed for the included studies. Study eligibility criteria included (1) randomized controlled trials (RCTs) and/or prospective, (2) studies with at least 10 patients, (3) direct comparison between connection types and (4) publications in English language. The Cochrane risk of bias tool was used to assess the quality and risk of bias in RCTs, while Newcastle-Ottawa scale was used for non-RCTs.

Source: A comprehensive search strategy was designed to identify published studies on PubMed/MEDLINE, Scopus, and The Cochrane Library databases up to October 2017.

Study selection: The search identified 661 references. Eleven studies (seven RCTs and four prospective studies) were included, with a total of 530 patients (mean age, 53.93 years), who had received a total of 1089 implants (461 external-connection and 628 internal-connection implants). The internal-connection implants exhibited lower marginal bone loss than external-connection implants ($P < 0.00001$; Mean Difference (MD): 0.44 mm; 95% Confidence interval (CI): 0.26–0.63 mm). No significant difference was observed in implant survival ($P = 0.65$; Risk Ratio (RR): 0.83; 95% CI: 0.38–1.84), and complication rates ($P = 0.43$; RR: 1.15; 95% CI: 0.81–1.65).

Conclusion: Internal connections had lower marginal bone loss when compared to external connections. However, the implant-abutment connection had no influence on the implant's survival and complication rates. Based on the GRADE approach the evidence was classified as very low to moderate due to the study design, inconsistency, and publication bias. Thus, future research is highly encouraged.

Clinical significance: Internal connection implants should be preferred over external connection implants, especially when different risk factors that may contribute to increased marginal bone loss are present.

1. Introduction

Dental implants are a favorable treatment modality for partially or totally edentulous patients [1]. The success of the prostheses along with bone level stability and soft tissue health maintenance around dental implants are critical components for long-term success of implant therapy [2]. According to Albrektsson et al. [3] success criteria established as acceptable comprised an average bone loss of 1.5 mm during the first year in function and of less than 0.2 mm annually in the subsequent years without clinical sign of peri-implant infection.

The implant-abutment connection design seems to be an important factor in modulating bone level changes in implant-supported reconstructions [4]. Marginal bone changes around implants with different connection types have been attributed to several etiological factors, such as biomechanical factors that increase the stress at marginal bone tissue and potentially contribute to alveolar bone resorption [5]. Moreover, biological factors such as peri-implant accumulation of inflammatory cells at the implant-abutment interface may contribute to

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marginal bone loss [6].

Although there is a plethora of marketed implant designs, implant-abutment connection designs may be classified into two main groups: external and internal connections [7]. The external hexagon implants are the most widely used external connections. They have been in use since the early era of modern implantology, through the Branemark implant system. Although widely used today, this connection type has some drawbacks, including abutment micromovement, which has been associated with mechanical and biological complications [8,9].

Internal connections were designed to reduce the complications found in external connections and long-term clinical data support this assumption [10]. When internally connected, implant-abutment mechanical complications such as screw loosening and fracture are reduced, while stress dissipation is enhanced around the implant [5]. A systematic review reported a higher incidence of technical complications for externally connected implant systems compared with internal connections [11]. However, the European Association for Osseointegration Consensus Conference, suggested that more randomized clinical studies were needed to confirm these findings [12]. In particular, more research is required to evaluate the differences in marginal bone loss between implant systems, since secondary failure of implants is often preceded by marginal bone resorption, which can progress to peri-implantitis and contribute to implant failure [13].

Thus, the aim of this systematic review and meta-analysis was to evaluate the influence of external and internal implant-abutment connections by means of the following null hypotheses: (1) there are no differences between external and internal connections in terms of marginal bone loss; and (2) there are no differences in terms of implant survival rate and complications (mechanical or biological) between the different implant-abutment connections.

2. Materials and methods

2.1. Registry protocol

This systematic review was structured based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist [14], in accordance with models proposed in the literature [15–17]. The methods for this systematic review were registered on the international prospective register of systematic reviews (PROSPERO—CRD 42016053196).

2.2. Eligibility criteria

The population, intervention, comparison, outcomes (PICO) approach was used to address the question: “Do patients that received external connection implants show similar marginal bone loss, implant survival and complication rates as internal connection implants?” According to these criteria, the population comprised patients rehabilitated with dental implants; the intervention was rehabilitation with internal connection implants; and the comparison was with patients who received external connection implants. The primary outcome evaluated was the marginal bone loss around the implant, while the implant survival and complication rates were considered as secondary outcomes.

Eligible studies should present the following characteristics: (1) randomized controlled trials (RCTs) and/or prospective; (2) studies with at least 10 patients; (3) studies that compared both external and internal connection implants in the same report; and (4) studies published in English.

The exclusion criteria were: (1) *in vitro* studies, (2) animal studies; (3) case series or case reports; (4) retrospective studies; (5) biomechanical studies; (6) patients or data repeated in other included articles; and (7) studies that evaluated only one connection type (external or internal) without a comparison group.

2.3. Information sources and search strategy

Two independent authors (C.A.A.L. and J.F.S.J) conducted an electronic search of PubMed/MEDLINE, Scopus, and the Cochrane Library for articles published before October 2017 using the search terms: “internal connection and external connection and dental implant OR external and internal and dental implant OR Morse taper and external connection and dental implant OR internal and external and conical and dental implant”.

To complement this search, the same researchers manually searched for articles published in journals of specific areas: *Clinical Implant Dentistry and Related Research, Clinical Oral Implants Research, International Journal of Oral and Maxillofacial Implants, International Journal of Oral and Maxillofacial Surgery, Journal of Clinical Periodontology, Journal of Dentistry, Journal of Oral and Maxillofacial Surgery, Journal of Oral Implantology, Journal of Oral Rehabilitation, Journal of Periodontology, and Periodontology 2000*. In addition, OpenGrey (www.opengrey.eu) was used to search gray literature.

Initially, studies were selected and classified according to the eligibility criteria based on the title and the abstract of the articles. To make a decision regarding inclusion of studies with insufficient data in their titles and abstracts, the full manuscript was obtained. A third author (E.P.P.) analyzed all differences in choices between the investigators and consensus was reached through discussion.

2.4. Data collection process

One of the authors (C.A.A.L.) collected relevant information from the articles, and a second author (J.F.S.J.) reviewed all the collected information. A careful analysis was performed to check for disagreements among the authors, and a third author (E.P.P.) settled all the disagreements between the investigators through discussions until consensus was reached. The variables collected from the articles were as follows: author; study design; number of patients and implants; mean age; system, diameter and length of the implant; retention system; connection type; follow-up; complication; marginal bone loss (mean/standard deviation); and implant survival rate.

2.5. Risk of bias

Two investigators (C.A.A.L. and F.R.V.) assessed the quality and risk of bias of the RCTs included in this systematic review using The Cochrane Risk of Bias Tool which checks for selection bias (random sequence generation and allocation), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), attrition bias (incomplete outcome data), reporting bias (selective reporting), and other bias (bias from other sources). The risk of bias for non-RCTs (prospective) was assessed using the Newcastle-Ottawa scale [15,17], which is based on three major components for cohort studies: selection, comparability, and outcomes [18].

The Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to assess the quality of evidence for each outcome across studies. The GRADE assessment is based on the study design, inconsistency, indirectness, imprecision, and publication bias. According to GRADE, the rating quality of evidence is rated into four categories, high, moderate, low, and very low, which are applied to a body of evidence in the evaluated outcome, but not to individual studies. Furthermore, the GRADEpro Guideline Development Tool (www.gradepro.org), was used to perform a summary of the findings [19–21].

2.6. Summary measures

The meta-analysis was based on the inverse variance (IV) and Mantel–Haenzel (MH) methods. Marginal bone loss was considered the continuous outcome and evaluated using the mean difference (MD).

The implant survival rates of implants and complications were dichotomous outcomes using the risk ratio (RR). The RR and MD values were considered significant at $P < 0.05$, both with corresponding 95% confidence intervals (CI). In the case of statistically significant ($P < 0.10$) heterogeneity, a random-effects model was used to assess the significance of the treatment effects. Where no statistically significant heterogeneity was found, analysis was performed using a fixed-effects model [22,23]. The software Reviewer Manager 5 (Cochrane Group) was used for the meta-analysis. In addition, a funnel plot (effect size *versus* standard error) was drawn for each evaluated outcome. Asymmetry of the funnel plot may indicate publication bias and other biases related to sample size. However, the asymmetry may also represent a true relationship between the trial and effect sizes [22].

2.7. Additional analysis

The Kappa score was used to calculate the inter-reader agreement during the inclusion process for publication-evaluated databases. Any disagreements were resolved by discussion and consensus of all authors.

3. Results

3.1. Literature search

The database search yielded 661 references, including 276 from PubMed/MEDLINE, 286 from Scopus, and 99 from the Cochrane Library. After removing duplicate references, 487 studies remained. After reviewing the titles and abstracts of the manuscripts and applying the inclusion/exclusion criteria, 23 studies were eligible for further analysis. After reading these studies, 12 were excluded as they were retrospective studies [24–32] or had their data included in other articles with longer follow-ups [33–35] Altogether, 11 studies were selected for this systematic review [2,4,34,36–44] Fig. 1 depicts a flow diagram detailing the search strategy.

The inter-investigator agreement (Kappa) values for articles selected by titles and abstracts from different sources were as follows: PubMed/MEDLINE (0.91), Scopus (0.87), and Cochrane Library (1.0). The values indicate a high level of agreement between the reviewers [45].

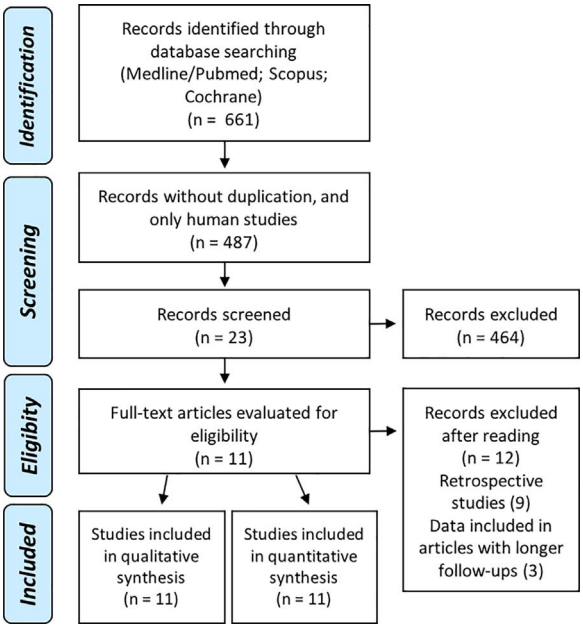

Fig. 1. Flowchart describing the search and selection strategies.

3.2. Description of the studies

Table 1 summarizes detailed information of the 11 included studies. Of the 11 studies, seven were RCTs and four were prospective studies. A total of 1089 implants, including 461 implants with external connection and 628 implants with internal connection were placed in 530 patients with a mean age of 53.93 years. The mean follow-up period was 26.6 months (range, 12–60 months).

Nobel Biocare was the most commonly used implant system [38,39,41,43], while cemented prostheses were chosen by most of the selected studies [4,34,37–39,41–44]. Single crowns were the most prevalent prostheses between the selected studies [2,4,34,37–39,41,44]. Most studies evaluated both arches [2,4,34,37–41,43,44], while two studies evaluated only the mandibular arch [36,39], and one study only the maxillary arch [42].

3.3. Quality assessment of the studies

Among the RCTs, a low risk of bias to random sequence generation and allocation concealment (selection bias) was observed. Regarding blinding of the participants and personnel (performance bias), two studies reported that no participant/surgeon was blinded, while other studies were unclear on this mater. Blinding of the outcome assessment (detection bias) was performed in most of the studies, except for two that were graded as high risk. Incomplete outcome data, selective reporting, and other biases were considered low risk for the all selected studies (Fig. 2). The risk of bias for non-RCTs was judged based on Newcastle-Ottawa. Two studies scored nine stars, while two scored eight, indicating a low risk of bias (Table 2).

The summary of the findings based on the GRADE approach for the outcomes can be found in Appendix A in Supplementary material. The overall quality of the body of evidence for the main outcomes was judged as very low to moderate due to study limitations, inconsistencies, and publication bias. Funnel plot analysis showed asymmetry when the studies reporting the outcome ‘marginal bone loss’ were analyzed, thus indicating possible publications bias. However, the funnel plot of ‘survival rates of implants’ and ‘complications rates’ showed symmetry, indicating absence of publication bias (Appendix B).

3.4. Marginal bone loss

All selected studies evaluated the mean marginal bone loss (mm) around the implants after a minimum of 12 months of follow-up (range, 12–60 months). A random-effects model showed that internal connection implants lead to lower marginal bone loss than external connection implants ($P < 0.00001$; MD: 0.44 mm; 95% CI: 0.26 mm–0.63 mm; Fig. 3).

Sub-analysis was performed with studies that had classified the implants by the type of prosthesis (single-unit crowns and multiple prostheses including fixed partial denture, overdenture, and full arch). Lower marginal bone loss was associated with internal connection implants than with external connection implants for single crowns ($P < 0.0001$; MD: 0.79 mm; 95% CI: 0.43 mm–1.14 mm) and multiple prostheses ($P < 0.0001$; MD: 0.60 mm; 95% CI: 0.33 mm–0.86 mm; Fig. 4).

3.5. Implant survival rates

The assessed studies showed that 22 out of the 1089 implants had failed (2.02%); 7 out of 461 external connection implants (1.52%) and 15 out of 628 internal connection implants (2.39%). No significant difference was observed between the rates of failure of external connection and internal connection implants ($P = 0.65$; RR: 0.83; 95% CI: 0.38–1.84; Fig. 5).

Table 1
Characteristics of included studies.

Author	Study Design	Patient, n	Impla-nt, n	Mean age, years	Implant system/Diameter/ Lenght	Retention System	Prosthesis/Arch	Connection type	Follow-up, months	Complications, n	Mean (SD) MBL	Survival rates of implants, n (%)
Pessoa et al.[36]	RCT	12	24	63.1	Unitite – SIN Implants/Ø 3.8/13 mm	SR	FA/Mandible	EC: 12	12 months	NR	EC: 1.17 (0.44)	EC: 12 (100%)
								IC: 12			IC:0.17 (0.54)	IC: 12 (100%)
Cooper et al. [4]	RCT	39	93	53	EC: Osseotite – Biomet 3i	CR	SC/Maxilla and Mandible	EC: 46	36 months	Healing AL: (EC: 4/IC: 1)	EC: 0.50 (0.93)	EC: 44 (95.6%)
					Ø 4.0/8.5–13 mm			IC: 47		Definitive AL: (EC: 7/IC: 0)	IC: 0.25 (0.60)	IC: 45 (95.7%)
					IC: Astra Tech – Dentsply Ø 4.5/9–13 mm							
Esposito et al.[37]	RCT	120	203	52	Ez Plus – MegaGen	SR or CR	SC, FPD/Maxilla and Mandible	EC: 96	60 months	EC: 10 (5AL; 3CPL; 2PI)	EC: 1.36 (1.04)	EC: 95 (98.9%)
					Ø 3.3–5.5/7–15 mm			IC: 107		IC: 9 (2I; 3AL; 4 PI; 1CPL)	IC: 1.28 (1.11)	IC: 104 (97.2%)
Kaminaka et al. [38]	PS	32	34	56.9	EC: Brånemark System – Nobel	CR	SC/Maxilla and Mandible	EC: 11	12 months	NR	EC: 1.94 (0.87)	EC: 11 (100%)
					IC[1]: NobelReplace – Nobel			IC[1]: 11			IC[1]: 0.79 (1.30)	IC[1]: 11 (100%)
					IC[2]: NobelActive – Nobel			IC[2]: 12			IC[2]: 0.25 (0.87)	IC[2]: 12 (100%)
					Ø 3.3–4.3/11.5–13 mm							
Pozzi et al. [33]	RCT	34	88	52.2	EC: NobelSpeedy – Nobel	CR	SC/Mandible	EC: 44	36 months	EC: 1 M	EC: 1.24 (0.47)	EC: 44 (100%)
					Ø 4.1/10–13 mm			IC: 44		IC: 0	IC: 0.67 (0.39)	IC: 44 (100%)
					IC: NobelActive – Nobel Ø 3.9/10–13 mm							
Peñarrocha-Diago et al. [40]	RCT	15	120	56.9	EC: Osseous – Mozo-Grau	NR	O, FA/Maxilla and Mandible	EC: 56	12 months	EC: 2 1CR; 1Mo	EC:0.38 (0.51)	EC: 55 (98.6%)
					Ø 3.75–4.25/10–13 mm			IC: 64		IC: 2 1CR; 1Mo	IC: 0.12 (0.17)	IC: 63 (98.6%)
					IC: Inhex– Mozo-Grau Ø 3.75–4.25/10–13 mm							
Arnhart et al. [41]	RCT	127	236	48.8	EC: NobelActive External – Nobel	SR or CR	SC, FPD, FA/Maxilla and Mandible	EC: 66	36 months	EC: 11 (6SF; 2Mo; 1BE; 1SP)	EC: 1.18 (0.91)	EC: 63 (95.5%)
					IC[1]: NobeReplace – Nobel			IC[1]: 86		IC[1]: 18 (11SF; 3Mo; 4 Pa; 2PI; 1S)	IC[1]: 1.71 (1.28)	IC[1]: 82 (95.3%)
					IC[2]: NobelActive – Nobel			IC[2]: 84		IC[2]: 21 (11SF; 1Mo; 1IF; 3S; 1R)	IC[2]: 1.41 (1.54)	IC[2]: 79 (94.1%)
					Ø 3.5–4.3/8–16 mm							
Canullo et al. [42]	RCT	40	80	58.2	EC: EH, Brånemark System IC: Amplified, Brånemark System/Ø 4.3/13 mm	CR	FPD/Maxilla	EC: 40 IC: 40	18 months	NR	EC: 1.6 (0.3) IC: 0.5 (0.1)	EC: 40 (100%) IC: 40 (100%)
Koo et al. [2]	PS	40	40	54.3	Oneplant – Warantec	NR	SC/Maxilla and Mandible	EC: 20	12 months	NR	EC: 1.14 (0.54)	EC: 20 (100%)
					Ø 4.5/8.5–13 mm			IC: 20			IC: 0.24 (0.29)	IC: 20 (100%)

(*continued on next page*)

Table 1 (*continued*)

Author	Study Design	Patient, n	Impla-nt, n	Mean age, years	Implant system/Diameter/ Lenght	Retention System	Prosthesis/Arch	Connection type	Follow-up, months	Complications, n	Mean (SD) MBL	Survival rates of implants, n (%)
Bilhan et al. [43]	PS	26	107	49.06	EC: Brånemark System Mk III – Nobel IC[1]: Astra Tech – Dentsply IC[2]: ITI Dental Implant SLA – Straumman AG Ø NR/10–17 mm	CR	FPD/Maxilla and Mandible	EC: 36 IC[1]: 42 IC[2]: 29	24 months	EC: 2 PF IC[1]: 0 IC[2]: 0	EC: 1.1 (0.1) IC[1]: 0.66 (0.1) IC[2]: 0.8 (0.1)	EC: 36 (100%) IC[1]: 42 (100%) IC[2]: 29 (100%)
Crespi et al. [44]	PS	45	64	48.73	EC: Seven – Sweden & Martina Ø 3.80–5.0/13 mm IC: Ankylos – Dentsply/Ø 4.5–5.5/14 mm	CR	SC, FPD/Maxilla and Mandible	EC: 34 IC[CC]: 30	24 months	EC: 3 AL IC[CC]: 0	EC: 0.78 (0.45) IC: 0.73 (0.52)	EC: 34 (100%) IC: 30 (100%)

RCT: Randomized Controlled Trial; PS: Prospective Study; NR: Not reported; EC: External Connection; IC: Internal Connection; SR: Screw-retained; CR: Cement-retained; FA: Full-arch; SC: Single crown; FPD: Fixed Partial Denture; O: Overdenture; AL: Abutment Loosening; CPL: Contact Point Loss; PI: Perilmplantitis; I: Infections; M: Mucositis; PF: Porcelain Fracture; CR: Continuous Radiolucency; Mo: Mobility; SF: Suprastructure failures; E: Buccal exostosis; SP: Sinus perforation; Pa: Pain; S: Swelling; IF: Implant fracture during insertion; R: Recession

Fig. 2. Assessment of the risk of bias in the included studies based on the Cochrane Risk of Bias tools.

3.6. Complications rates

The complication rates were reported in seven studies [4,34,37,39–41,44], and considered any biological or mechanical complications. Most of the complications were related to mechanical problems associated with the prostheses. Although the complication rate for external connection implants was higher, there was no significant difference when these were compared with internal connection implants (P = 0.43; RR: 1.15; 95% CI: 0.81–1.65; Fig. 6).

4. Discussion

The choice of implant-abutment connection design is usually based on the professional's clinical experience. However, the implant-abutment connection system can be considered a factor that influences bone remodeling around implants after functional loading [36]. This systematic review verified whether the implant-abutment connection has an influence on the magnitude of bone loss. The results indicated that the internal connection implants were associated with lower bone loss than the external connection implants; thus, we reject the first hypothesis. These results corroborate previous studies that reported lower values of marginal bone loss in association with internal connection implants [26,27,46]. Such improved bone level maintenance may be related to mechanical, biological, and patient-related factors that modulate the process of bone remodeling [4,5,8].

Biomechanical studies have demonstrated that internal connection implants have a greater centralization of stress along the implant [5,47], with higher lateral stability of the abutment due to reduction in the length of the lever arm to the middle third of the implants [48]. This could reduce the stress in the peri-implant cortical bone, consequently reducing bone resorption. In addition, most internal connection implants present a mismatched implant-abutment platform (platform-switching) which contributes to placing the microgap away from the

Table 2
Assessment quality of Non-RCT included studies based on New Castle Ottawa.

Studies	Selection				Comparability		Outcome			Total.
	Exposed Cohort[b]	Non exposided cohort[b]	Ascertainment of exposure	Outcome of interest not present at start	Main Factor	Additional Factor	Assessment of outcome	Follow-up long enough	Adequacy of follow-up[b]	
Kaminaka et al. [38]	☆	☆	☆	☆	☆	0[a]	☆	☆	☆	8
Koo et al. [2]	☆	☆	☆	☆	☆	0[a]	☆	☆	☆	8
Bilhan et al. [43]	☆	☆	☆	☆	☆	☆	☆	☆	☆	9
Crespi et al. [44]	☆	☆	☆	☆	☆	☆	☆	☆	☆	9

[a] Authors not reported complications rate outcome.
[b] One year was considered adequate follow-up period for outcomes.

peri-implant bone tissue [49,50] and to preserving the bone tissue [51].

Previous studies have demonstrated that internal connections are favored by the switching concept [51], better stress distributions [5], lesser micromovements [9], and higher survival probability [52]. The combination of these factors may have contributed to the findings observed in this systematic review, but they certainly do not explain the complex host to biomaterial dynamic bone remodeling process, including those observed in systemically compromised patients or those with a history of periodontal disease [53]. Although a systematic review previously reported that no particular type of dental implants presents superior performance, the same study showed higher peri-*peri*-implant bone loss for a specific implant surface [54]. This finding was recently corroborated in a clinical study that showed that bone loss due to peri-implant disease is more severe for some implant surfaces, such as those modified by anodic oxidation, when compared to others [55]. In this systematic review, the studies that used rough and anodized surface presented higher bone loss values [38,39,41,43], especially in implants with external connections [38,39,43]. Thus, considering that if peri-implant disease is underway and untreated, it may lead to implant loss. Considering that the patients' life expectancy has increased, all efforts to stabilize the implant bone levels are recommended. In situations where maximal bone level preservation is required, such as immediate implantation in esthetic areas, the use of internal conical implants should be mandatory because as it results in greater stability of the peri-implant tissues [56], especially when zirconia abutments are used in patients with thin gingival biotypes [57].

Although the influence of the implant-abutment connection was evaluated in the present study, the implant thread type/design was also shown to influence marginal bone loss in another systematic review [58]. Of the 11 selected studies, only five [2,34,36,37,42] evaluated the influence of the implant-abutment connection design with the same implant macro-design, which can be considered as a limitation of the selected studies.

Another limitation is related to the location of the implant-abutment interface in relation to the bone crest [4]. Some studies have reported that the use of internal connection at the subcrestal level is better to preserve the bone tissue [59–61]. However, only two studies reported on implants placed subcrestally (0.5 mm [36] and 1 mm [44]), although in both external and internal connections. This is possibly due to methodological standardization of the implant surgical placement, since external connection implants are positioned at the bone level. Thus, it may be recommended that further RCTs be conducted to verify the optimum placement levels for the different implant connections.

Most of the selected studies showed bone loss within the limits established in the literature for external hexagon implants (< 1.5 mm during the 1st year, with annual bone loss < 0.2 mm thereafter) [3]. Although acceptable for this connection design, it must be acknowledged that the success criteria for marginal bone level changes established more than 30 years ago may not be appropriate in the present days. Widely published implant systems currently present much lower bone loss levels after 5 years than formerly suggested as acceptable [62].

An important factor to be considered was the high variation in the values of marginal bone loss, which probably contributed to the increase in the heterogeneity of the included studies. This may be related to differences in methods used to evaluate the marginal bone loss. Most studies reported marginal bone loss values measured through periapical radiographs using the parallelism technique. Four studies reported the use of film holders for radiographic taking [4,39,40,44], while three studies performed the preparation of customized film holders for each patient [2,36,42]. The use of customized holders should be preferred since it allows radiographic imaging standardization during the follow-

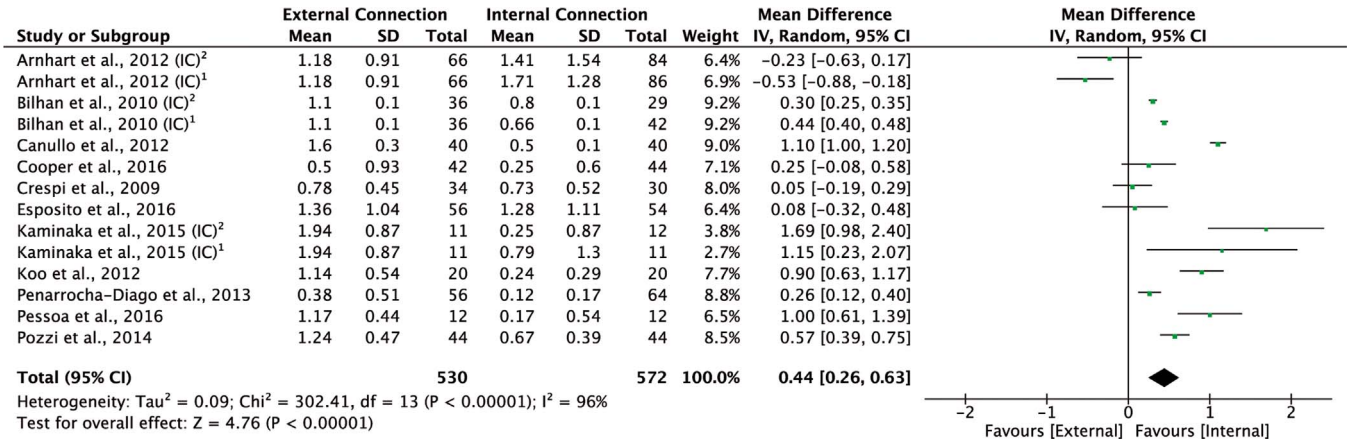

Fig. 3. Forest plot of external connection event in comparison with internal connection for marginal bone loss.

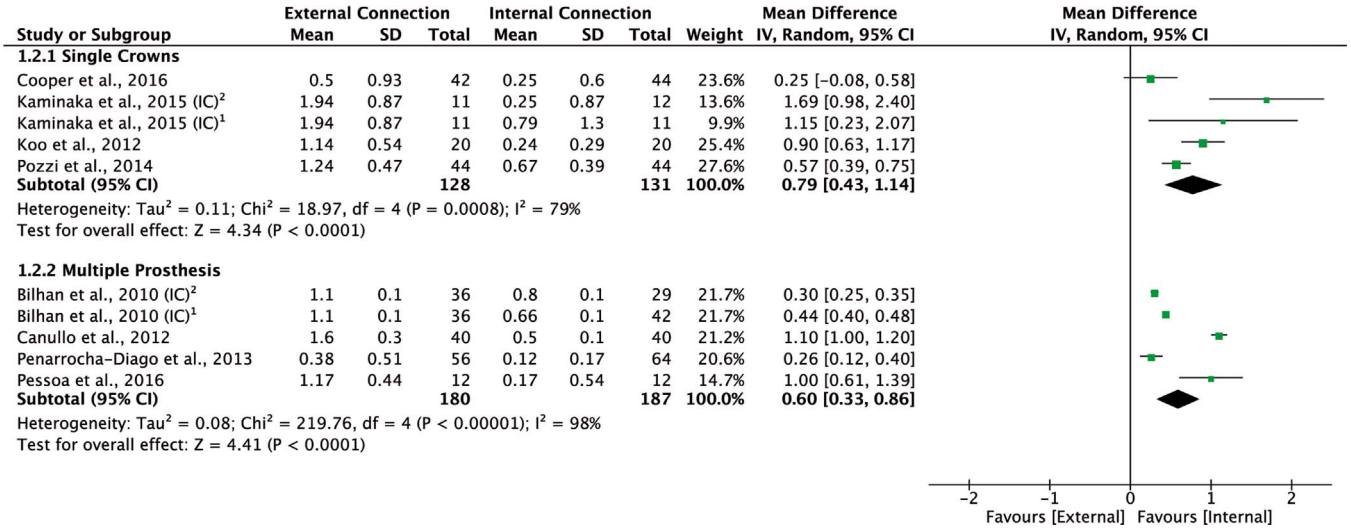

Fig. 4. Forest plot of external connection event in comparison with internal connection for marginal bone loss in the single crowns and multiple prosthesis.

up period. Only one study [38], evaluated marginal bone loss using cone-beam computed tomography to acquire three-dimensional images and evaluate changes over time in bone tissue not only in horizontally, but also changes in the buccal alveolar bone and soft tissue dimensions around the implants. This technique contributed to higher agreement between two different examiners which further increased the reliability of the marginal bone loss evaluation method.

The second null hypothesis was not rejected, since no difference was found in implant survival and complication rates between the external and internal connection implants. Implant failure can be caused by primary and/or secondary factors, such as surgical, local, systemic, and prosthetic factors. Therefore, sometimes it is difficult to determine the reason for implant failures [13]. The primary factors often result in non-osseointegration failure of the implant, while secondary factors most often result in marginal bone loss [13]. Thus, the implant-abutment connection can be considered one of these risk factors. However, it has a greater influence on the rate of complications (mechanical and/or biological) than on the failure of implants [63].

In this study, although external connection implants presented a greater number of complications, no significant difference was observed in comparison with internal connection implants. In a previous systematic review, Gracis et al. [11] verified that the implant-abutment connection influenced the loosening of the abutment/screw, with a greater incidence in external than in internal connection implants. This difference could be justified as the complication rates were reported only in seven studies. Moreover, the selected studies had short follow-up periods and complications are usually observed after longer periods in function (> 5 years) [63–65]. In a 20-year retrospective follow-up study internal conical connection implants presented very low complication rates (3.4% biological; 10.3% prosthetic/mechanical) [10].

The results obtained in this study should be interpreted with caution, because there are uncontrolled factors that may have had a direct influence on marginal bone loss, implant survival, and complication rates. These factors include the dimensions of the implants (length and diameter) [1], arch/bone type [66], abutment material [31], and retention system [67], all of which may influence bone loss level alterations. However, sub-analyses could not be performed to verify the influence of the implant-abutment interface in association with these variables. In addition, the follow-up period should also be considered as a limitation, since one of the selected studies presented a follow-up period of 5 years. Thus, to allow the evaluation of survival and success of implants a minimum evaluation of 5 years of follow-up is recommended [68]. Therefore, we suggest further RCTs be conducted with longer follow-up periods to evaluate the direct influence of the abutment-implant interface in association with the abovementioned factors.

5. Conclusion

The internal connections showed lower marginal bone loss than the

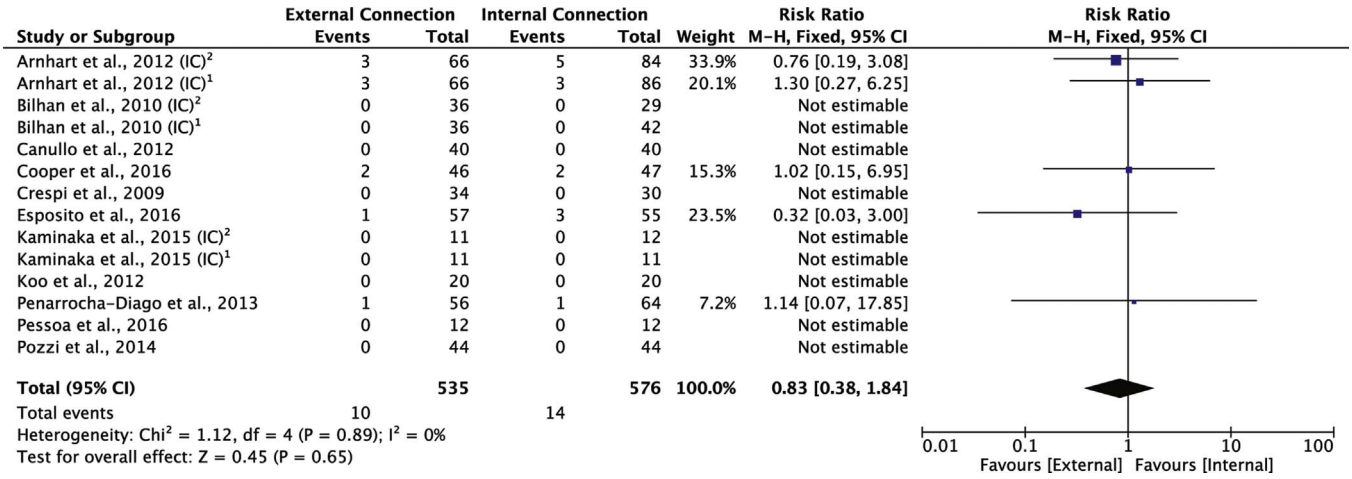

Fig. 5. Forest plot of external connection event in comparison with internal connection for implant survival.

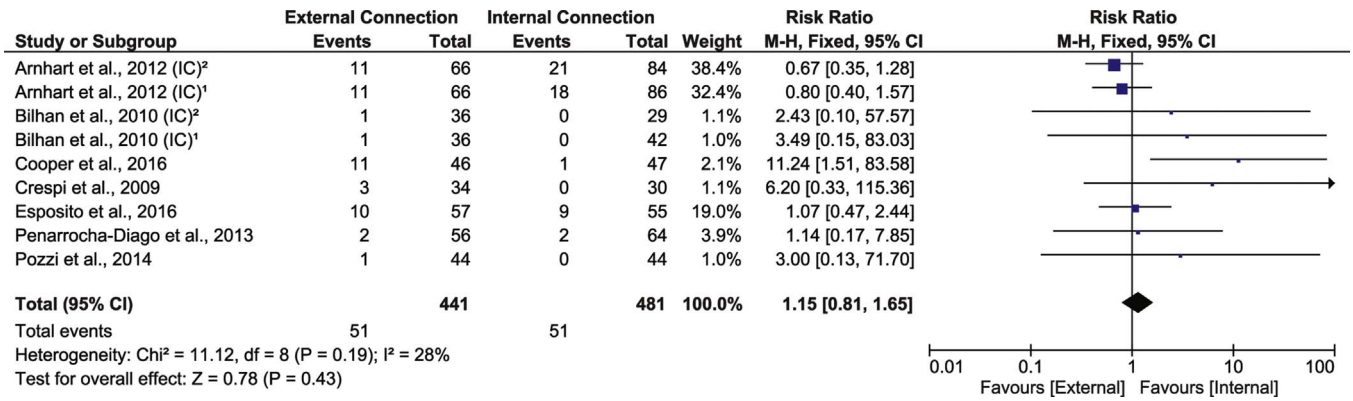

Fig. 6. Forest plot of external connection event in comparison with internal connection for complication rates.

external connections. The implant-abutment interface had no influence on the implants survival and complication rates during a mean follow-up period of 26.6 months. Based on The GRADE approach the evidence was classified as very low to moderate. Thus, future research is highly encouraged to reassess the impact of new data.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jdent.2017.12.001.

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