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REVIEW

Is the clinical performance of internal conical connection better than internal non-conical connection for implant-supported restorations? A systematic review with meta-analysis of randomized controlled trials

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Abstract

Purpose: To evaluate bone loss, prosthodontics and biological complications, and implant survival rates of internal conical connections (ICC) compared with internal non-conical connection (INCC) implants.

Methods: The systematic review was registered on PROSPERO (CRD42021237170). Meta-analysis was performed using standardized mean difference (SMD) for bone loss and risk ratio (RR) for implant survival and complication rates. Risk of bias analysis was evaluated using RoB 2.0, whereas the GRADE tool was used to evaluate the certainty of evidence. A systematic search of the PubMed, Web of Science, Embase, Cochrane, and ProQuest databases was performed independently by two reviewers for articles published up to March 2022. The search criteria had no language or publication date restrictions. Handsearching analysis was performed in the reference list of potential articles.

Results: Twelve randomized clinical trials, including 678 patients and 1006 implants (ICC [n = 476]; INCC [n = 530]), were included. Meta-analysis revealed that ICC demonstrated a lower risk for marginal bone loss (SMD: −0.80 mm; p = 0.004) and prosthodontics complications (RR: 0.16; p = 0.01) than INCC. However, both internal connections demonstrated no significant difference in implant survival rates (RR: 0.54; p = 0.10) and biological complications (RR: 0.90; p = 0.82). The overall risk of bias revealed some concerns and a low risk of bias for most of the included studies. However, the certainty of evidence of outcomes was considered low to moderate.

Conclusion: ICC may be considered a more favorable treatment option than INCC owing to greater preservation of peri-implant bone tissue and a lower probability of prosthodontics complications. However, well-conducted studies with long-term follow-up are warranted.

KEYWORDS
implant–abutment, internal butt joint, internal hexagon, tapered, tri-channel

Dental implants are considered to be one of many viable alternatives for treating complete and partial edentulism.[1,2] The demand for their use has been growing since their introduction to the global dental market and continues to expand.[3] Many factors can influence the longevity of rehabilitation with dental implants, including the implant–abutment connection interface.[4–6]

Current studies have described the superiority of internal over external connections, mainly in relation to maintenance and peri-implant bone tissue.[5–7] Preservation of the peri-implant bone tissue should be an essential consideration because bone loss is one of the main factors associated with late implant failures.[4]

Internal connections can be subdivided according to their geometric features and the relationship between implant and abutment connection.[8] Internal non-conical connections (INCC) present a clearance-fit connection with abutment and internal portion of implant walls with a small gap to avoid friction between the components. INCC incorporates geometric designs (hexagon, trilobe, octagon, polygonal, and others) to avoid the rotation between implant–abutment interface and facilitate the abutment positioning.[6,8] Internal conical connections (ICC), such as the Morse taper connection,[6] are composed of a conical portion of the abutment tapered internally of the conical portion of the implant wall without the need for clearance-fit between components.[8] Despite the superiority of internal over external connections, there is no consensus in the literature to support a better choice between different types of internal connections.[9,10] Studies have reported that bone loss with ICC is significantly lower than that in an INCC.[11,12] Conversely, some studies have reported no differences in internal connections in terms of implants survival, prosthodontics and biological complications and bone loss.[9,13]

A recently published study evaluated only the prognosis of internal connection implants, but without comparison with INCC.[14] Therefore, given the lack of evidence supporting differences among the types of internal connections, this systematic review and meta-analysis aimed to assess the clinical performance through marginal bone loss, complications, and implant survival rate of conical and non-conical internal connections. The null hypotheses were as follows: (1) There is no influence of the type of internal connection on the values of marginal bone loss, (2) ICCs demonstrate complication rates similar to INCCs, and (3) both connection types yield similar implant survival rates.

METHODS

This systematic review was structured in accordance with guidelines from the Cochrane Handbook of Systematic Reviews of Interventions[15] and followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement 2020.[16] The methodological protocol was accepted and registered in the International Prospective Register of Systematic Reviews (i.e., PROSPERO) with number CRD42021237170.

The participants, intervention, comparison, outcomes, and study design (PICOS) for the present study considered the following question: "Do patients with missing teeth and rehabilitated using internal conical connection implants exhibit marginal bone loss, complications, and implants survival rates similar to those who receive internal non-conical connection implants?" According to the question, marginal bone loss was the primary outcome, whereas complications (biological and prosthodontics) and implant(s) survival rates were secondary outcomes.

The inclusion criteria for this review were randomized clinical trials (RCTs) that compared an ICC with an INCC within the same study, contained at least 10 implants for each group evaluated, and had a minimum follow-up period of 1 year. Non-randomized studies, in vitro studies, animal studies, case series or case reports, in silico studies, studies with repeated data, or repeated patients in another included study with a longer follow-up were excluded.

Two independently calibrated authors (V.V.M.R. and D.S.F.) performed the literature search using the Medline/PubMed, Web of Science, Embase, and Cochrane databases for articles published up to March 2022. The retrieved records were exported and imported into the Rayyan QCRI program[17] to enable the removal of duplicate articles retrieved from the various databases and to enable the article selection process. First, studies were chosen in accordance with eligibility criteria, through title and abstract. In cases for which it was not possible to establish a judgment based on reading the title and abstract, the decision was made based on the reading of the full text. A complementary search of the gray literature (ProQuest database) and a manual review of the reference lists of eligible studies were also performed. Furthermore, a search in the ClinicalTrials.gov to find registers with results that met the eligibility criteria was performed. A third author (C.A.A.L.) analyzed the decisions of the other two authors and, in case of divergence in the analyses, inclusion or exclusion of the article was made by consensus discussion (Table 1).

One author (V.V.M.R.) extracted information from the studies, including first author, publication year, study design, number of patients/sex, mean age, number of implants (separated by group), implant system, diameter and length of implant, retention system (screwed or cemented)/prosthesis type and rehabilitated arch, marginal bone loss (in mm); number of complications and implant failures for each group, and follow-up period (in months). The second author (C.D.D.R.D.) was responsible for data verification to avoid the extraction of incorrect information.

Two investigators (M.F.L.S.L. and V.A.A.B.) considered the risk of bias evaluation of the RCTs using the RoB 2.0 tool.[18] RoB 2.0 consider five domains of bias: the randomization process, deviations from intended interventions, missing outcome data, measurement of outcome(s), and selection of the reported results. After domain definition, overall bias was determined for each study. Each of these domains was categorized as low, high, or certain concerns.

The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system was used to evaluate the certainty of evidence for each outcome. The GRADE assessment considers study design, inconsistency, indirection, imprecision, and publication bias. The certainty of evidence rating is classified into four categories, high, moderate, low, and very low. The GRADEpro Guideline Development Tool (www.gradepro.org) was used to summarize the findings.[19]

TABLE 1 Characteristics of included studies

References	Patient, *n* sex	Mean age, years	Implants, *n*	Implant system/diameter/length	Retention system/type of prosthesis/arch	Mean (SD) MBL (mm)	Complications, *n* (type of complications)	Survival rates of implants, *n* (%)	Follow-up, months
21	**30** 17 Fe 13 Ma	45	ICC: 15 INC: 15	ICC: M12 implant, Oxtein Iberia S.L. INC: N35 implant, Oxtein Iberia S.L. 3.75–4.2 mm/10–11.5 mm for both implants	Screw-retained/single crown/mandible	ICC: 0.15 (±0.13) INC: 0.56 (±0.44)	ICC: 0 INC: 4 (Ceramic Chipping, Suppuration, Crown loosening)	ICC: 15 (100%) INC: 15 (100%)	12
22	**49** 21 Fe 28 Ma	NR	ICC: 48 INC: 48	ICC: C1, MIS/INC: SEVEN, MIS 3.5–4/10–11.5 mm for both implants	Screw-retained/single crown/mandible	ICC: 0.64 (±0.45) INC: 0.68 (±0.50)	ICC: 0 INC: 0	ICC: 46[b] (95.8%) INC: 46[b] (95.8%)	36
23	**33** 16 Fe 17 Ma	67.4	ICC: 34 INC: 34	ICC: NeO Conical Standard, Alpha-Bio Tec/3.75 mm/10 mm INC: NeO Internal Hex, Alpha-Bio Tec/3.75 mm/10 mm	Cement-retained/single crown/mandible and maxilla	ICC: 0.48 (±0.18) INC: 0.57 (±0.24)	ICC: 0 INC: 0	ICC: 34 (100%) INC: 34 (100%)	12
24	**47**[a] 22 Fe 25 Ma	50.2	ICC: 22[a] INC: 25	ICC: Ankylos, Dentsply/3.5–4.5/9.5–14 mm INC: Xive, Dentsply/3.8–4.5 mm/9.5–3 mm	NR/single crown and fixed partial denture/mandible and maxilla	ICC: 0.16 (±0.25) INC: 0.17 (±0.26)	NR	ICC: 22 (100%) INC: 25 (100%)	12
25	**47** 26 Fe 21 Ma	58.73	ICC: 33 INC: 28	ICC: TG Implants, Sweden and Martina Premium/ INC: SLR, Due Carrare, 3.8–5 mm/7–13 for both implants	Screw-retained/single crown and fixed partial denture/mandible and maxilla	ICC: 0.26 (±0.22) INC: 0.11 (±0.20)	ICC: 0 INC: 1 (Abutment fracture) 3 (Screw loosening)	ICC: 33 (100%) INC: 27 (96.4%)	24
8	**90** 47 Fe 43 Ma	52	ICC: 45 INC: 45	ICC: JDIcon, J Dental Care Mean diameter/length: 4.3/10.4 mm INC: JDIEvolution, J Dental Care Mean diameter/length: 4.1/10.8 mm	Screw-retained/single crown and fixed partial denture/mandible and maxilla	ICC: 0.56 (±0.53) INC: 0.60 (±0.62)	ICC: 2 (Pain/Pus and Mucositis) INC: 2 (Screw loosening and Mucositis)	ICC: 44 (98%) INC: 45 (100%)	12

(Continues)

TABLE 1 (Continued)

References	Patient, *n* sex	Mean age, years	Implants, *n*	Implant system/diameter/length	Retention system/type of prosthesis/arch	Mean (SD) MBL (mm)	Complications, *n* (type of complications)	Survival rates of implants, *n* (%)	Follow-up, months
26	**26** 7 Fe 19 Ma	57.73	ICC: 13 INC: 13	ICC: SuperLine, Dentium/3.8 mm/NR INC: Zimmer TSV, Zimmer Dental/3.7 or 4.1 mm/NR	NR/single crown and fixed partial denture/maxilla	ICC: 0.21 (±0.56) INC: 0.74 (±0.47)	ICC: 0 INC: 0	ICC: 13 (100%) INC: 13 (100%)	12
27	**64** 80 Fe 61 Ma	45	ICC: 48 INC[1]: 49 INC[2]: 44	ICC: OsseoSpeed, Dentsply Implants INC[1]: NobelSpeedy Replace, Nobel Biocare/NR INC[2]: NanoTite Certain Prevail, Biomet 3i/NR	Cement-retained/single crown/maxilla	ICC: 0.22 (±0.28) INC[1]: 1.20 (±0.64) INC[2]: 1.32 (±1.01)	NR	ICC: 48 (100%) INC[1]: 40 (85.7%) INC[2]: 36 (86.4%)	12
12	**141** 80 Fe 61 Ma	45	ICC: 71 INC: 73	ICC: Way Milano, Geass/ INC: Kentron, Geass/ 3.8–5.5/915 mm for both implants	Cement- or Screw-retained/single crown and fixed partial denture/maxilla and mandible	ICC: 0.73 (±0.07) INC: 0.84 (±0.07)	ICC: 1 (Infection) INC: 1 (Peri-implant soft tissue inflammation)	ICC: 71 (100%) INC: 70 (95.9%)	12
28	**25** 20 Fe 5 Ma	41	ICC: 43 INC: 50	ICC: Nobel Active—Nobel Biocare/NR/NRNobel Replace Tapered INC: Groovy—Nobel Biocare/NR/NR	Cement-retained/NR/mandible and maxilla	ICC: 0.35 (±0.13) INC: 0.83 (±0.16)	NR	ICC: 43 (100%) INC: 50 (100%)	12
9	**86** NR	48	ICC: 84 INC: 86	ICC: NobelActive, Nobel Biocare; INC: NobelReplace Tapered Groovy, Nobel Biocare 3.5–4.3/8–16 mm for both implants	Screw- and Cement-retained/single crown and fixed partial and denture/mandible and maxilla	ICC: 0.85 (±1.32) INC: 0.89 (±1.65)	ICC: 4 (mobility) INC: 5 (peri-implantitis, mobility)	ICC: (95.2%) INC: (93.9%)	36
29	**40** 25 Fe 15 Ma	46	ICC: 20 INC: 20	Samo smiler implants-biospark/NR/NR	Cement-retained/single crown/maxilla	ICC: 0.19 (±0.17) INC: 0.49 (±0.25)	ICC: 0 INC: 2 (loose screw and crown fractured)	ICC: 18 (94,7%) INC: 19 (100%)	12

Abbreviations: EC, external connection; Fe: female; ICC; internal conical connection; INC, internal non-conical connection; Ma, male; NR, not reported; SD, standard deviation.
[a]Considered only implants placed within the same bone level.
[b]Considering dropout of follow-up period.

TABLE 2 Certainty of evidence of evaluated outcomes

Certainty assessment								No. of patients		Effect		
Outcomes	**No. of studies**	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**ICC**	**INCC**	**Relative (95% CI)**	**Absolute (95% CI)**	**Certainty**
Marginal bone loss (mm)	12	RCT	Not serious	Serious[a]	Not serious	Not serious	Strongly suspected[b]	461	531	–	**SMD 0.8** (1.34 lower to 0.25 lower)	⊕⊕◯◯ Low
Prosthodontics complications	9	RCT	Not serious	Not serious	Not serious	Serious[c]	None	0/361 (0.0%)	10/360 (2.8%)	**RR 0.16** (0.04 to 0.68)	**23 fewer per 1.000** (from 27 fewer to 9 fewer)	⊕⊕⊕◯ Moderate
Biological complications	8	RCT	Not serious	Not serious	Not serious	Serious[c]	None	7/315 (2.2%)	8/314 (2.5%)	**RR 0.90** (0.34 to 2.35)	**3 fewer per 1.000** (from 17 fewer to 34 more)	⊕⊕⊕◯ Moderate
Implants survival	11	RCT	Serious[d]	Not serious	Not serious	Serious[c]	None	9/476 (1.9%)	23/530 (4.3%)	**RR 0.54** (0.25 to 1.13)	**20 fewer per 1.000** (from 33 fewer to 6 more)	⊕⊕◯◯ Low

Abbreviations: CI, confidence interval; ICC: internal conical connection; INCC, internal non-conical connection; RCT, randomized clinical trial; RR, risk ratio; SMD, standardized mean difference.
[a]Without overlap of confidence intervals (CI), high I^2 and heterogeneity.
[b]After new analysis without studies with conflict of interest the results were changed.
[c]Optimal information size (OIS) below of 300 events.
[d]Excluding the studies with high risk of bias in the analysis the results were changed.

Reviewer Manager version 5.4 (The Cochrane Collaboration) was used for meta-analysis, which was based on the inversion of variance for continuous outcomes, with marginal bone loss (in mm) being evaluated by standardized mean difference (SMD). For dichotomized outcomes, the Mantel–Haenszel method was used to assess survival and complication rates using risk ratio (RR). For the analysis of complication rates, a sub-analysis was performed considering the different types of complications (prosthodontics and biological). Values were statistically significant at α level of 0.05. The random effects model was used for analyses that revealed qualitatively and significant data heterogeneity ($p < 0.10$). If significant heterogeneity was not observed, the fixed-effects model was considered.[20] A funnel plot (effect size vs. standard error) was drawn to evaluate the publication bias.

An additional analysis was performed to compare the level of Cohen's kappa coefficient ($\varkappa$) for inter investigator agreement during individual searches in the study selection process. The kappa inter investigator agreement for articles selected from MEDLINE/PubMed ($\varkappa = 0.92$), Web of Science ($\varkappa = 0.99$), Embase ($\varkappa = 0.94$), and Scopus ($\varkappa = 0.91$) demonstrated a high level of agreement.[21]

RESULTS

The initial literature search of the various databases retrieved 354 articles: MEDLINE/PubMed, $n = 91$; Web of Science, $n = 89$; Embase, $n = 74$; Scopus, $n = 94$; and ProQuest, $n = 6$. In addition, four registers were retrieved in ClinicalTrials.gov. After importing the results into Rayyan QCRI and removing 123 duplicates, 235 studies were considered for analysis based on title and abstract according to the eligibility criteria. After reading the titles and abstracts, 30 articles were considered for full-text reading, of which 18 were excluded because they did not fulfill the eligibility criteria (Table 2). Thus, 12 RCTs were included.[9,13,22–30] Details of the search are shown in Figure 1.

In total, 678 patients were rehabilitated using a total of 1006 implants: conical connection, $n = 476$; INCC, $n = 530$ (internal hexagon, internal butt joint, and internal tri-channel connections). Various implant systems, dimensions, and retention systems were investigated among the included studies. Most studies investigated single-unit rehabilitation of implants in the mandibular and maxillary arches. The mean follow-up was 17 months (range from 12 to 36 months) (Table 1).

INCC demonstrated higher values of marginal bone loss compared with ICC ($p = 0.004$), with an SMD of −0.80 mm (95% confidence interval [CI] −1.34 to −0.25 mm). Although most studies reported a favorable trend for conical internal connections, significant heterogeneity among the studies was observed ($p < 0.00001$; $I^2 = 94\%$) (Figure 2).

Additionally, ICC implants were associated with a lower incidence of prosthodontics complications ($p = 0.01$). The RR observed between the analyzed groups was 0.16 (95% CI

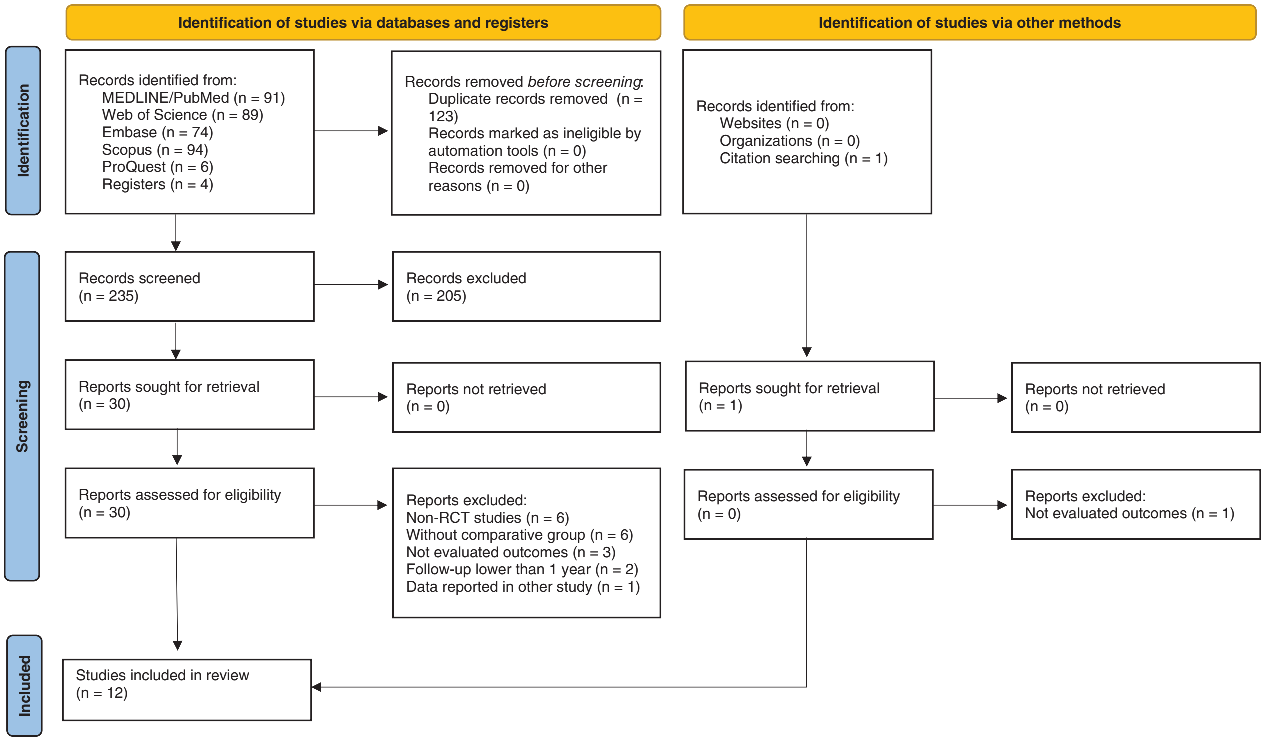

FIGURE 1 Flow diagram describing the search strategy.

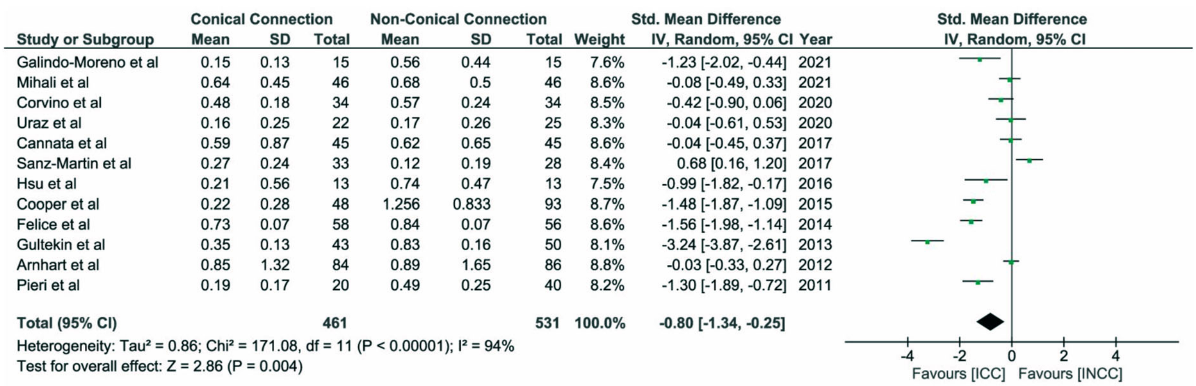

FIGURE 2 Forest plot of marginal bone loss event.

0.04–0.68). Prosthodontics complications included ceramic chipping, screw and crown loosening, and abutment and crown fractures. However, when analyzing the rates of biological complications, no differences were observed between the different types of internal connections (RR 0.90 [95% CI 0.34–2.35]; $p = 0.82$). Analysis of prosthodontics and biological complication rates revealed no significant heterogeneity ($p = 0.95$, $I^2 = 0\%$; $p = 0.82$; $I^2 = 0\%$ for both analyses, respectively) (Figure 3).

Regarding implant survival rates, no significant difference was observed between the internal conical and INCC implants (RR 0.54 [95% CI 0.25–1.13]; $p = 0.10$). Moreover, no significant heterogeneity was detected ($p = 0.30$; $I^2 = 17\%$) (Figure 4).

The RoB 2.0 plots are shown in Figure 5. Most RCTs were classified as "low risk of bias," whereas four were considered to have some "concerns." Two studies reported a high risk of bias for bias during randomization process[23] and bias due to deviations from intended intervention.[10] The judgment related to some concerns was attributed to bias due to deviations from intended intervention,[23,28] bias due to missing outcome data,[13,28] bias in the measurement of outcome,[13,30] and bias in the selection of the reported results.[9,10,13,27,28,30] The funnel plots showed slight asymmetry (mainly marginal bone loss) indicating a possible publication bias or small study effect size (Figure 6).

The certainty of evidence of the outcomes evaluated using the GRADE approach showed low certainty of evidence for marginal bone loss and implant survival rate, and moderate certainty of evidence for prosthodontics and biological complications. The explanation about the downgraded for each outcome was reported in Table 2.

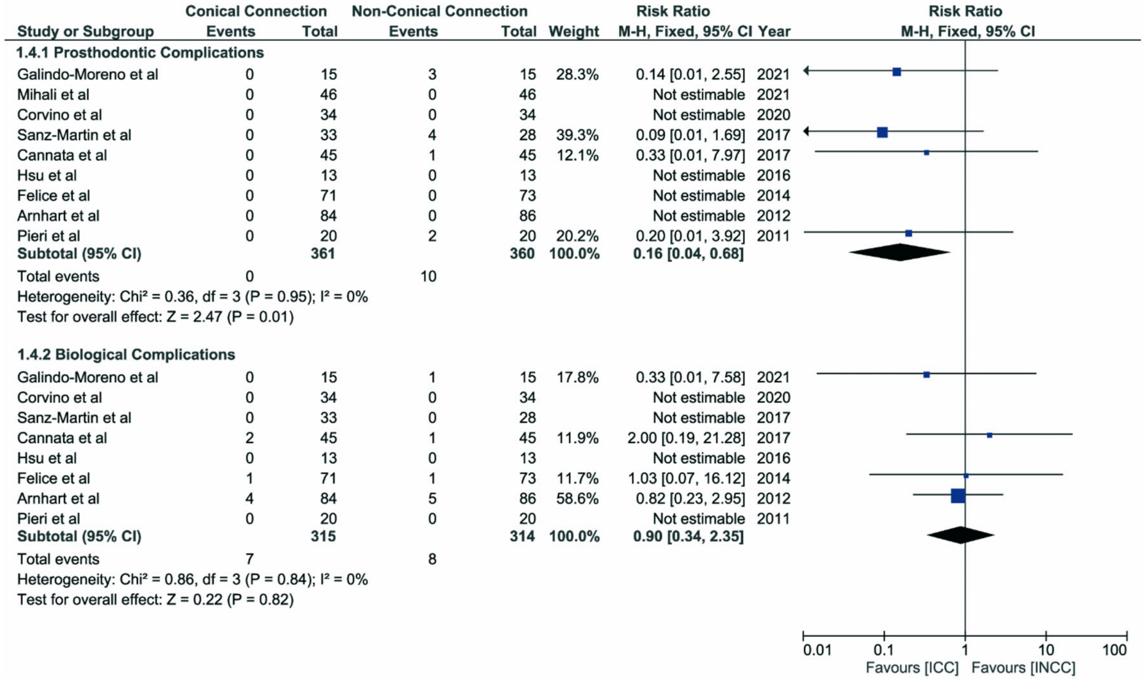

FIGURE 3 Forest plot of subgroup analysis considering the prosthodontic and biological complications event.

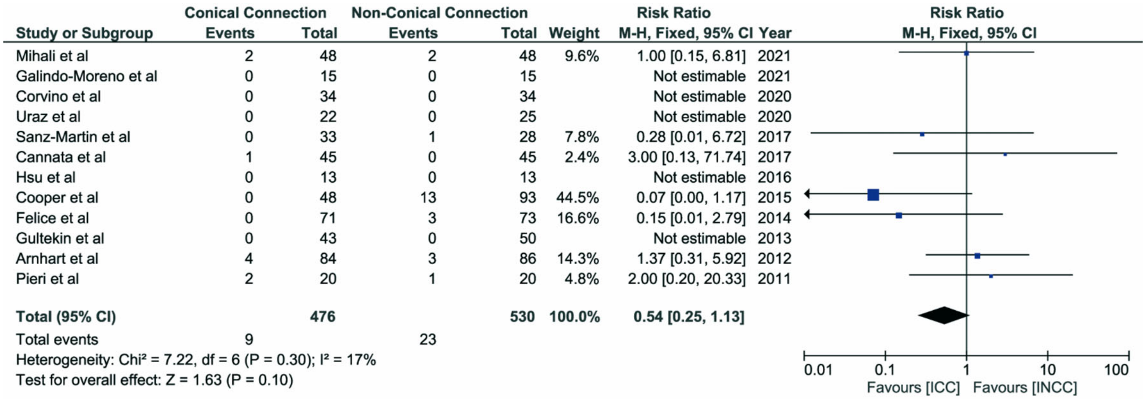

FIGURE 4 Forest plot of implants survival event.

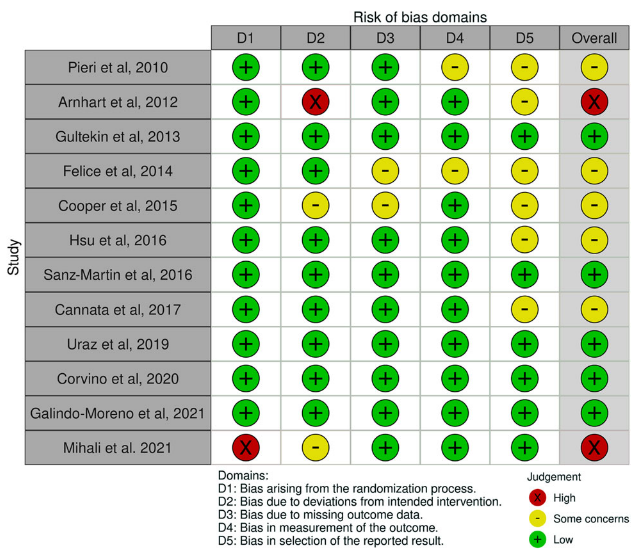

FIGURE 5 Risk of bias using the tool RoB 2.0 of included studies.

DISCUSSION

The hypothesis tested in the present study—that there is no influence of the type of internal connection on the values of marginal bone loss—was rejected because higher marginal bone loss was observed for INCC. Although previous studies have highlighted the superiority of internal connections,[5–7] the comparative relationship between different internal connections (i.e., internal conical vs. internal non-conical) was less evident in the literature.[6]

One of the possible reasons for the superiority of ICC may be linked to biological factors such as greater sealing capacity,[31] which reduces microgaps and increases resistance to bacterial infiltration.[32,33] However, other studies have reported no differences in resistance against bacterial microleakage between various types of internal connections.[34,35]

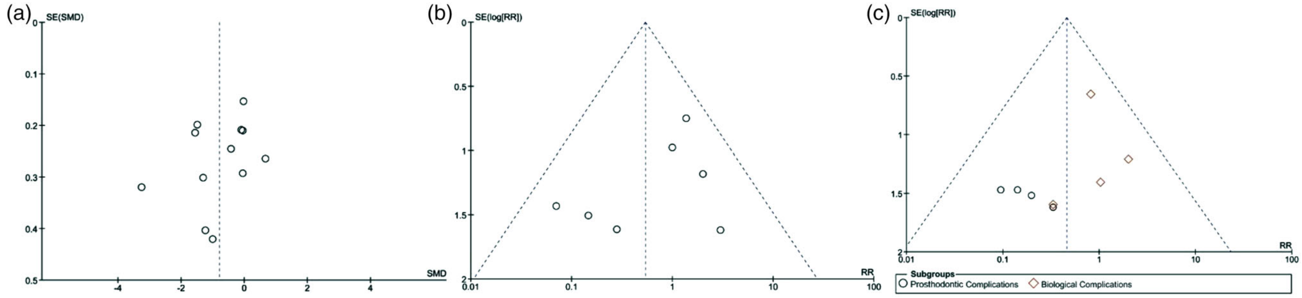

FIGURE 6 Funnel plot of each evaluated outcomes: (a) marginal bone loss; (b) implants survival rates; (c) complication rate (prosthodontics and biological).

Another factor that may contribute to higher bone preservation with ICC is related to biomechanics. Many ICC implants exhibit a platform switching design,[36] which contributes to the centralization of stresses in the long axis of the implant[37,38] and reduces stresses in the peri-implant region. In addition, the stabilization of the conical connection reduces micro-movement between the implant/abutment when compared to non-conical connection implants,[22,33,36] which also contributes to the superiority of these implants.

In the meta-analysis, most studies reported lower marginal bone loss for implants with ICC, except for one that demonstrated significant favorable differences—but of small magnitude—for INCC.[26] This difference may be not related to the connection itself but to the difference in the type of implant (one-piece vs. two-piece), as well as the higher rates of plaque and bleeding in the group experiencing greater marginal bone loss.[26]

Differences among the selected studies, as well as the lack of standardization of the reported data, may have contributed to the increase in data heterogeneity. However, it is important to note that all studies, except for one,[28] reported bone loss values <1 mm for both groups. This can be explained by the fact that many studies had a follow-up period of 1 year, which should be considered a limitation of those studies. Thus, further RCTs with long-term follow-ups are recommended to confirm these results.

The same biomechanical relationship that may have contributed to lower marginal bone loss may have also reduced the incidence of prosthodontics complications for ICC implants, thus rejecting the second hypothesis. Coppedê et al.[39] reported that the force required to cause deformation or fracture of ICC implants must be greater than that of internal non-conical connection implants. This emphasizes the higher incidence of loosening and fractures of the screws and crowns in this group. Only four studies reported prosthodontics complications, and two studies contributed significantly to the differences between the groups evaluated.[22,26] Sanz-Martín et al.[26] reported that an additional 20° of conical internal connection implants promote greater stability and, consequently, lowers the risk for prosthodontics failure(s). Galindo-Moreno et al.[22] reported that the use of screw-retained metal-ceramic crowns in UCLA abutments could be even more impaired in cases of internal non-conical implants. Therefore, these factors must be considered during reverse treatment planning. However, owing to the reduced incidence of prosthodontics failures, a longer follow-up period is recommended.

Regarding implant survival rates, the hypothesis was accepted given that no significant differences were found between both connections. These findings should also be interpreted with caution considering that the mean follow-up period of the included studies was 14 months, with most studies having a follow-up of 1 year. The literature recommends a minimum of 5 years to assess the survival rate of dental implants[40]; however, these studies were included due to only three studies[10,23,26] comparing this variable with a follow-up period of up to 1 year. Short follow-up period was one of the main limitations of this systematic review, thus highlighting the need for new studies with longer follow-up periods to support the conclusions, especially regarding implant survival rates. In addition, uncontrolled and non-standard factors between included studies related to the study designs, abutment conical degrees, implant systems, dimensions, retention systems, implant geometry, rehabilitated arch, prosthesis type, and restorative materials may directly affect the data heterogeneity of evaluated outcomes. However, sub-analyses considering possible variables were not possible due to the absence of information by included studies or a small number of comparative studies. Therefore, the results should be interpreted with caution, and further studies investigating this association may overcome these limitations.

CONCLUSION

ICC implants may be considered a more favorable treatment option than INCC for the rehabilitation of edentulous patients because they result in greater preservation of peri-implant bone tissue and a lower possibility of prosthodontics complications. However, further studies with longer follow-up periods are warranted.

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CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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