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Systematic Review

Effect of Different Dental Implant Prosthetic Joints on Marginal Bone Loss: Emerging Findings from a Bayesian Network Meta-Analysis (NMA) and Systematic Review

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Abstract: Background: A key point in assessing dental implant prosthetic joints is their mechanical strength and biological response under the masticatory loading. The aim of the present systematic review was to evaluate the marginal bone loss and prosthetic behaviour of different internal/external bi-phasic implants. Methods: Randomized Clinical Trials (RCTs) have been considered for analytic purposes. The article screening was conducted on the Pubmed/MEDLINE, EMBASE and Google Scholars databases through an electronic process. Eligibility and risk of bias assessments were conducted for an article to be included in the data process. A series of pairwise meta-regressions for continuous variables was conducted considering the mean differences and 95% CI at two different timepoints: baseline and 1-year follow-up. The meta-analysis was performed comparing the following groups: internal conical prosthetic joint with index (IC), external hexagon bone level position (EI), internal tri-channel connection bone level position (ITC), internal hexagon 1 mm below the bone level (HI), internal hexagon bone level position (HI crest), cone morse 1 mm below the bone level (CM), cone morse bone level position (CM crest) and internal octagon bone level position (IO). The following parameters were considered for descriptive data synthesis: sample size, implant manufacturer, prosthetic joint type, prosthetic complications, marginal bone loss, study outcomes. Results: A total of 247 papers were identified by the electronic screening and 241 were submitted for the full text assessment. The eligibility process excluded 209 articles, and 32 studies with a low risk of bias were considered for the qualitative synthesis and further statistical methods. At the baseline, the CM showed a more effective efficiency and reduced marginal bone loss compared to IC, EI, ITC, internal hexagon, cone morse and internal octagon ($p < 0.05$). CM showed the lower rate of prosthetic complications and structural device failure including abutments and joint components under the loading compared to other joint types. Conclusion: Within the limits of the present investigation, the heterogeneity, the weight of the study model considered and the inherent differences between the dental implant properties, the pure CM showed a more consistent control of marginal bone loss at short- and medium-term follow-up. Despite the low rate of cumulative complications for all joints considered, the CM abutment joints were less prone to prosthetic failure at an early and medium-term follow-up.

Keywords: dental implant therapy; dental implant-abutment connection; implant-supported dental prosthesis; prosthetic loading

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1. Introduction

The implant–abutment joint is a well-known factor in two stage implantology due to the related biological and biomechanical implications. A submerged implant is considered to be a supportive protocol to avoid early biofilm colonization and preserve the osteointegration process during the early healing phases from bacteria and local inflammatory stress [1,2]. On the contrary, immediate functional loading could emphasize solicitations at the level of the peri-implant marginal components and consequently produce a consistent instability in the peri-implant soft and hard tissues [3]. As such, the implant–abutment design, the length and the stability of the prosthetic joint and the platform components' tolerance play a key role in the creation of a hypothetical bacterial reservoir and sustaining a chronic inflammatory status, triggering peri-implant marginal bone loss (MBL) [4]. In the literature, the implant's success is considered with a −1.5 mm MBL during the first year after loading and afterwards <0.2 mm/year [5–7]. Different factors have been recognized as being correlated with peri-implant marginal bone resorption. The most extensively investigated factor is the peri-implant inflammation reaction that is recognized to be a consequence of bacteria colonization at the level of the dental implant interfaces [8]. The biofilm adhesion is determined a few seconds after the surface's exposure to the oral cavity environment [8]. The prosthetic joint micro-gap could potentially generate a reservoir of bacteria and biofilm subproducts resulting in chronic inflammation at the level of the surrounding tissues [9]. In fact, the microleakage is able to produce a pump effect under the functional loading determined by the mismatch generated by the abutment joint prosthetic components [9,10]. At present, microleakage prevention seems to be the main challenge for transmucosal dental implants design. In the literature, many different prosthetic joint design have been investigated for this purpose [11,12]. The most common implant joint in the market are external connection, internal connection and conical/cone morse joint [7,13]. The aim of the present systematic review was to determine the more recent evidence regarding dental implant prosthetic joint design through a network meta-analysis.

2. Materials and Methods

2.1. Search Strategy

The present study has been registered on International Prospective Register of Systematic Reviews (PROSPERO) prot. n. CRD42024500303. The database screening has been performed following the PRISMA guidelines and checklist (Suppl. S1) (Preferred Reporting Items for Systematic Reviews and Meta-analyses) [14] and was conducted on the Pubmed/MEDLINE database, Google Scholar, Scopus and Web of Science using the following keywords: (dental implant* OR dental prosth* OR implant-supported prosth* OR endosseous implant*) AND (conical OR tapper OR tapered OR fractional OR locking)) and (internal connection OR internal hexagon OR non conical OR non tapered OR internal tri-channel OR butt-joint)) AND (survival OR success OR bone loss OR bone level OR complications). The PICO question has been detailed:

(1) P = Population/Patient/Problem—Subjects needing dental implant for prosthetic rehabilitations;
(2) I = Intervention—dental implant treatment positioning and fixed oral rehabilitation;
(3) C = Comparison—comparison between different internal, external and conical prosthetic joint;
(4) O = Outcome—Marginal bone loss, major prosthetic complications.

2.2. Inclusion Criteria

The articles written in English language were included with no restrictions regarding the date publication. The titles and abstracts list were considered for a first-level initial screening by two independent reviewers (FL, IA). Clinical trials were included for descriptive synthesis and meta-regression.

2.3. Study Data Extraction

The following parameters were extracted from the selected studies: publication date, study model design, population size, age, marginal bone loss, prosthetic complications, follow-up. For the scope of this article, a specially designed electronic database form has been used (Excel, Microsoft Office 360, Redmont WA, USA).

2.4. Risk of Bias (RoB)

The Risk of Bias Rating Tool for Human and Animal Studies (OHAT) tool has been assessed to measure the risk of bias of the articles assessed. The assessment categories were "low risk", "unclear risk" and "high risk" of bias [15].

The tool categories considered were: random sequence generation, allocation concealment, blinding of patients and personnel, blinding of outcome assessment, attrition bias, reporting bias and other biases [15].

2.5. Heterogeneity and Meta-Analysis Assessment

The high heterogeneity is determined by the differences in articles' publication year, study model design, healing duration period, and sample size. The meta-regression has been conducted through the dedicated statistical software package Review Manager (RevMan 5.0, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) and the freely available MetaInsight v5.1.2 software (Shinyapps, Leicester, UK) for continuous variables with full R code [16].

2.6. Inconsistency Assessment

The node-splitting measurement has been conducted to evaluate the inconsistency of the variables' comparison. No inconsistency was considered at $p > 0.05$. The level of evidence was assessed by the CINeMA (Confidence in Network Meta-Analysis) system [17,18].

2.7. Study Data Analysis

Bayesian NMA was performed using the Bayesian framework with random-effects hierarchical models through the freely available MetaInsight v5.1.2 software (Shinyapps, Leicester, UK) for continuous variables with full R code [16]. A forest plot of relative effects from Bayesian random effect has been calculated to evaluate the consistency model and the significance of the ranks. The I^2 test considered a low heterogeneity with a value <40%. For I^2 test > 40%, the heterogeneity was further investigated through meta-regressions. The data were presented considering the mean differences and the 95% CI of the means. The surface under the cumulative ranking curve (SUCRA) rank-o-gram has been applied to assess the robustness of the comparison categories.

3. Results

3.1. General Parameters

The electronic search identified a total of 247 articles. A total of three duplicates and three articles written in a non-English language have been removed (Figure 1). A total of 241 papers were submitted to the eligibility process by two independent reviewers. The reasons for excluding papers were: ninety-one articles were off topic, eighty-four were conducted with the wrong study design (invitro/in silico/on animal model), seventeen were literature reviews, fourteen studies used the wrong sampling and three studies had incomplete reporting regarding the implant prosthetic joint type. A total of thirty-two articles were considered for the descriptive synthesis and meta-regression analysis.

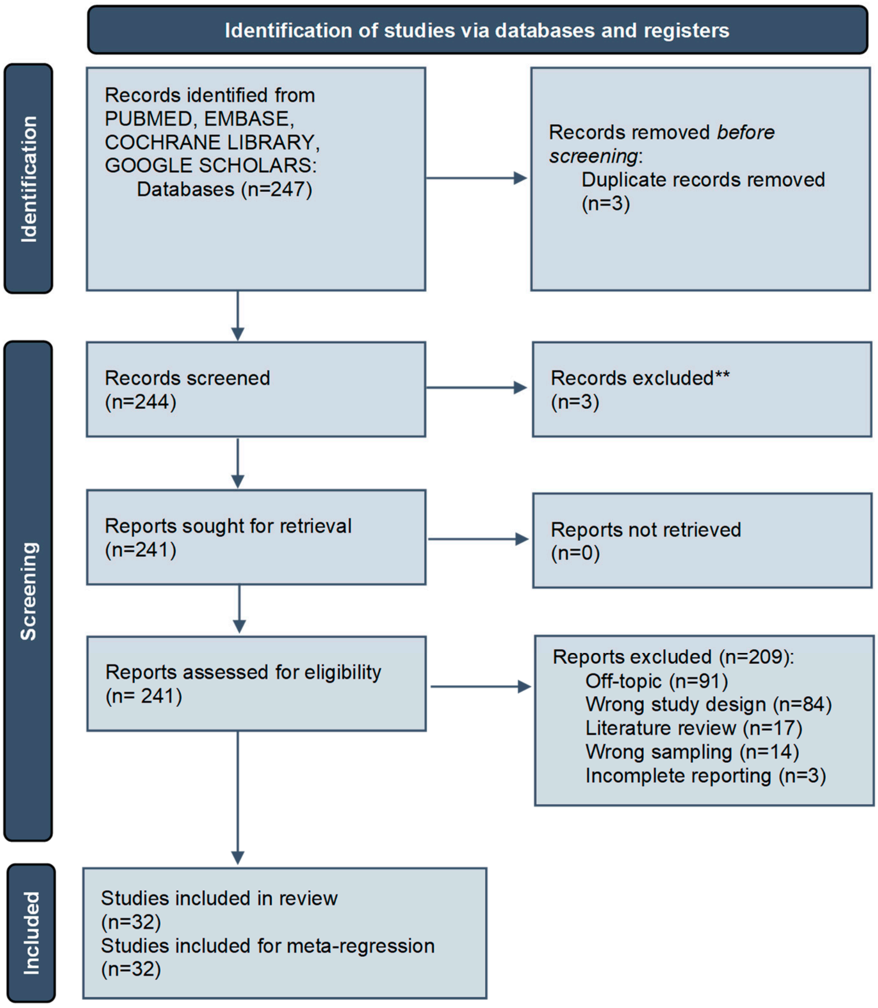

Figure 1. Article screening process following the PRISMA guidelines [**record exclusion performed by automated tool] [14].

A cumulative total of 2064 patients [mean: 64.5; sd: 45.2; 95 CI: 48.2-80.8] and 4943 implants [mean: 156.1 sd:149.1; 95 CI: 102.3-209.8] have been evaluated in the present analysis (Table 1).

Table 1. Search strategy for the electronic database screening.

	Search Strategies
Keywords search:	(dental implant* OR dental prosth* OR implant-supported prosth* OR endosseous implant*) AND (conical OR tapper OR tapered OR fractional OR locking)) and (internal connection OR internal hexagon OR non conical OR non tapered OR internal tri-channel OR butt-joint)) AND (survival OR success OR bone loss OR bone level OR complications)
Timespan	No limitations (1995–2023)
Electronic Databases	Pubmed/Medline, EMBASE, Google scholars

A total of eight different prosthetic joint connections have been considered: internal hexagonal joint 1 mm below the bone level position [19–27], internal hexagonal joint at bone level position [19], external hexagonal joint at bone level position [23,25,26,28–31], Internal conical prosthetic joint with index [19,22,27,28,31–46], cone morse 1 mm below the bone level position [23–26,30,47–49], cone morse at the bone level position [49], internal octagon [26] and internal tri-channel connection bone level position [49]. The median follow-up period was 12 months [range: 3-156 months] (Table 1).

3.2. Prosthetic Complications and Joint Failure

The most common prosthetic joint complications, including provisional/final crown debonding, provisional/final abutment screw loosening, provisional/final framework fracture, chipping/cracking of veneering material, no mechanical failure and prosthetic joint failure, have been detected for all included studies (Tables 2 and 3).

Table 2. Descriptive synthesis of the studies included.

Author	Journal	Year	Population	Implant	Connection
Arnhart C	Eur J Oral Implantol.	2012	177 patients	325 implants	Internal Conical Prosthetic Joint W/Index External Hexagon Internal Tri-Channel Connection
Ackermann KL	Int J Implant Dent	2020	94 patients	130 implants	Internal Conical Connection W/Index
Cannata M	Eur J Oral Implantol	2017	90 patients	90 implants	Internal Hexagon Internal Conical Prosthetic Joint W/Index
Ceruso FM	Materials	2022	30 patients	30 Implants	Internal Hexagon Internal Conical Prosthetic Joint W/Index
Ceruso FM	Dent J (Basel)	2021	13 patients	13 implants	Internal Hexagon Connection
Corvino E	Int J Oral Implantol (Berl)	2020	33 patients	53 implants	Internal Hexagon Internal Conical Prosthetic Joint W/Index
de Melo L.A.	Braz Dent J	2017	20 patients	40 implants	External Hexagon Cone Morse
Fügl A.	Clin Oral Invest	2017	97 patients	102 implants	Internal Conical Connection W/Index
Galindo-Moreno P	Clin Oral Implants Res	2022	19 patients	160 implants	Internal Conical Prosthetic Joint W/Index
Galindo-Moreno P	J Clin Med	2021	30 patients	30 implants	Internal Conical Prosthetic Joint W/Index
Galindo-Moreno P	Clin Oral Implants Res	2016	108 patients	228 implants	Cone Morse
Galindo-Moreno P	J Dent Res	2014	131 patients	315 implants	Internal Conical Prosthetic Joint W/Index
Gualini F.	Eur J Oral Implantol	2017	60 patients	120 implants	Internal Conical Connection W/Index
Inoue M	Clin Implant Dent Relat Res	2020	140 patients	310 implants	Internal Hexagon Internal Conical Prosthetic Joint W/Index
Kaminaka A	Clin Implant Dent Relat Res	2015	33 patients	34 implants	Internal Hexagon External Hexagon Cone Morse

Table 2. *Cont.*

Author	Journal	Year	Population	Implant	Connection
Lin MI	J Dent Res	2013	63 patients	103 implants	External Hexagon Internal Octagon Cone Morse
Lombardi T.	J. Clin. Med.	2019	55 patients	83 implants	Internal Conical Connection W/Index
Lops D	J Clin Med	2022	80 patients	312 implants	Internal Conical Prosthetic Joint W/Index
Lops D	Materials	2020	93 patients	410 implants	Internal Conical Prosthetic Joint W/Index
Machtei EE	Clin Oral Implants Res	2006	27 patients	73 implants	External Hexagon Cone Morse
Moergel M	Clin Oral Implants Res	2021	24 patients	52 implants.	Internal Conical Connection W/Index
Moergel M	Clin Oral Implants Res	2016	24 patients	52 implants	Internal Conical Connection W/Index
Oda Y	Clin Oral Implants Res	2021	60 patients	592 implants	Internal Hexagon External Hexagon Cone Morse
Ogino Y	Int J Oral Maxillofac Implants	2021	25 patients	30 implants	Cone Morse
Palaska I	Clin Oral Implants Res	2016	81 patients	105 implants	Internal Polygonal Butt-Joint Cone Morse
Pieri F	Int J Oral Maxillofac Implants	2011	40 patients	40 implants	Internal Hexagon Cone Morse
Pozzi A	Int J Oral Maxillofac Implants	2016	64 patients	148 implants	Internal Conical Connection W/Index
Pozzi A	Eur J Oral Implantol	2015	54 patients	118 implants	Internal Conical Connection W/Index
Pozzi A	Clin Implant Dent Relat Res	2014	34 patients	68 implants	External Hexagon Internal Conical Prosthetic Joint W/Index
Rasouli Ghahroudi A	J Dent (Tehran)	2010	31 patients	170 implants	Internal Conical Prosthetic Joint W/Index
Szyszkowski A	Implant Dent	2019	184 patients	540 implants	Internal Conical Connection W/Index
Toia M	Clin Oral Implants Res	2022	50 patients	119 implants	Internal Conical Prosthetic Joint W/Index

Table 3. Descriptive synthesis of the included study.

Author	Journal	Year	Prosthetic Complications	Follow Up	Marginal Bone Loss	Outcomes
Arnhart C	Eur J Oral Implantol.	2012	prov. debonding (n = 9) prov. Abut. screw loose (n = 5) prov. framework fracture (n = 3) chipping veneering mat. (n = 7) restoration debonding (n = 2) screw loosening (n = 1) occlusal adjustments (n = 1)	3 years	(a) baseline IC: −0.60 ± 0.83 mm; EH: −1.01 ± 1.02 mm; ITC: −0.84 ± 1.09 mm; (b) 1 year: IC: −1.48 ± 1.26 mm; EH: −1.66 ± 1.04 mm; ITC: −1.49 ± 0.96 mm; (c) 2 year: IC: −1.41 ± 1.54 mm; EH: −1.18 ± 0.91 mm; ITC: −1.71 ± 1.28 mm;	Stable or improving bone levels for all implant groups after the initial tissue remodelling.
Ackermann KL	Int J Implant Dent	2020	Crown loosening (3) Ceramic chipping (1)	5 years	(a) baseline: −0.52 ± 0.55 mm (b) 1 year: −0.04 ± 0.37 mm (c) 2 years: −0.04 ± 0.40 mm (d) 5 yars: −0.09 ± 0.43 mm	High peri-implant tissue stability over the 5 to 7 years of follow up.
Cannata M	Eur J Oral Implantol	2017	Screw loosening (2) [HI group]	1 year	(a) baseline: IC: 0.03 ± 0.06 mm; HI: 0.02 ± 0.05 mm (b) 1 year: IC:0.59 ± 0.61 mm; HI. 0.56 ± 0.53 mm	No significant differences concerning ICC and HI concerning marginal bone loss.
Ceruso FM	Materials	2022	None	1 year	(a) Baseline: IC: 0.04 ± 0.06; HI: 0.01 ± 0.02 (b) 1 year: IC: 0.99 ± 0.71; HI: 0.65 ± 0.48	Similar findings regarding marginal bone levels, implant survival, and periodontal parameter
Ceruso FM	Dent J (Basel)	2021	-	1 year	(a) 1 year: 0.65 ± 0.48 mm	The IH implants showed no mechanical complications.
Corvino E	Int J Oral Implantol (Berl)	2020	-	1 year	(a) baseline: CS: 0.33 ± 0.34 mm; HI: 0.43 ± 0.37 (b) 1 year: CS: 0.48 ± 0.18 mm; HI: 0.57 ± 0.24 mm	ICC seems to be correlated to lower level of MBL after the loading.

Table 3. *Cont.*

Author	Journal	Year	Prosthetic Complications	Follow Up	Marginal Bone Loss	Outcomes
de Melo L.A.	Braz Dent J	2017	-	1 year	(a) baseline: EH: −0.34 ± 1.90; CS: 0.12 ± 1.83 (b) 1 year: EH: −1.28 ± 1.68; CS: −0.73 ± 2.54	Significantly higher marginal bone loss of HE compared to CM. Success rate in the groups EH of 100% and MT of 94.4%.
Fügl A.	Clin Oral Invest	2017	-	1 year	(a) baseline: −0.37 ± 0.75 mm (b) 6 months: −1.35 ± 1.16 mm (c) 1 year: −1.25 ± 1.15 mm	Marginal bone levels followed the expected initial bone loss, and soft-tissue outcomes improved suggesting favorable tissue response.
Galindo-Moreno P	Clin Oral Implants Res	2022	14 implants > 2 mm of MBL (8.75%)	5 years	baseline: −0.423 ± 0.069	Abutment height 1 mm more MBL than 2, 4 and 6 mm. Narrow implant more MBL then wider diameter implant
Galindo-Moreno P	J Clin Med	2021	Ceramic chipping (1) [HI]	12 months	(a) 1 year: IC: −0.25 (0.12) HI: −0.70 (0.43)	HI implants produce higher MBL after 12 months of follow-up
Galindo-Moreno P	Clin Oral Implants Res	2016	-	18 months	(a) baseline: −Implant diam. 4.5: Short abutment: 0.562 ± 0.09 mm Long abutment: 0.195 ± 0.05 mm −Implant diam.Short abutment: 5.0 mm: 0.557 ± 0.21 mm Long abutment: 0.549 ± 0.06 mm	Abutment height seems to affect MBL at the short/medium term period.
Galindo-Moreno P	J Dent Res	2014	-	18 months	(a) baseline: SA: 0.210 ± 0.025 mm LA: 0.068 ± 0.015 (b) 1 year: SA: 0.681 ± 0.051 mm LA: 0.316 ± 0.042	Higher MBL associated with short abutment height. butment height is a key factor in MBL. MBL is higher during the first 6 months post-loading.

Table 3. *Cont.*

Author	Journal	Year	Prosthetic Complications	Follow Up	Marginal Bone Loss	Outcomes
Gualini F.	Eur J Oral Implantol	2017	Crown loosening (1)	1 year	(a) baseline: 0.5 mm subcrestal: 0.07 ± 0.21 mm; 1.5 mm subcrestal: 0 04 ± 0.13 mm (b) 2 months: 0.5 mm subcrestal: 0.16 ± 0.30 mm; 1.5 mm subcrestal: 0 10 ± 0.38 mm (c) 1 year: 0.5 mm subcrestal: 0.21 ± 0.51 mm; 1.5 mm subcrestal: 0 11 ± 0.36 mm	No significant differences concerning implants positioned 0.5 mm or 1.5 mm subcrestally
Inoue M	Clin Implant Dent Relat Res	2020	-	1 year	(a) baseline: 0.61 ± 0.43 mm	ICC showed lower MBR compared to internal connection. No significant difference in mBI and MBL comparing cement and screw crowns.
Kaminaka A	Clin Implant Dent Relat Res	2015	-	1 year	(a) baseline: EH: −0.08 ± 0.33 mm; IH: 0.21 ± 0.32; CM:−0.04 ± 0.84 (a) 1 year: EH:−1.94 ± 0.87 mm; IH: −0.79 ± 1.30; CM: 0.25 ± 0.87	Implants with a conical connection preserve peri-implant alveolar bone and soft tissue more effectively than other connection types.
Lin MI	J Dent Res	2013	-	6 months	(a) baseline: EH: –0.45 ± 0.19 mm IO: 0.44 ± 0.15 mm; CM: –0.38 ± 0.14 mm (b) 3 months: EH: –0.21 ± 0.13 mm IO: –0.18 ± 0.12 mm; CM: –0.19 ± 0.11 mm (c) 6 months: EH: −0.32 ± 0.19 mm IO: –0.38 ± 0.22 mm; CM: –0.32 ± 0.14 mm	Implant–abutment connection appears to have no significant impact on short-term MBL.

Table 3. *Cont.*

Author	Journal	Year	Prosthetic Complications	Follow Up	Marginal Bone Loss	Outcomes
Lombardi T.	J. Clin. Med.	2019	-	1 year	(a) baseline: 0.46 ± 0.59 mm (b) 2 months: 0.5 ± 0.34 mm (c) 3 months: 0.18 ± 0.22 mm (d) 9 months: 0.11 ± 0.20 mm (e) 15 months: 0.00 ± 0.19 mm	Peri-implant bone levels seems to be stabilized over long-term loading.
Lops D	J Clin Med	2022	None	3 years	Emergency angle > 30°: MBL: 0.25 ± 0.3 mm Emergency angle < 30°: MBL: 0.4 ± 0.3 mm	The emergency angle seems to play no significant effect on MBL at 3-year follow up
Lops D	Materials	2020		9 years	(a) Baseline: −1.09 ± 0.65 mm (b) 9 years: −1.00 ± 0.37 mm	MBL are correlated to the implant's vertical position and the of type-2 controlled diabetes comorbidity
Machtei EE	Clin Oral Implants Res	2006	-	2.9 years	(a) baseline: EH: 2.15 ± 0.67 mm; CM: 0.95 ± 0.21 mm	Similar clinical and MBL response. Non-submerged implants might suggest future higher bone resorption compared to submerged healing protocol.
Moergel M	Clin Oral Implants Res	2021	Screw fracture (1):	5-year	(a) Baseline: −0.5, ± 0.4 mm (b) 60 months: 0.27 ± 0.47 mm	Conical abutment-joint connection was associated with a marginal bone levels maintainment after 5 years of loading
Moergel M	Clin Oral Implants Res	2016	Screw fracture (1)	1 year	(a) Baseline:0.53 ± 0.40 mm; (b) 1 year: 0.12 ± 0.42 mm (c) 18 months: 0.11 ± 0.36 mm	No implant loss after 1 year of loading

Table 3. *Cont.*

Author	Journal	Year	Prosthetic Complications	Follow Up	Marginal Bone Loss	Outcomes
Oda Y	Clin Oral Implants Res	2021	-	13 years	(a) FSI: 0.60 ± 0.51; FTI: 0.41 ± 1.03 mm	FSI and FTI implants showed similar MBL. HI and HE showed higher MBL compared to Cone Morse abutment joint connection
Ogino Y	Int J Oral Maxillofac Implants	2021	-	3 years	(a) Baseline: −0.41 ± 0.61 mm (b) 1 year: −0.08 ± 0.54 mm (c) 3 years: −0.04 ± 0.95 mm	ICC are able to prevent marginal bone loss after 3 years of follow up
Palaska I	Clin Oral Implants Res	2016	-	3 months	(a) baseline: Group 1HI [subcrestal]: 0.68 ± 0.07 mm, Group 2 HI [crestal]: 0.79 ± 0.06 mm, Group 3 CM [subcrestal]: 0.49 ± 0.06 mm, Group 4CM [subcrestal]: 0.40 ± 0.07 mm.	The fixture/abutment joint rather than vertical implant placement in relation to marginal bone level seems to affect peri-implant marginal bone resorption
Pieri F	Int J Oral Maxillofac Implants	2011	-	1 year	(a) baseline: HI: 0.51 ± 0.24 mm; CM: 0.2 ± 0.17 mm	Slight difference in MBL in favour of cone morse joint group.
Pozzi A	Int J Oral Maxillofac Implants	2016	-	2 years	(a) baseline: 0.42 ± 1.16 mm 1 year: 0.71 ± 1.53 mm 2 years: 0.17 ± 1.01 mm	Immediately loaded implants revealed well-maintained MBL, and soft tissue conditions.
Pozzi A	Eur J Oral Implantol	2015	Crown failure (1)	3 years	(a) baseline: 0.42 ± 0.29 mm (b) 1 year: 0.19 ± 0.21 mm (c) 2 years: 0.07 mm ± 0.13 mm	Prosthetic Cumulative Success Rate (CSR) of 98.15 for ICC.
Pozzi A	Clin Implant Dent Relat Res	2014		1 year	(a) baseline: CM: 0.37 ± 0.23 mm EH: 0.95 ± 0.56 mm (b) 1 year: 0.14 ± 0.20 mm EH: 0.16 ± 0.19 mm	Lower MBL of back-tapered neck compared to external hexagon joint.

Table 3. *Cont.*

Author	Journal	Year	Prosthetic Complications	Follow Up	Marginal Bone Loss	Outcomes
Rasouli Ghahroudi A	J Dent (Tehran)	2010	-	1 year	(a) baseline: 0.935 ± 0.905 mm	ICC seems to provide a useful maintenance of the peri-implant bone levels at 1 year follow-up.
Szyszkowski A	Implant Dent	2019	-	2 years	(a) baseline: 0.99 ± 0.79 (b) 1 year: 1.12 ± 1.00 (c) 2 years: 1.22 ± 1.03 (d) 3 years: 1.30 ± 1.15	ICC revealed lower MBL compared to internal hexagon joint connection. Both of implant groups revealed 100% survival rate.
Toia M	Clin Oral Implants Res	2022	(a) Screw loosening (2): [Abutment level Group (AL) (1)/Implant level Group (IG) (1)] (b) Screw fracture (2): [Abutment level Group (AL)]	3 years	(a) Baseline: AL: 0.11 ± 0.24; IC: 0.15 ± 0.31 (b) 1 year: AL: 0.12 ± 0.31; IC: 0.23 ± 0.26 (c) 2 years: A(L: 0.15 ± 0.34; IC: 0.17 ± 0.22 (d) 3 years: AL: 0.18 ± 0.39; 0.15; IC: 0.21	The MBL change was similar in the groups. No relevant complicaitons were detected in the soft tissue.

3.3. Risk of Bias Assessment

The risk of bias assessment is shown in Figures 2 and 3. The randomization bias [43% wlr; 7% ur; 50% whr], selection bias [92% wlr; 8% ur; 5% whr], performance bias [28% wlr; 20% ur; 52% whr], detection bias [28% wlr; 20% ur; 52% whr], attrition bias [79% wlr; 21% ur; 0% whr], reporting bias [87% wlr; 13% ur; 0%whr] and other bias [100% wlr; 0% ur; 0% whr]. A total of twelve studies reported a low risk of bias [22,24,30,31,34,36,37,39,42,43,49,50].

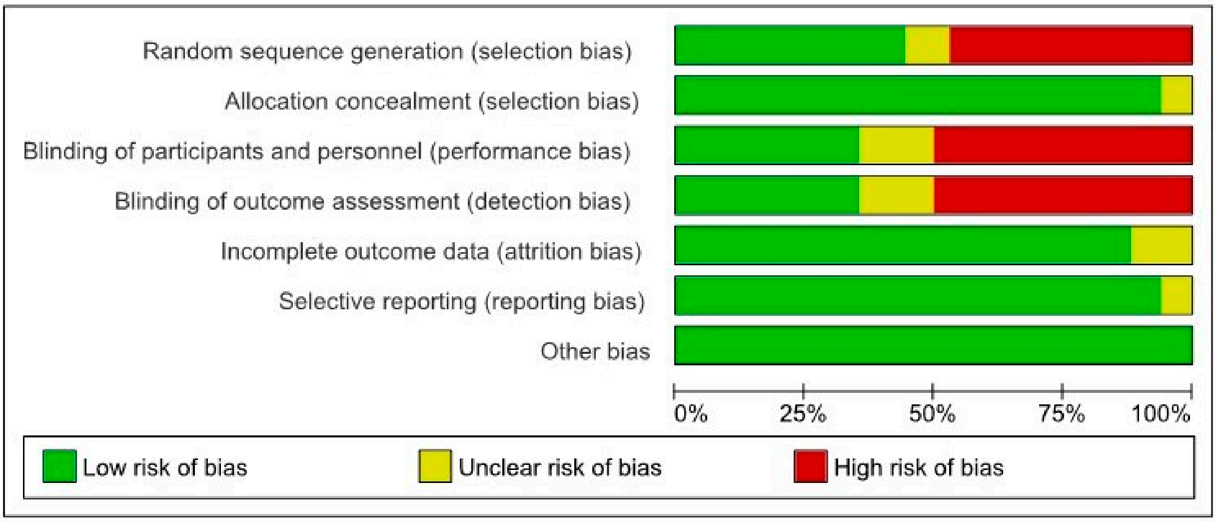

Figure 2. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies [wlr: weighted low risk; ur: unclear risk; weighted high risk: whr].

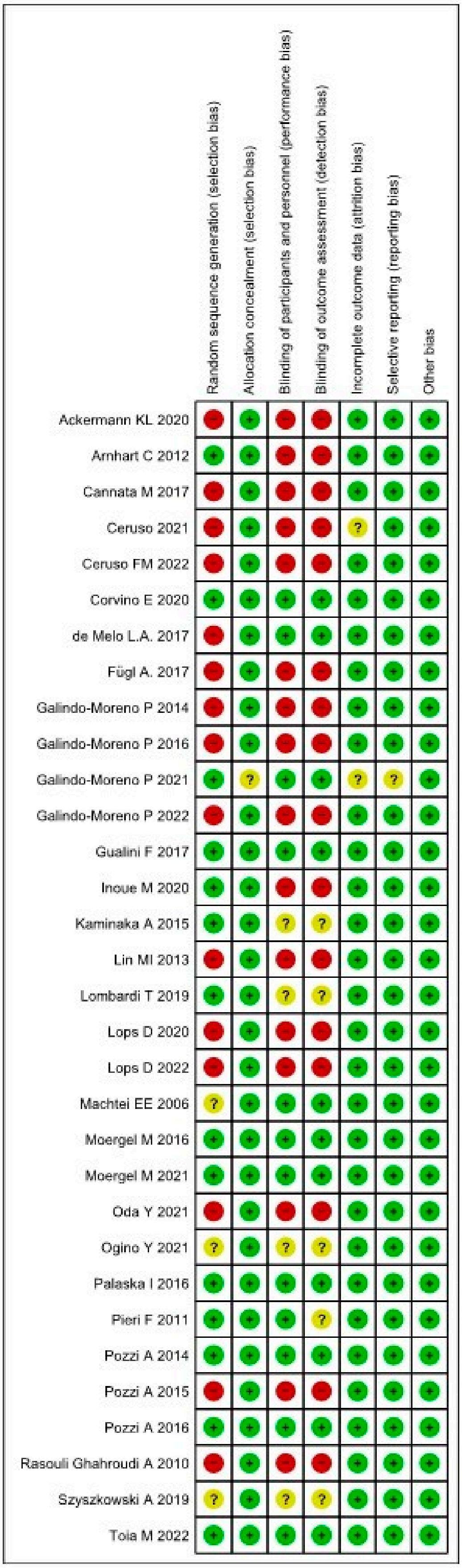

Figure 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study [19–21,23–49].

3.4. Meta-Regression MBL

A plot of the relative effects from the Bayesian random effect consistency model is shown in Figures 4 and 5. The higher SUCRA (Surface Under the Cumulative Ranking Curve) values and cumulative ranking curves nearer the top left indicate better performance. The plot represents each data points' contribution to the residual deviance in the NMA in terms of consistency (horizontal axis) and the unrelated mean effect (ume) inconsistency models (vertical axis) along with the line of equality, while the radial SUCRA plot showed that higher SUCRA values indicate better treatments; the size of nodes represents number of participants, and thickness of lines indicates the number of trials conducted. At the baseline, the CM positioned 1 mm under the bone level resulted in the most effective reduction in marginal bone resorption at the baseline. The forest plot for the baseline indicated that CM abutment joint showed a significant advantage in marginal bone loss reduction over HI crest group (MD: 0.74; 95% CI: −1.02, −0.56), HI group (MD: 1.23; 95% CI: 0.96, 1.59), CM crest (MD: −1.09; 95% CI: −1.50, −0.80) and EH (MD: −1.52; 95% CI: −1.81, −1.21) (Figures 4 and 5)

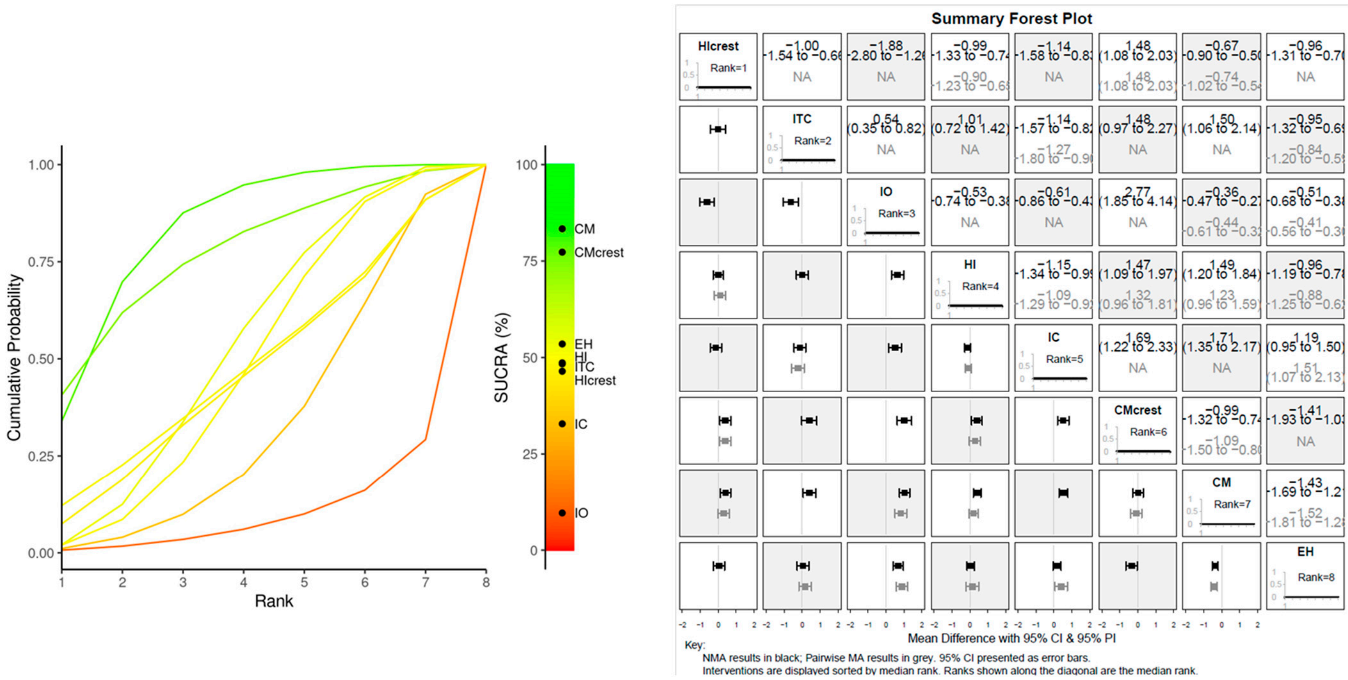

Figure 4. BASELINE MBL: Litmus rank-o-gram SUCRA (left); forest plot of relative effects of Bayesian random effect consistency model (right).

The forest plot indicated that, after 1 year of loading, the CM abutment joint positioned 1 mm under the bone level showed a significant advantage in terms of marginal bone loss reduction over the IO crest group (MD: 0.94; 95% CI: −1.42, −0.63), HI group (MD: 1.72; 95% CI: 0.88, 3.33) and EH (MD: 1.43; 95% CI: −1.1, 1.64) (Figures 6 and 7).

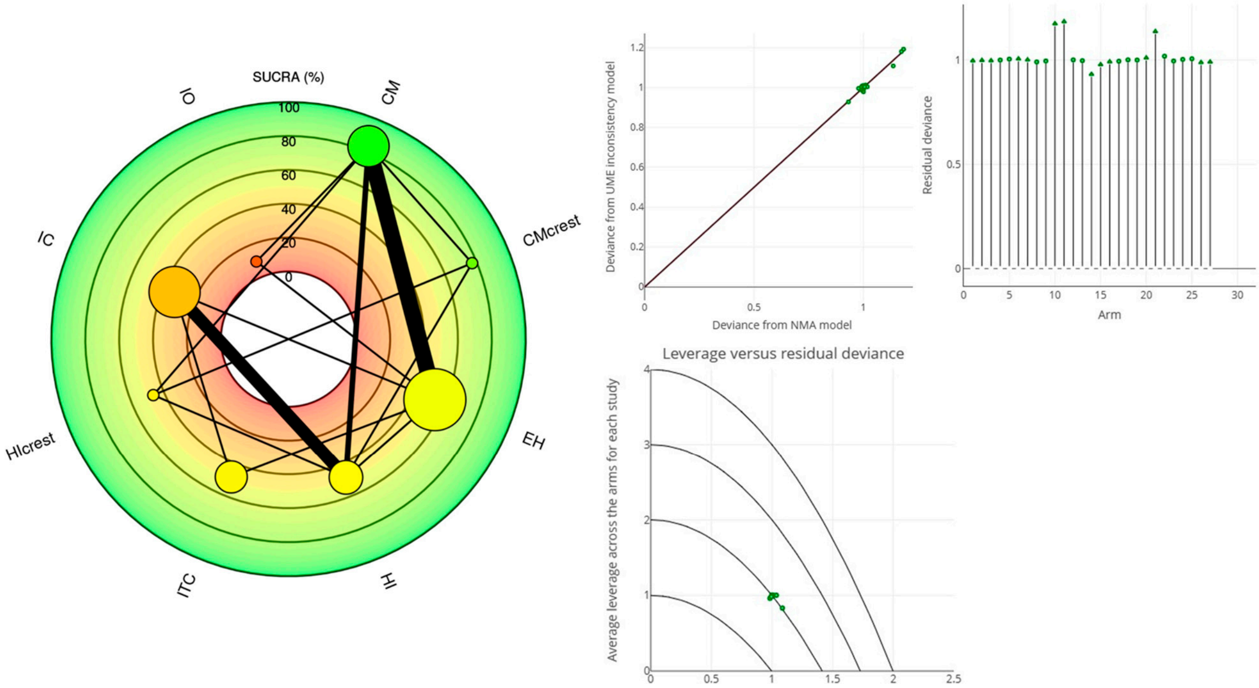

Figure 5. BASELINE MBL: Radial SUCRA plot (left); The stem plot represents the posterior residual deviance per study arm. The total number of stems equals the total number of data points in the network meta-analysis (NMA). The square root plot showed the average leverage across the arms for each study (right).

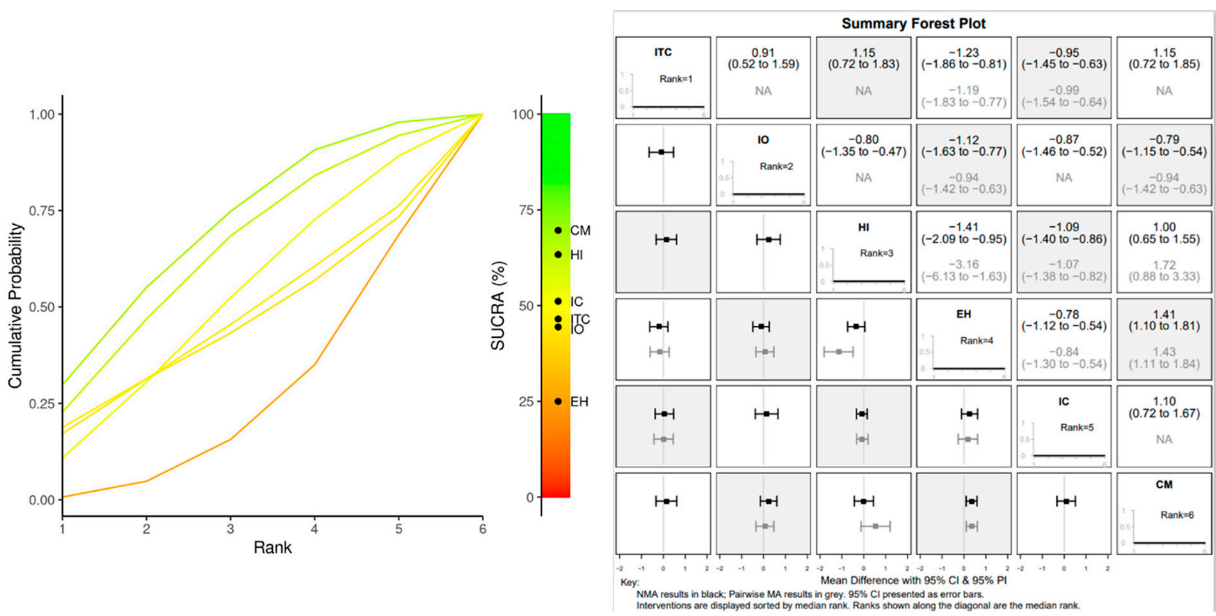

Figure 6. 1 YEAR MBL: Litmus rank-o-gram SUCRA (left); forest plot of relative effects of Bayesian random effect consistency model (right).

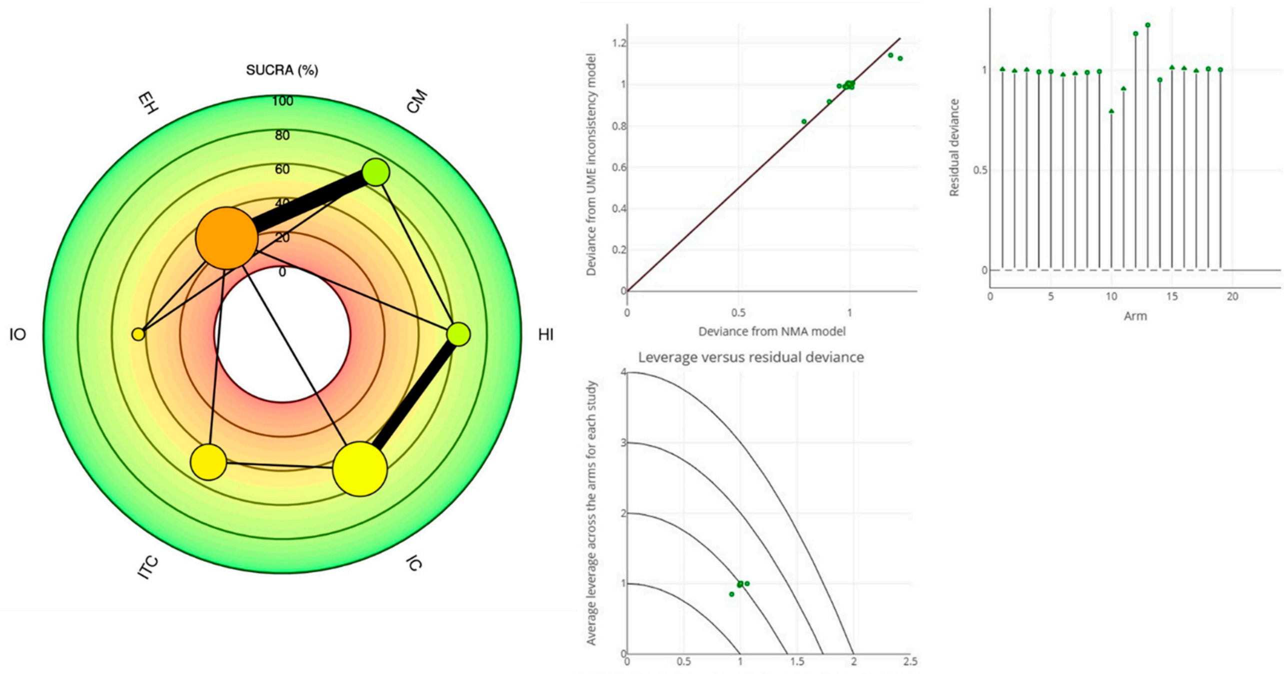

Figure 7. 1 YEAR MBL: Radial SUCRA plot (left); The stem plot represents the posterior residual deviance per study arm. The total number of stems equals the total number of data points in the NMA. The square root plot showed the average leverage across the arms for each study (right).

4. Discussion

This NMA evaluates the effect of different implant–abutment prosthetic joints on marginal bone loss through direct and indirect pairwise comparisons. A total of eight studies have been conducted from 2005 to 2015. The risk of bias represented one of the key assessments within the present investigation. A total of 36.36% of the articles included reported a low risk of bias while only 18 studies reported the adoption of a randomized approach for the population sample allocation. Due to the significance of the marginal bone loss for dental implant survival rate, we compared the early healing period of a submerged implant at the baseline (uncovering) and after 1 year. The CM abutment joint showed a significantly lower amount of marginal bone loss evidence compared to the other connections at the baseline. The same results emerged 1 year after the loading, except for the comparison between the HI and CM groups which revealed a similar resorption rate at the 1-year timepoint. Significantly higher resorption patterns for EH implants have been observed during the 1-year follow up. Several studies in the literature documented the internal flat-to-flat and conical press-fit joint as more favourable compared to an external abutment joint with a lower peri-implant resorption rate [27,30,51]. This evidence seems to support the findings observed in the present NMA. The reasons for peri-implant bone resorption are multifactorial, and they include surgical, mechanical and biological factors, including several comorbidities [32]. The bone level positioning vs. subcrestal implant's effects on marginal bone loss resulted in non-clear evidence from the NMA due to the low effect size documented in the meta-regression. The abutment joint stability and interface micro-gaps could play a role in functional microleakage creating a critical bacterial reservoir at the level of the crestal bone interface [52,53]. In the literature, the press-fit joint has been proposed to reduce the micro-gaps and improve the stability of the implant–abutment joint [32,51]. A precise adaptation of the prosthetic components is certainly important to produce a higher stability at the implant interfaces avoiding the creation of gaps [54]. The prosthetic joint precision fit is also a theoretical critical point for external and internal flat-to-flat systems, where the loading and the bending impairment could produce a marginal decoupling of the components [51]. The presence of an interface is able to produce a physiological reaction determined by bacterial contamination and marginal micromovements [55]. This evidence is histologically accompanied by a chronic inflammatory infiltrate at the level of the peri-implant tissues [55]. The mechanical complications seem to be a heterogeneous occurrence that transversely affects all systems considered with a cumulative rate ranging from 0 to 8.53% including major and minor events and a cumulative prosthetic success rate >95%. The screw loosening/fracture is a common joint complication for both internal flat-to-flat and conical connections with index [12]. Despite the limited follow-up of the present investigation, no abutment joint decoupling has been documented for CM joints in any of the studies included. Although the implant prosthetic joint could be considered as a relevant risk factor for late implant failure, no significant evidence in this NMA has been detected. A consistent critical point in the present NMA is that implant success could be determined by the type of rehabilitation. In fact, the present investigation considered no limitations for either provisional or final restoration. In addition, the surrounding bone loss is mainly influenced by many factors other than prosthetic joint type, including gingival biotype and thickness, bone width, bone density, biologic width around the implant and other factors related to prosthetic provision. These aspects could be considered a relevant limitation of the present study and the methodology. On the other hand, the lack of homogeneity of the study data represented a critical factor for the network meta-analysis where bone level position data were not available after 1 year for the CM and HI groups, but only at the baseline. These data could be useful for improving the relevance of the findings in relation to the biomechanical behaviour of the different prosthetic joints and the bone level depth.

The biomechanical behaviour could significantly affect the MBL, creating a confounding factor for the NMA calculations and masking the effects of the variables. On the other hand, a rigid inclusion criteria approach could reduce the sample size leading to the investigation making more assumptions. Another limitation of the present study is determined by the follow-up, where very few studies carried out more than 24 months of follow-up. Further long-term randomized clinical trials including implants with similar macro-/and micro-topography are necessary for an equal and comparative evaluation.

5. Conclusions

Within the limits of the present systematic review and NMA, the CM implant joint showed significantly lower MBL after 1 year compared with external hexagonal and internal flat-to-flat and conical connections. On the other hands, the CM joint reported a lower rate of prosthetic complications and implant–abutment decoupling events.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/prosthesis6010015/s1, Suppl. S1. Checklist according to the PRISMA guidelines. Reference [56] is cited in the supplementary materials.

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