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Influence of soft tissue thickness on marginal bone level around dental implants: a systematic review with meta-analysis and TSA.

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Influence of soft tissue thickness on marginal bone level around dental implants: a systematic review with meta-analysis and trial-sequential analysis.

Running title: Influence of soft tissue thickness on marginal bone level

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EB: conception and design, drafting the manuscript

RG: acquisition of data, drafting the manuscript

CT: analysis and interpretation of data, drafting the manuscript

TGP: acquisition of data, drafting the manuscript

PGM: drafting the manuscript, revising the manuscript

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LC: conception and design, revising the manuscript

Conflict of interest statement:

The authors declare they have no conflict of interest.

Abstract:

Objectives: The aim of the present review and meta-analysis was to evaluate the influence of soft tissue thickness on initial bone remodeling after implant installation.

Material and methods: A Literature search was conducted by two independent reviewers on electronic databases up to May 2022. Randomized controlled trials (RCTs) and controlled clinical trials (CCTs) performed on human subjects were included. The risk of bias was evaluated using Cochrane Collaboration's tool. Meta-analysis and Trial Sequential Analysis (TSA) were performed on the selected articles. The primary outcome was marginal bone loss.

Results: After screening, 6 studies were included in the final analysis, with a total of 354 implants, and a follow-up from 10 to 14 months. 194 implants were placed in a ≥ 2 mm soft tissue thickness, while 160 had < 2 mm soft tissue thickness before implant placement. The included studies had a high level of heterogeneity (I^2 > 50%). The meta-analysis indicated a statistically significant difference between the two groups (0.54; p=0.027) and the TSA analysis confirmed the results, despite the limited number of dental implants. Additional analysis showed that age and follow-up parameters were not statistically significant factors influencing the bone loss (p=0.22 and p=0.16 respectively).

Conclusions: Based on the available RCTS and CCTs, initial soft tissue thickness seems to influence marginal bone loss after a short follow-up period. Based on TSA analysis, further studies are needed to assess the influence of the soft tissue thickness on marginal bone loss.

PROSPERO registration number: CRD42021235324

Introduction

Marginal bone and soft tissue stability around dental implants have been established as the main characteristics for implant health. (Berglundh et al., 2018) Healthy soft tissue condition support peri-implant bone stability allowing a more efficient seal around dental implant and prosthetic

components. The structure of peri-implant soft tissues establish a biological barrier against the bacteria and act as a protective factor against peri-implant diseases. (Tavelli et al., 2021)

One of the criteria to define the potential presence of peri-implant pathology is the evidence of progressive bone loss. However, marginal bone loss (MBL) must be distinguished in early MBL (remodeling) and late MBL. Early MBL is an initial bone remodeling with a non-infective process of variable entity occurring within the first year after implant placement. It has a multifactorial etiology and might be influenced by many local contributing factors such as surgical and post-surgical/prosthetics aspects. (Monje et al., 2015) However it must be noted that also in an early phase an infection process can occur.

Late MBL may be related to an infective process called peri-implantitis which needs a diagnostic evaluation including clinical and radiological parameters. Peri-implantitis is a pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant connective tissue and progressive loss of supporting bone. (Schwarz et al., 2018)

Several factors related to the surgical or to the prosthetic procedure may influence early bone remodeling. Among these, one mechanism that has been described in animal models is the re-establishment of a “biologic width”. (Berglundh & Lindhe, 1996) In that study, the thinning of the marginal tissues around the implant resulted in a re-establishment of the soft tissue dimensions at the expense of some bone resorption. The histologic structure of peri-implant soft tissues has been investigated in numerous animals and some human studies. In analogy with the supracrestal tissue attachment at teeth, the soft tissue compartment is constituted by an epithelial portion (junctional epithelium) and a connective component with no fiber attached to the implant surface. In fact, this histologic structure represents a functional barrier between the oral cavity and the bone and is represented by a dense connective tissue with few fibroblasts and endothelial cells isolated by a junctional epithelium facing the abutment in the most coronal portion. (Tomasi et al., 2016)

According to some authors, the peri-implant phenotype is composed of a soft tissue component (peri-implant keratinized mucosa width, mucosa thickness, supracrestal tissue height) and an osseous component (peri-implant bone thickness). (Avila-Ortiz et al., 2020) Others claim that the soft tissue component is critical for the peri-implant bone maintenance, and implants placed with initially thicker peri-implant soft tissues show better peri-implant bone stability. (Linkevicius et al., 2009; Linkevicius, Puisys, Steigmann, et al., 2015; Suárez-López Del Amo et al., 2016)

A recent systematic review has suggested that approaches including soft tissue augmentation by the use of a soft tissue graft can reduce marginal bone loss surrounding implants, although other authors reported controversial results when assessing peri-implant health improvement. (Roccuzzo et al., 2016; Tavelli et al., 2021)

The last systematic review by Fickl and the Statement of the 6th EAO consensus conference state that depending on the indication of these interventions, clinical, radiographic, and aesthetic outcomes may improve, whereas the effect on PROMs is limited. (Fickl et al., 2021)(Thoma et al., 2021)

A systematic review published in 2017 investigated whether soft tissue thickness has an influence on early crestal bone loss, and concluded that there was insufficient evidence to support a correlation. (Akcalı et al., 2017) However, new evidence has been published since then.

Accordingly, the aim of the present review and meta-analysis was to evaluate the influence of soft tissue thickness on initial bone remodeling after implant placement.

Materials and Methods

The present systematic review and meta-analysis were performed according to Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines and trial sequential analysis (TSA) was used to adjust results of meta-analysis for both type 1 and 2 errors and assess the required power of the meta-analytic sample. (Page et al., 2021)

The proposed focused question for the present review was: "What is the effect of soft tissue thickness on peri-implant bone loss assessed by RCTs/CCTs in initial bone remodeling?"

The focused question was established according to the PICO-T strategy:

- Population: Healthy patients with at least one dental implant
- Intervention: implant placement and soft tissues healing
- Comparison: thickness of the soft surrounding tissues (measured by periodontal probe or with endodontic file)
- Outcomes: marginal bone level changes (measured by periapical radiograph or OPG)
- Time observation: min 10 months – max 14 months

The test hypothesis was that there is no difference in outcome measures in the presence of initial thin (<2 mm) or thick (≥2 mm) soft tissue around implants against the presence of a difference. (Akcalı et al., 2017).

The present study was registered on PROSPERO with the following number: CRD42021235324.

Ethics approval was not required for the present systematic review.

Search Strategy and Data Extraction

A comprehensive and systematic electronic search was created in the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE via PubMed, Scopus, and Web of Science databases. The

search strategy was: ((dental implants) OR (dental implantation) OR (dental prosthesis implant-supported) OR (oral implants) OR (endosseous implants) OR (implant restoration) OR (osseointegrated implants)) AND ((clinical outcomes) OR (early bone loss) OR (marginal bone loss) OR (bone level changes) OR (marginal bone level) OR (marginal bone resorption) OR (marginal bone remodeling) OR (marginal bone preservation) OR (crestal bone level) OR (crestal bone loss) OR (crestal bone resorption)) AND ((tissue thickness) OR (tissue biotype) OR (tissue phenotype)). Filters: Clinical Trial, Randomized Controlled Trial.

Studies until May 2022 were sought. A manual search was also conducted on the upper quartile dentistry journals. A search through the reference lists of the included studies was also conducted. Titles and/or abstracts of selected studies were evaluated autonomously by two reviewers (R.G. and T.G.) in order to select the publications that potentially meet the inclusion criteria. Full texts were retrieved and independently assessed for eligibility by the two reviewers. Any disagreement between the reviewers was evaluated through discussion with a third reviewer (L.S.). A Microsoft Excel pre-piloted form was created to extract data from the included studies. This was used both for the assessment of study quality and for evidence synthesis. Extracted information included: study setting, study population, participant demographics and baseline characteristics, details of the intervention and control conditions, study methodology, marginal bone level, and information to assess the risk of bias. Two reviewers performed this process independently (R.G. and T.G.). Disagreements were identified and solved through discussion (with a third author (L.S.), if necessary).

The final search date was May 31, 2022.

Studies were included if the following criteria were met:

- Randomized clinical trials (RCTs)
- Clinical Trials and Controlled clinical trials (CCTs)

- Marginal Bone Level clearly described
- Human studies

Studies not meeting all these inclusion criteria were excluded.

The following studies were also excluded:

- Studies with post extraction implant placement
- Studies with prosthetic immediate loading (<3 months)
- Studies reporting hard or soft tissue graft

No language restrictions were applied. Follow-up was referred to implant insertion.

Quality Assessment and Risk of Bias

The quality assessment and the risk of bias in individual studies were conducted using the Cochrane Collaboration's tool for assessing the risk of bias. (Higgins et al., 2011)

RoB 1 for CCTs and RoB2 for RCTs following the Cochrane handbook were evaluated for all included studies.

Quality assessment and Risk of Bias were conducted in duplicated (T.G. and R.G.) and any disagreement between the reviewers was evaluated through discussion with a third reviewer (L.S.)

Data Synthesis and Statistical Analysis

At the stage of full-text screening, a data extraction form was completed to check the eligibility of the studies and, if eligible, to collect detailed information about population, intervention, and outcomes.

Aggregate participant data, from each of the included studies, have been used in order to perform a quantitative synthesis of the extracted data. Implant-level data were extracted (when available) for the analyzed outcomes and entered in ProMeta3 2015 (Internovi, 2015). The mean difference

(MD) and its 95% confidence interval were calculated as meta-analytic effects. A fixed- or a random-effect model was used on the basis of the presence/absence of heterogeneity (I^2> 50%). Differences between groups were analyzed using the inverse of variance test, setting a P-value lower than .05 as the threshold of statistical significance.

The same software (ProMeta 2015) was also used to evaluate the effect of age and follow-up as modulating factors on bone loss. P-value was set at .05 as the threshold.

Additionally, in order to evaluate the power of evidence and to adjust the meta-analytic findings for type 1 and 2 errors, TSA was performed (software: Trial Sequential Analysis, v0.9 β, Copenhagen Trial Unit) for the continuous outcome MBL change. Values of 5% and 20% were applied respectively for type 1 and 2 errors, in order to calculate trial sequential monitoring boundaries, futility boundaries, and the required information size (RIS). Heterogeneity correction was applied using a model variance-based approach. A graphical evaluation was performed to ascertain whether the cumulative Z-curve crossed the monitoring boundaries, the futility boundaries, and the RIS threshold.

Results

Search

All three-stage screening (titles, abstract and full text) were carried out in duplicate and independently by two reviewers (R.G. and T.G). Kappa statistics showed a high level of agreement between the reviewers ($K > 0.90$).

The flowchart of the study screening was reported in Fig. 1.

186 articles were selected, after duplicate removal. After title reading 131 articles were excluded and 55 articles were selected for abstract reading. After abstract reading, 33 articles were selected for full-text reading. Finally, 6 articles were included for data extraction and quantitative analysis.

Characteristics of the Included Studies

The study characteristics selected for data analysis were reported briefly in Tab 1.

A total of 354 implants were evaluated. 194 had a ≥ 2 mm soft tissue thickness, while 160 had < 2 mm soft tissue thickness before implant placement. The heterogeneity test to determine the total variation between studies showed a value $I^2 > 50\%$, indicating a high heterogeneity between studies. Mean age of the patients included ranged between 47.3 and 61 years. (Puisys & Linkevicius, 2015a; van Eekeren et al., 2017) Each study considered at least 26 dental implants with a maximum of 74 implants included. (Garaicoa-Pazmino et al., 2021; van Eekeren et al., 2017)

Four studies excluded smoking patients (Garaicoa-Pazmino et al., 2021; Linkevicius, Puisys, Linkeviciene, et al., 2015; Puisys & Linkevicius, 2015a; Spinato et al., 2019), one study included both smoking and non-smoking patients (Linkevicius et al., 2018; Papapetros et al., 2019) and one study did not provide information about patients smoking habits. (Linkevicius et al., 2009; van Eekeren et al., 2017)

All studies used a periodontal probe to assess the soft tissue thickness. Bone level was measured with periapical radiographs with individual bite blocks for each study included. The administration time of the antibiotics varied among the studies. Except for the study of Van Eekeren (van Eekeren et al., 2017), the other authors administered amoxicillin peri-operatively. Two authors did not report information about the implant placement level. (Spinato et al., 2019, 2020; van Eekeren et al., 2017) Three authors placed implants crestally. (Garaicoa-Pazmino et al., 2021; Linkevicius et al., 2018; Puisys & Linkevicius, 2015b) Linkevicius in one study placed implants both crestally and supracrestally. (Linkevicius et al., 2009, 2018) Porcelain fused screw-retained implant prosthesis was used to restore the considered dental implants by the following authors: Spinato, Van Eekeren, Puisys and Linkevicius. (Linkevicius et al., 2018; Puisys & Linkevicius, 2015b; Spinato et al., 2019; van Eekeren et al., 2017) Linkevicius in one study used only cement-retained prosthesis (Linkevicius et al., 2018) while in another study used both screw- and cement-retained prosthesis. (Linkevicius, Puisys, Linkeviciene, et al., 2015). Garaicoa-Pazmino et al. used screw-retained restorations. (Garaicoa-Pazmino et al., 2021) None of the studies reported changes in papillary height or success rate.

Quality Assessment: Risk of Bias in Individual Studies

The risk of bias, according to the Cochrane Collaboration (Higgins et al., 2011) of the included study is reported in Tab. 2 and Tab. 3. All the included studies presented at least one or more unclear risks of bias. Two studies presented at least one high risk of bias. (Garaicoa-Pazmino et al., 2021; Puisys & Linkevicius, 2015b) Precisely, Garaicoa-Pazmino were considered at high risk for random sequence generation and allocation concealment, and Puisys presented incomplete outcome data.

Meta-Analysis and TSA on Marginal Bone Level

Meta-analysis was carried out with the statistical software ProMeta3 (Internovi, 2015).

The random-effects model showed that the weighted mean of marginal bone level differences between thick and thin soft tissue was estimated to be 0.54 mm (0.06 to 1.03) and was statistically significantly different from 0 (p=0.027). The forest plot in Fig 2 shows a trend in favor of thick tissue allowing for less bone remodeling compared to thin tissue.

Results from the meta-analysis were furtherly investigated using TSA (Figure 3), which were confirmed along with the addition of studies. Indeed, there was a statistically significant difference, since the cumulative z-curve resulted outside the conventional test boundary. While for the first two studies included, the results were significant also for the TSA, this was not confirmed once more studies were added. Specifically, after the addition of the study of Van Eeekeren et al. 2017, the Z-curve crossed back the monitoring boundary, although outside of conventional test boundary. Moreover, RIS was not reached (433 implants included in this meta-analysis versus 597 required by TSA), making these results inconclusive, but encouraging for more studies in order to definitively assess the role of soft tissue thickness in marginal bone loss. Considering the age as a modulating factor, a not statistically significant influence was reported (p=0.224): Fig. 4.

The duration of the follow-up showed the same trend as age, with more bone loss in the longer follow-ups, but the value was statistically not significant (p=0.165). Fig. 5.

Discussion

Data from the present systematic review and meta-analysis show a significant difference in terms of bone remodeling between implants inserted in patients with thin or thick soft tissue width. The present data differ from the results of a previous systematic review by Akcalı et al. (Akcalı et al., 2017) In fact, the present review included new studies published after the review by Akcali. The former meta-analysis included only two articles and found no significant crestal bone level changes between the two groups (P=0.189). In the present meta-analysis, it should be noted that even if the difference is statistically significant, the confidence interval is not far away from the zero value and the confidence interval is wide. It could be argued that the present review results may change if a single study was added or removed. However, the width of the confidence interval was mostly related to the great variability between studies of different research groups.

In terms of bone remodeling, the presence of a significant difference between thin and thick soft tissue seems to follow the concept of minimal biological width. In particular, in the study by Berglundh and Lindhe, a thinning of the soft tissue around implants resulted in a bone remodeling to reestablish a supracrestal soft tissue height. (Berglundh & Lindhe, 1996) However, Tomasi demonstrated a soft tissue thickening during 12 weeks of healing, both in animal models and in human models. (Tomasi et al., 2014) Therefore, it could not be excluded that, in cases where soft tissue thickness is less than 2 mm, an increased thickness re-established the supracrestal soft tissue dimension without bone remodeling. In future studies, it would be interesting to measure soft tissue thickness at the end of the observational period.

On the other hand, there are many factors that could influence initial bone remodeling regardless of soft tissue thickness. These factors could be related to surgical procedures, such as open or flapless surgery, drilling and insertion protocol, bone compression due to the press-fit, tridimensional implant positioning, or microscopical contamination of the implant surface. (Buser

et al., 2004; Lemos et al., 2020; Stocchero et al., 2016; Suárez-López Del Amo et al., 2016) At the same time, post-surgical/prosthetics factors may have an influence on additional bone resorption: prosthetic procedures, abutment/crown design, and material, abutment/crown microbial leakage. (Caricasulo et al., 2018; Schwarz et al., 2014; Sommer et al., 2020) Also, alveolar crest pre-operative dimensions could have an influence. (Monje et al., 2019)

It should be noted that follow-up presented a small range (from 10 to 14 months) and this allows the studies to be considered homogeneous.

Results from the pair-wise model were also confirmed using TSA. However, significance in TSA was not achieved; so far results should not be considered definitive since the threshold of RIS was higher compared to the number of implants included in the meta-analysis. Therefore, such findings should be considered with caution and strongly encourage the execution of further studies on this topic, to reach a reliable statistical power in meta-analysis. Some limitations of the present study have to be pointed out. The first is that half of the included studies were performed by the same scientific group. Three papers, Puisys 2013, Linkevicius 2015a and Linkevicius 2018 were conducted by the same group and, therefore, a bias can't be excluded. (Linkevicius et al., 2018; Linkevicius, Puisys, Linkeviciene, et al., 2015; Puisys & Linkevicius, 2015b) Furthermore, the aforementioned studies included different types of dental implants and prosthetic abutments with different geometry and shape, and this could be a confounding factor for the bone response to remodeling. The high heterogeneity value of the included studies confirms this aspect of the review. In addition, the different positioning of the implants (crestal or subcrestal) can be a limiting factor for the pooled evaluation of the studies. Furthermore, two of the included studies have not reported the position of the implants which can play an important role on initial bone remodeling. Another limitation is the use of a periodontal probe to assess soft tissue thickness. In most cases, in fact, the final position of the implant and of the above abutment does not match with the initial incision line.

More prospective randomized studies with a long-term follow-up and a consistent number of implants should be carried out to have more solid data to test. Soft tissues clinical assessment must be carefully taken into consideration due to the importance of the health of this tissue in maintaining per implant bone stability. In addition, more standardized well-designed studies could decrease the level of heterogeneity and thus improve the level of significance of the meta-analysis. This could certainly help to improve understanding of peri-implant biology in the medium to long term and give clinicians more precise indications.

Conclusion

Within the limitations of the present systematic reviews, the evidence of peri-implant bone remodeling due to initial soft tissue thickness is confirmed, as the meta-analysis demonstrate a distinction between thin and thick tissue condition. It should be emphasized that from a clinical point of view this result must be taken into careful consideration and that neither post-extraction implant placement nor immediate loaded implants was included in the review.

Support

No financial support was obtained for this review.

Ethics approval

Ethics approval was not required for this systematic review.

Competing interests

No competing interests of the authors are present.

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Figures legends:

Figure 1: flow diagram of the article selection procedure.

Figure 2: forest plot for MBL changes at implant level.

Figure 3: Trial sequential analysis (TSA) for the continuous outcome MBL changes.

Figure 4: effect size considering age as a modulating factor. Significant influence was reported (p=0,005)

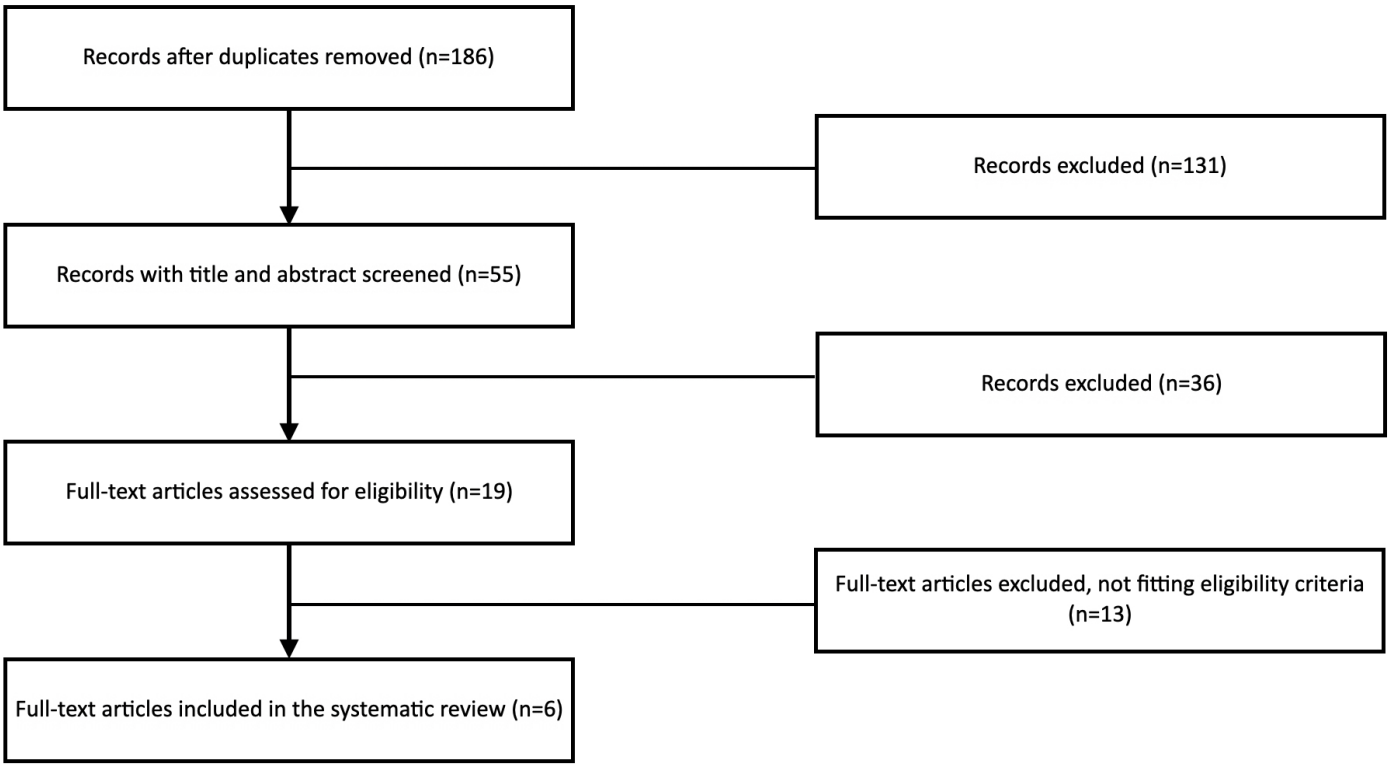
Figure 5: effect size considering follow-up as a modulating factor. Value was statistically not significant (p=0.232).

Table 1: Study characteristics and outcomes of included studies.

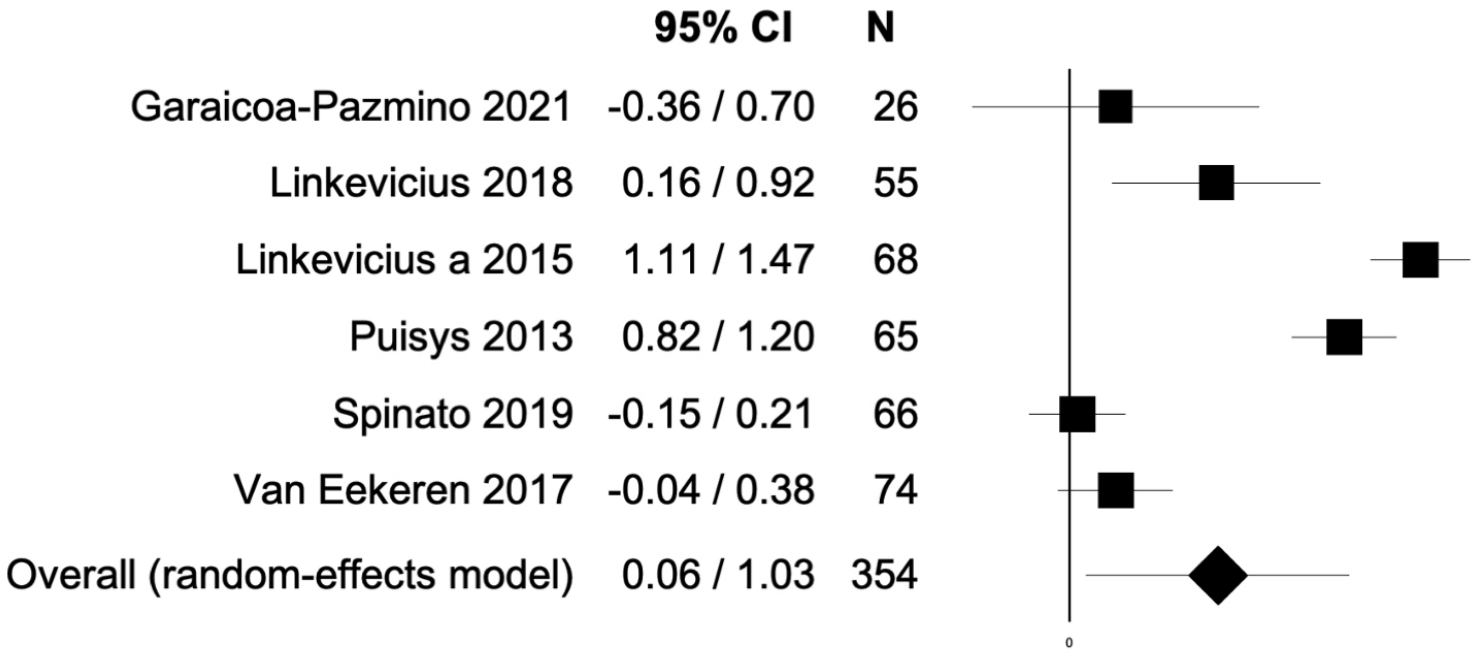
Table 2: Risk of bias summary.

Table 3: Risk of bias graph.

Table 4: Reason for exclusions.



CLR_14032_Figure 1.jpg



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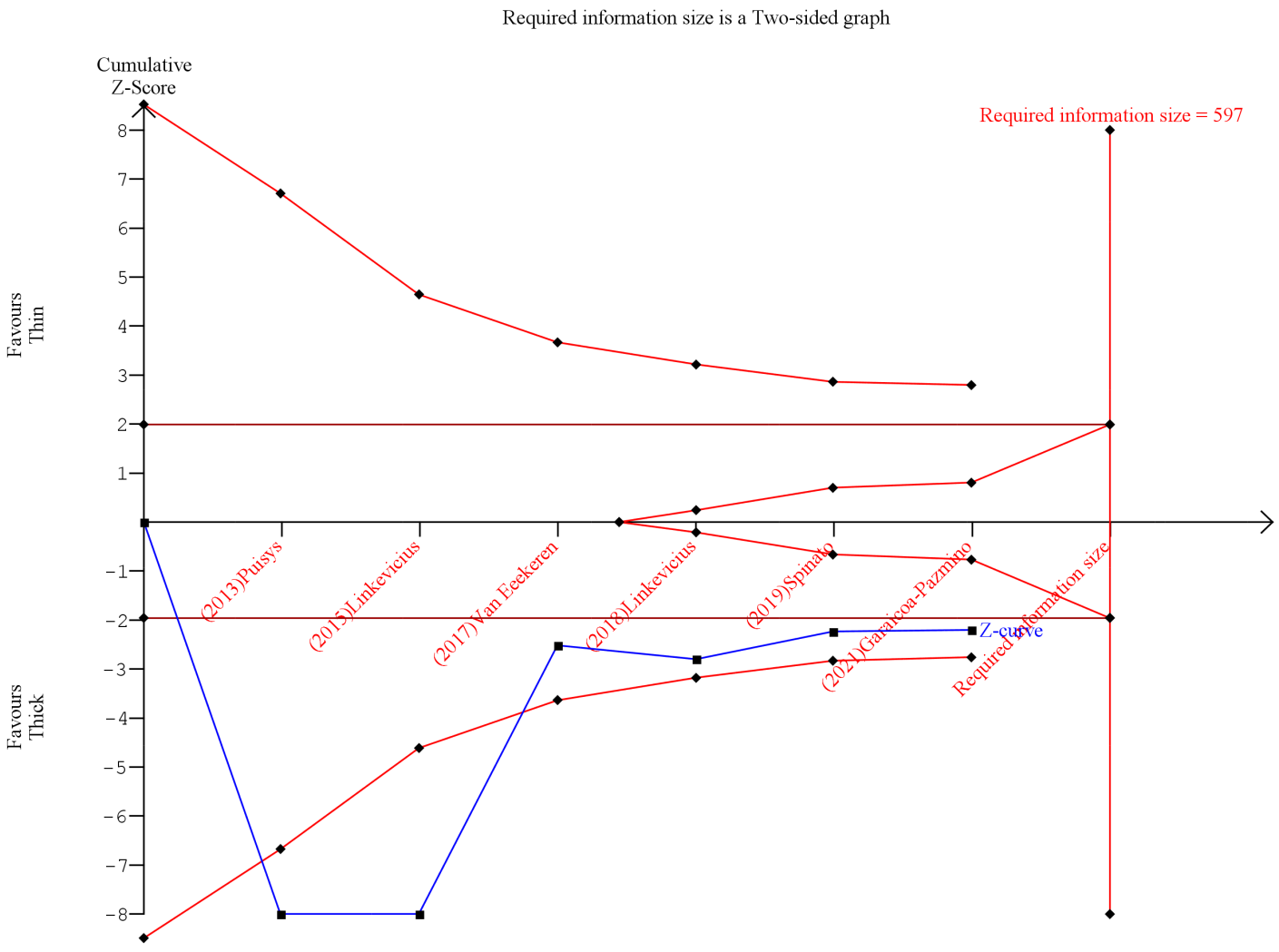

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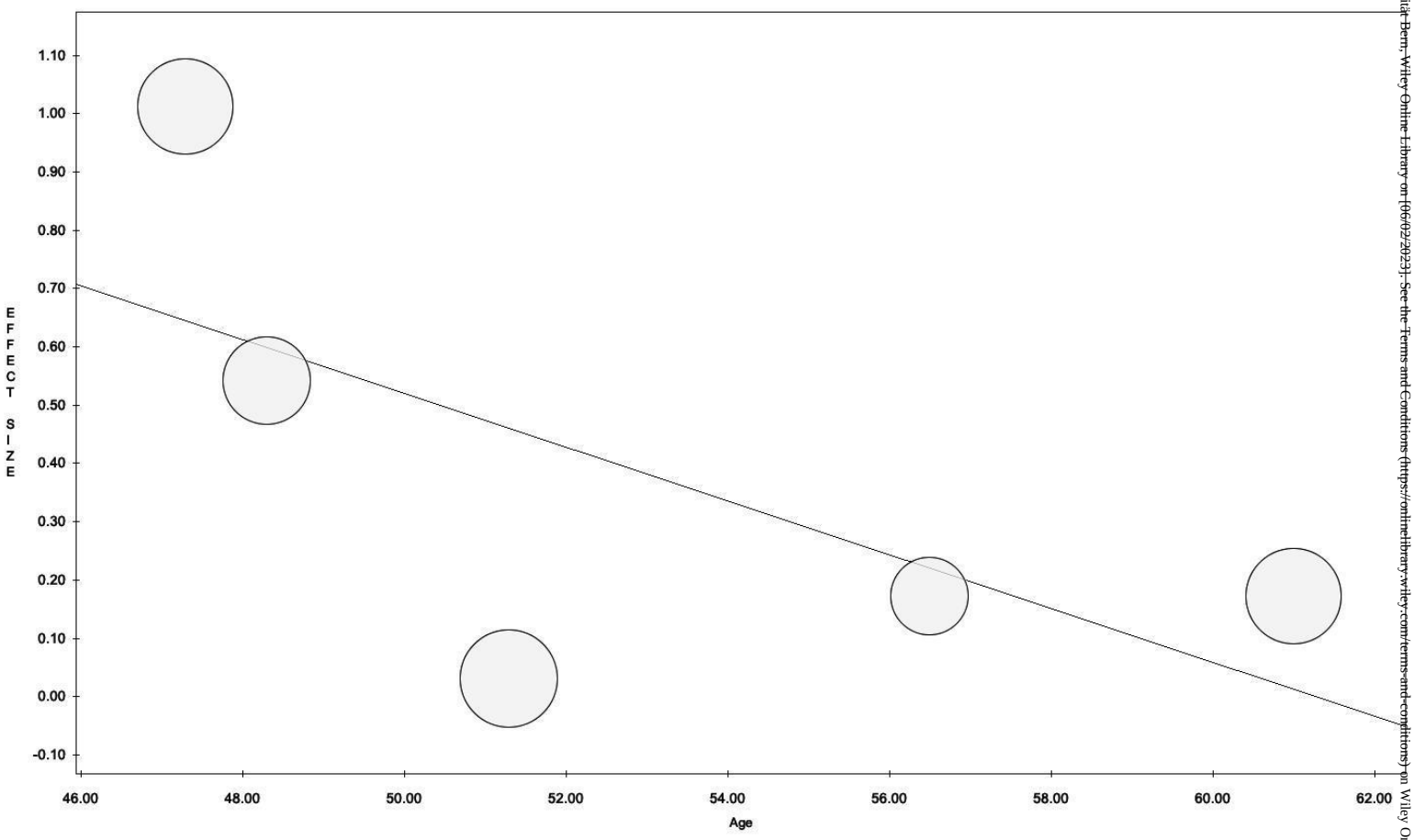

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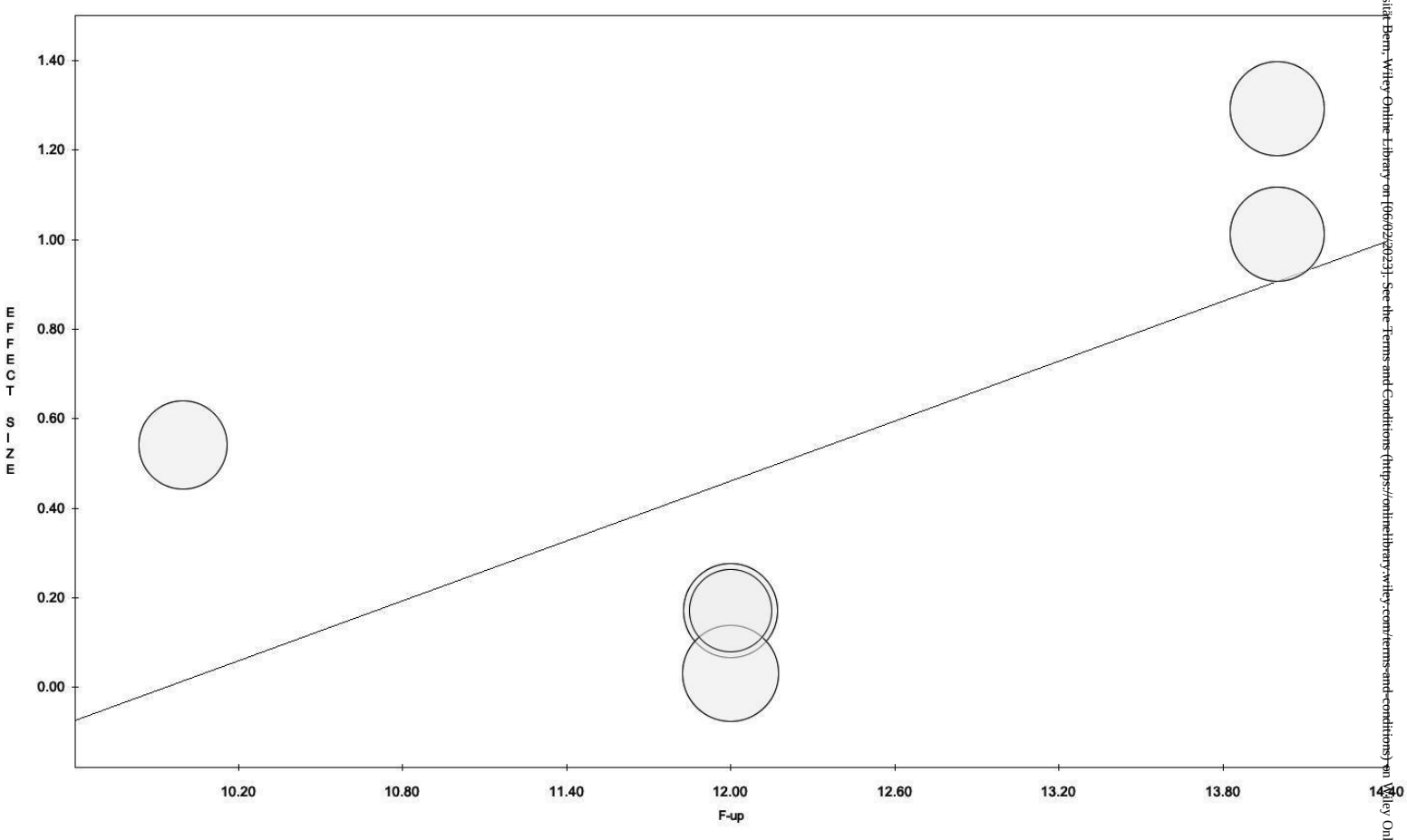
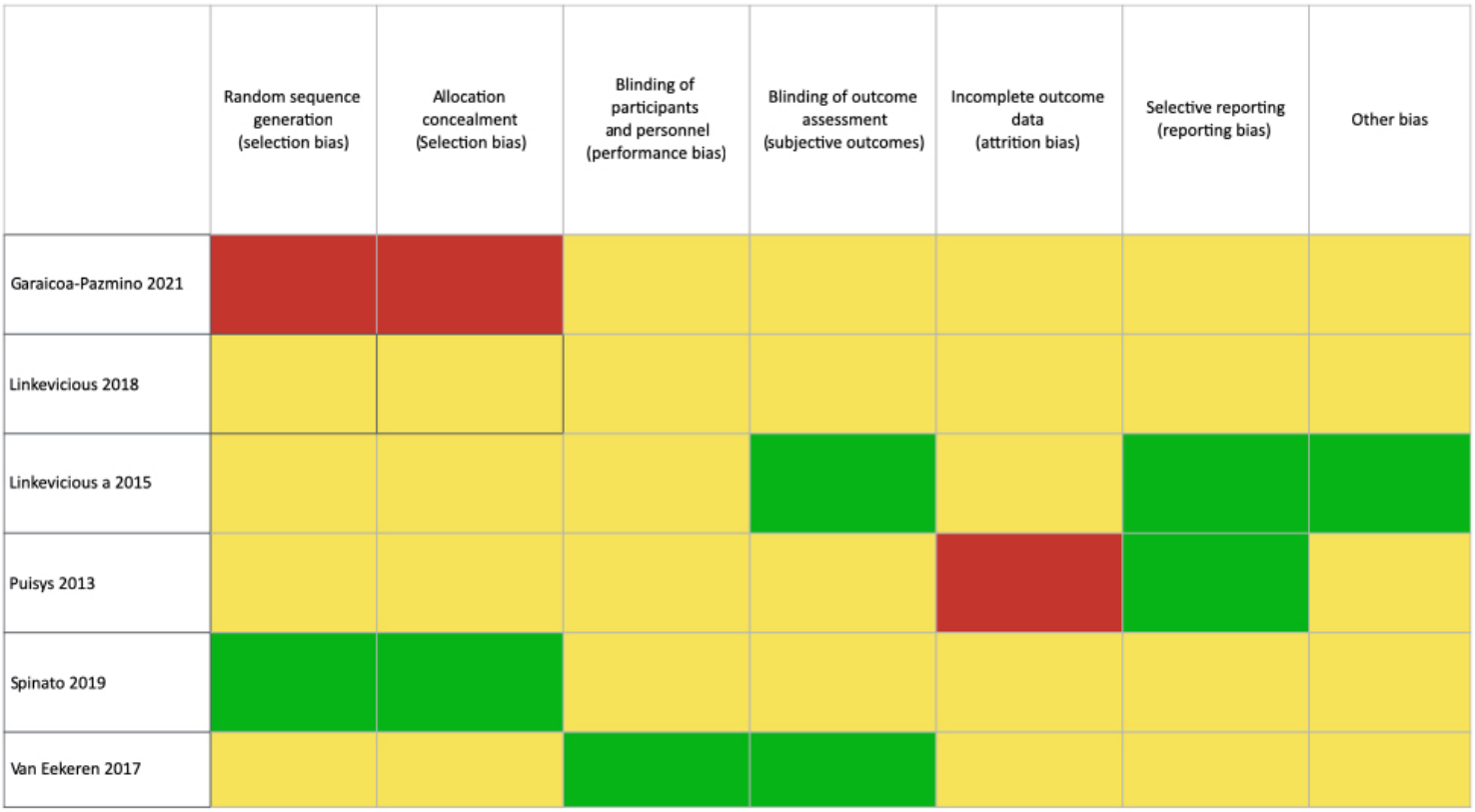


CLR_14032_Figure 5.jpg

Author	Year	study desing	Patients	Implants	Implants group thin	Implants group thick	Position of implnats	Type of prothesis	Implant surface type	Follow up (months)	Mean
Linkevicius	2015	CT		68	34	34	Bone level	single screw retained		14	nd
Linkevicius	2018	CCT	55	55	19	36	Bone level	single screw retained	Mis V3	10	48.3
Puisys	2013	CCT	65	65	33	32	Bone level	single screw retained	Straumman Bone Level	14	47.3
Spinato	2019	RCT	66	66	29	37	No info	single screw retained	Internal hex, platform-switched with 1mm machined collar (Shap1BC, i-RES)	12	51.3
Van Eekeren	2017	RCT	33	74	32	42	No info	single screw retained	Thomen Medical, Apliquiq	12	61
Garaicoa-Pazmino	2021	CT	26	26	13	13	Supracrestally (machined portion)	single screw retained	Tapered Tissue Level implant BioHorizons Birmingham, AL.	12	56,54

CLR_14032_Table 1.jpg



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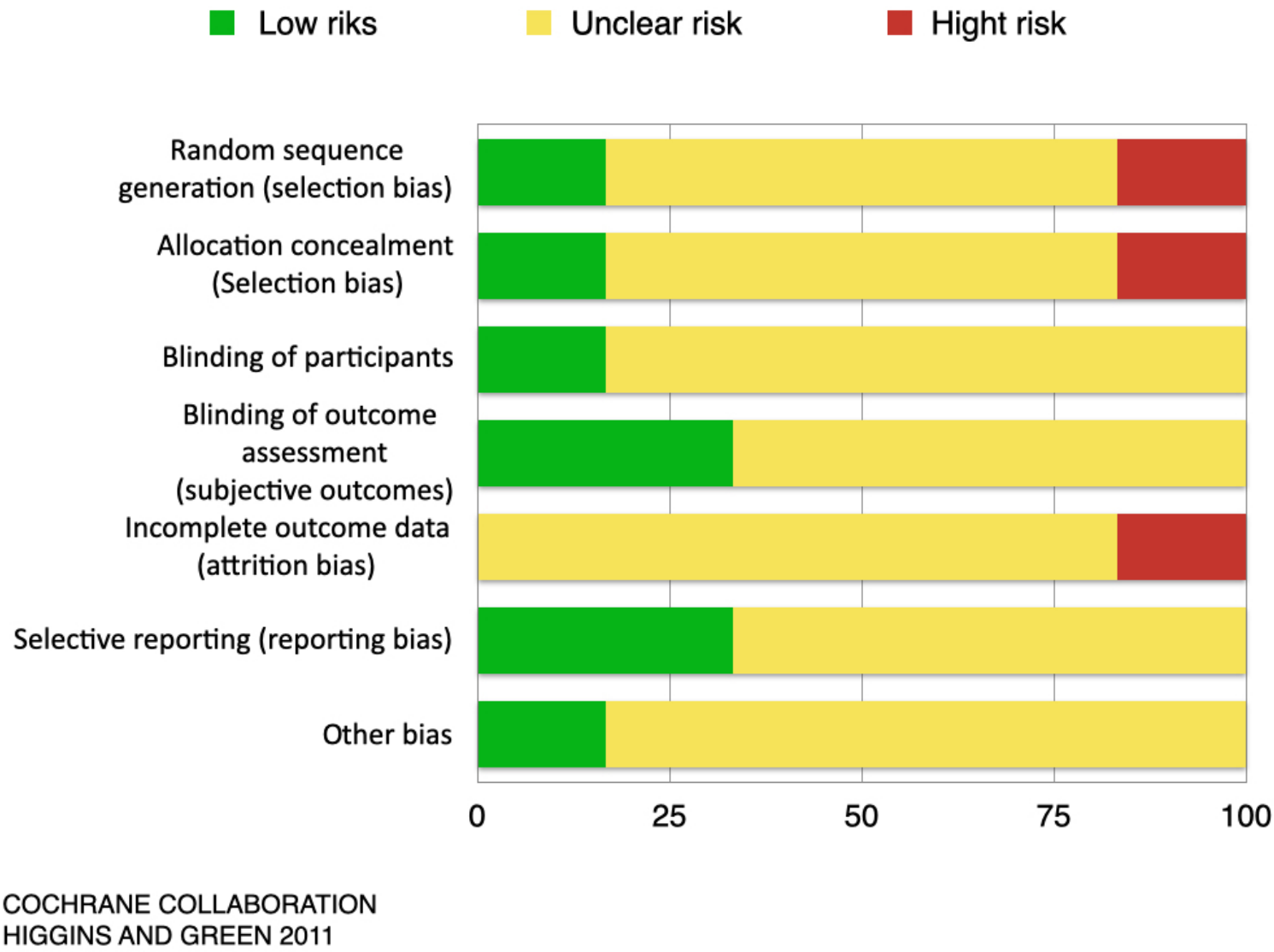

CLR_14032_Table 3.jpeg

de Siqueira	2020	immediate post extraction implant placement
de Siqueira	2017	prosthetic immediate loading
Ferrari	2015	not provided information about MBL
Galindo-Moreno	2021	not provided information about soft tissue thickness
Kaminaka	2014	not provided data on soft tissues
Koutouzis	2021	not provided information about MBL
Li Manni	2020	not provided information about soft tissue thickness
Linkevicius	2015 c	not provided data on soft tissues changes
Linkevicius	2022	different group allocation
Linkevicius	2009	missing data
Munoz	2021	not provided information about soft tissue thickness
Papapetros	2019	missing data
Zukauskas	2021	different group allocation

CLR_14032_Table 4.jpg