A Comparative Analysis of Marginal Bone Loss of Hydrophilic Implants versus non-hydrophilic Implants placed on Edentulous Ridge in Mandibular Implant Overdenture

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KEYWORDS
Hydrophilic implants, Marginal bone loss, Implant survival, Bone-to-implant contact.

ABSTRACT
Objective: This systematic review aims to evaluate the clinical outcomes of hydrophilic versus non-hydrophilic dental implants, focusing on key parameters such as marginal bone loss, implant survival rates, and bone-to-implant contact (BIC). The review seeks to determine whether hydrophilic surfaces offer a significant clinical advantage and to identify areas for future research. Materials and Methods: A comprehensive literature search was conducted across databases including PubMed, Scopus, and Cochrane Library, covering studies published from 2015 to 2023. Inclusion criteria were randomized controlled trials, prospective and retrospective studies, and in vivo experiments comparing hydrophilic and non-hydrophilic implants. Data extraction focused on outcomes related to marginal bone loss, implant survival, and BIC. Studies were assessed for methodological quality using the Cochrane Risk of Bias tool and the Newcastle-Ottawa Scale. Results: A total of 10 studies met the inclusion criteria, encompassing 450 implants in various clinical settings. The findings revealed that hydrophilic implants generally demonstrated lower marginal bone loss and higher BIC percentages compared to non-hydrophilic implants, with survival rates exceeding 97% in most studies. However, the differences in outcomes were not consistently significant across all studies, highlighting variability in results based on implant type, patient demographics, and follow-up duration. Conclusion: Hydrophilic implants show potential advantages in terms of marginal bone loss and BIC, particularly in early loading protocols. However, further long-term studies with standardized methodologies are needed to confirm these benefits and optimize clinical guidelines for implant selection.

1. Introduction

The advent of dental implants has revolutionized oral rehabilitation, offering patients a reliable solution for tooth loss with high success rates and long-term functionality. Among the various factors influencing the success of dental implants, the interface between the implant surface and the surrounding bone tissue plays a crucial role. This interface, often referred to as the bone-to-implant contact (BIC), is critical for achieving osseointegration—a process where the bone tissue directly bonds to the implant surface, ensuring stability and load-bearing capacity.[1] Over the years, advancements in implant surface technology have aimed to enhance osseointegration, reduce healing times, and improve the overall clinical outcomes for patients.[2]

One such advancement is the development of hydrophilic implant surfaces. Hydrophilic surfaces are designed to attract and retain moisture, facilitating better blood and cell attachment, which are essential for the initial phases of bone healing and osseointegration.[3] The rationale behind using hydrophilic surfaces is that by improving the wettability of the implant surface, the early biological response can be enhanced, potentially leading to faster and more improved osseointegration compared to conventional hydrophobic surfaces.[4] This is particularly advantageous in clinical situations where immediate or early loading of implants is desired, as well as in cases involving compromised bone conditions where achieving quick and stable osseointegration is critical.[5]

Despite these theoretical advantages, the actual clinical benefits of hydrophilic implants compared to conventional non-hydrophilic implants have been a topic of ongoing research and debate. Various studies have attempted to quantify the impact of hydrophilic surfaces on key outcomes such as marginal bone loss, implant survival rates, and BIC.[6-8] However, the results have been inconsistent, with some studies reporting significant improvements with hydrophilic implants, while others show minimal or no difference when compared to their non-hydrophilic counterparts.

Given the growing interest in hydrophilic implant surfaces and the mixed findings in the literature, a systematic review is warranted to critically evaluate and synthesize the available evidence. This review aims to compare

the clinical outcomes of hydrophilic versus non-hydrophilic implants, focusing on parameters such as marginal bone loss, implant survival rates, and bone-to-implant contact. By systematically analyzing the existing studies, this review seeks to provide a clearer understanding of whether hydrophilic surfaces offer a significant clinical advantage and to identify potential areas for future research.

2. Methodology:

The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and the protocol was registered in the PROSPERO database (Reference ID: CRD42024531190)

Search Strategy and Data Sources

A comprehensive literature search was conducted to identify relevant studies comparing MBL between hydrophilic implants subjected to early loading and non-hydrophilic implants subjected to conventional loading in mandibular implant overdentures. The search encompassed electronic databases, including PubMed, Scopus, Cochrane Library, and Web of Science, covering publications from January 2000 to August 2024. Keywords used in the search included "marginal bone loss," "hydrophilic implants," "early loading," "non-hydrophilic implants," "conventional loading," and "mandibular implant overdenture." Boolean operators were employed to refine the search strategy, and only English-language articles were considered. Additionally, the reference lists of selected studies and relevant review articles were manually screened for additional pertinent studies.

Selection Criteria

The population (P) included patients requiring mandibular overdentures and undergoing dental implant placement. The intervention (I) was the placement of hydrophilic implants subjected to early loading protocols. The comparison (C) involved non-hydrophilic implants subjected to conventional loading protocols. The primary outcome (O) assessed was the marginal bone loss measured at baseline and subsequent follow-up periods. The study design (S) criteria included randomized controlled trials, cohort studies, and case-control studies that provided quantitative data on marginal bone loss over a follow-up period of at least 6 months.

Studies were included in this systematic review if they met the following criteria: (1) randomized controlled trials (RCTs), non-randomized clinical trials, or cohort studies evaluating the impact of early loading of hydrophilic implants versus conventional loading of non-hydrophilic implants on marginal bone loss; (2) studies reporting quantitative data on MBL, measured as the change in bone levels from baseline to follow-up; (3) studies focusing on mandibular implant overdentures; and (4) studies published in peer-reviewed journals. Exclusion criteria included: (1) studies that did not provide sufficient data on MBL; (2) case reports, reviews, and editorials; (3) animal studies; and (4) studies with a follow-up period of less than six months.

Data Extraction, Quality Assessment, and Synthesis

Data extraction was performed by two independent reviewers to ensure accuracy and consistency. The extracted data included study characteristics such as author, year of publication, study design, sample size, patient demographics, implant types (hydrophilic vs. non-hydrophilic), loading protocols (early vs. conventional), measurement methods for MBL, and follow-up duration. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer. The methodological quality of the included studies was assessed using the Cochrane Risk of Bias tool for RCTs, ROBINS-I for non-randomized clinical trials, and the Newcastle-Ottawa Scale for cross-sectional studies. The data were synthesized qualitatively and descriptive statistics were used to summarize study characteristics and findings. The quality of evidence for the studies included in the analysis was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach.

3. Results:

The systematic review encompassed a total of 10 studies that met the inclusion criteria, conducted across various countries and spanning a period from 2010 to 2021. [9-18] The selection process of the articles for inclusion in the present systematic review is delineated in Figure 1. These studies varied in design, including randomized controlled trials, prospective and retrospective studies, and in vivo experiments, focusing on the comparative analysis of hydrophilic and non-hydrophilic dental implants. The characteristics and outcomes of all the studies are summarized collectively in Table 1.

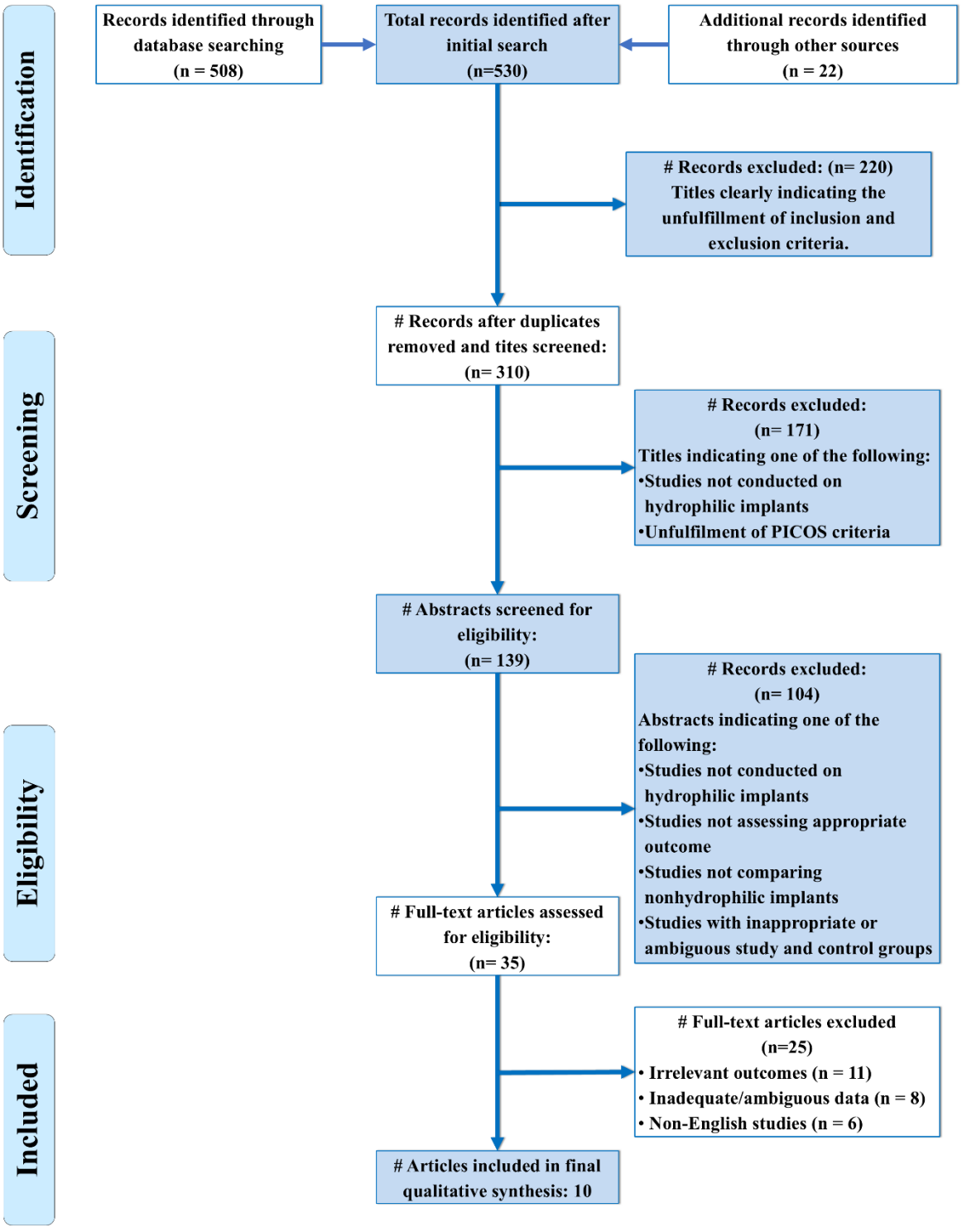

Figure 1: PRISMA Flow diagram indicating the selection process of the articles for the present systematic review

Table 1: Characteristics and outcomes of all the studies included in the present systematic review

Sr. No	Author	Year	Country	Study Design	Implants Used	Hydrophilic Modifications Done	Comparator	Tooth Region	Patient Age	Sample Size	Gender	Outcomes	Conclusions Reported
1	Karabuda et al	2010	Istanbul, Turkey	Randomized Controlled Trial	Group 1: Standard SLA implants	SLA implants were further rinsed under N2	Standard SLA implants	Bilateral	24 - 58 years (mean	96 implants	15 F, 7 M	Bone loss hydrophilic: 0.43 ± 0.11 mm	ModSLA implants demonstrated better stability and

					Group 2: Modified SLA implants (hydrophilic)	protection and stored in an isotonic NaCl solution			age: 46.68 years)			Survival rate hydrophilic: 97.91% Bone loss comparator: 0.46 ± 0.07 mm Survival rate comparator: 100%	reduced MBL at the loading stage. Both SLA and modSLA implants showed favorable success and survival at the end of the 15-month follow-up.
2	Lang et al	2011	Berne, Switzerland	In Vivo Experiment	Group 1: SLA active (hydrophilic) Group 2: SLA (hydrophobic)	Not Mentioned	Hydrophobic SLA	Bilateral retromolar region	21 - 48 years (Median 29 years)	30 implants	-	Degree of osseointegration after 4 weeks: 62% in both groups	The degree of osseointegration after 4 weeks was superior for the hydrophilic SLActive compared with the hydrophobic SLA surface.
3	Uwe Held et al	2013	Canton Arau	Prospective Study	Implants with a novel, chemically modified surface	Hydroxylation	-	Regions of D3 and D4 bone	18 - 75 years (Mean 50.9 years)	35 implants	7 Female, 3 Male	Bone loss hydrophilic: 1.46 ± 0.7 mm	Chemically modified, hydrophilic implants support early osseointegration even in D3 and D4 bone, potentially shortening the healing period.
4	Degasperi et al	2014	Feltre, Italy	Retrospective Study	A novel hydrophilic surface implant (Proactive™, Neoss)	Electro-wetting technology	-	Maxillary and mandibular arch	29 to 79 years (mean 50.9 years)	102 implants	29 Female, 20 Male	Bone loss hydrophilic: 0.7 ± 0.6 mm Survival rate hydrophilic: 99.00%	The use of a novel hydrophilic dental implant results in favorable short-term outcomes.
5	Eekeren et al	2015	Amsterdam, Netherlands	Prospective Study	SPI ELEMENT implants with thermal acid etched surface	Conditioning	Tissue level implants vs. Bone level implants	Maxillary and mandibular arch	36 to 85 years (Mean 61 years)	76 implants	19 Female, 13 Male	Mean tissue level ISQ: 67 Mean bone level ISQ: 75	ISQ values remained higher in bone level implants throughout the healing process.
6	Sartoretto et al	2017	Brazil	In Vivo Study (Histomorphometric Analysis)	Titanium (Ti) dental implants Titamax NeoPoros (TN), and Titamax Acqua (TA)	Conditioning with an isotonic solution of 0.9% sodium chloride	Standard sand blasted acid etched implant	Tibia of sheep	-	40 implants	-	Bone area hydrophilic: 64.2 ± 12.04 (p=0.005) Bone-to-implant contact (BIC): 60.6 ± 4.2 (p=0.004)	The TA group showed greater bone anchorage in the early period (14 and 21 days) compared with the hydrophilic surface, suggesting a reduction in the healing period post-implant placement.
7	Trisi et al	2017	Teramo, Italy	In Vivo Study	3.8 × 10-mm Dynamix implants (Cortex, Shlomi, Israel)	A low-voltage anodization process in highly metastable calcium and phosphorus-enriched aqueous solution	Standard sand blasted acid etched implant	Iliac crest of sheep	-	20 implants	-	Control group BIC: 49.49 ± 7.70% Test group BIC: 65.33 ± 6.35% Control group ISQ: 60 ± 1.15 Test group ISQ: 60.7 ± 0.71	Hydrophilic SLA titanium implant surface significantly increased % BIC in low-density bone compared with SLA dental implant surface.
8	Yamaner et al	2017	Istanbul, Turkey	Prospective Study	Straumann Dental Implants; Institut Straumann AG, Basel, Switzerland	Hydroxylation/ hydration	Standard sand blasted acid etched implant	Posterior regions of the maxilla and/or mandible	20 - 65 years	107 SLA implants, 68 SLActive implants	34 males, 21 females	After 81 months, mean marginal bone loss: SLA 0.71 mm, SLActive 0.53 mm (not statistically significant)	With both SLA and SLActive implants, successful clinical results could be achieved up to 6.5 years of follow-up.
9	Hicklin et al	2020	Bern, Switzerland	Prospective Study	Screw-shaped titanium implants with self-tapping threads, superhydrophilic surface, with 1 mm collar	Conditioning using 0.05-M NaOH solution	-	Mandibular molar and premolar	32 - 67 years (mean 52 years)	20 implants	7 female, 8 male	Survival rate hydrophilic: 100%	Early functional loading with hydrophilic implants is a safe and reliable option when placed in the posterior mandible.
10	Barbosa et al	2021	Brazil	Split Mouth Randomized Controlled Trial	Neoporos and Aqua, NeoDent	Stored in 0.9% saline solution	Implants modified by double acid etching and sand blasting	Posterior maxilla	Above 18 years	40 implants	-	No statistical difference in ISQ values between groups	Bo+A1:N21th groups showed similar median values for ISQ with no statistical difference. Surface wettability of implants with hybrid macrostructure did not increase the primary and secondary stability of implants in the posterior maxilla.

1. Quantitative Synthesis

The study conducted by Karabuda et al. (2010) showed that hydrophilic implants experienced slightly less bone

loss (0.43 mm) compared to non-hydrophilic implants (0.46 mm). The survival rate was slightly lower for hydrophilic implants (97.91%) compared to non-hydrophilic implants (100%).[9] Lang et al. (2011) reported a 62% osseointegration at 4 weeks for both hydrophilic and non-hydrophilic implants, suggesting superior performance for the hydrophilic SLActive implants.[10]

Uwe Held et al. (2013) found significant bone loss (1.46 mm) with hydrophilic implants but noted enhanced early osseointegration, particularly in poor bone quality areas (D3 and D4 bone).[11] Degasperi et al. (2014) observed a bone loss of 0.7 mm with a high survival rate of 99.00% for hydrophilic implants, indicating favorable short-term outcomes.[12]

Eekeren et al. (2015) reported higher Implant Stability Quotient (ISQ) values for bone-level implants (75) compared to tissue level (67), highlighting better performance in bone-level configurations.[13] Sartoretto et al. (2017) demonstrated greater bone area and BIC for hydrophilic implants in a histomorphometric analysis, suggesting improved early-period bone anchorage.[14]

Trisi et al. (2017) found that hydrophilic implants had a significantly higher BIC (65.33%) compared to non-hydrophilic implants (49.49%), with slightly better ISQ values, indicating stronger bone integration.[15] Yamaner et al. (2017) reported that after 81 months, the marginal bone loss was slightly less in hydrophilic implants (0.53 mm) compared to non-hydrophilic (0.71 mm), though not statistically significant, showing long-term clinical efficacy.[16]

Hicklin et al. (2020) reported a 100% survival rate for hydrophilic implants, supporting the safety and reliability of early functional loading in the posterior mandible.[17] Barbosa et al. (2021) found no statistical difference in ISQ values between hydrophilic and non-hydrophilic implants, indicating similar median values for primary and secondary stability.[18]

2. Qualitative Synthesis

The studies generally demonstrate favorable outcomes for hydrophilic implants in terms of bone loss and survival rates. Hydrophilic modifications appear to enhance early osseointegration and maintain better stability, particularly in challenging bone conditions. However, some studies like those by Uwe Held et al. and Yamaner et al. suggest that the improvements in bone loss metrics are not always statistically significant over the long term.

Hydrophilic implants seem particularly beneficial for early loading protocols, as evidenced by the high survival rates and improved bone-to-implant contact reported in multiple studies. These characteristics potentially make hydrophilic implants a more reliable choice in the clinical setting, offering faster rehabilitation with sustained implant stability and success.

However, the variability in study designs, sample sizes, and patient populations noted across the reviewed studies suggests the need for further research with standardized methodologies to confirm these findings and fully establish the advantages of hydrophilic over non-hydrophilic dental implants.

3. Risk of bias

Two studies (Karabuda et al., 2010; Barbosa et al., 2021) were assessed using the Cochrane Risk of Bias tool (Figure 2). Both studies were found to have a low risk of bias concerning random sequence generation and allocation concealment, suggesting an appropriate randomization process and allocation masking. However, there was high or unclear risk associated with blinding of participants, personnel, and outcome assessors, which could have influenced the outcomes due to detection and performance biases. Incomplete outcome data, selective reporting, and other potential sources of bias were deemed to be of low risk across these RCTs, indicating that the studies reported results comprehensively without major data discrepancies.

For the non-randomized studies (Uwe Held et al., 2013; Degasperi et al., 2014; Eekeren et al., 2015; Yamaner et al., 2017; Hicklin et al., 2020), the ROBINS-I tool was used to evaluate the potential for confounding and other biases (Figure 2). The overall assessment showed moderate risks due to confounding factors and deviations from intended interventions, which could reflect inherent differences between intervention and control groups. Measurement of outcomes was rated as moderate risk in some studies due to the lack of blinding of outcome assessors, which may have introduced measurement bias. Selection of participants and classification of interventions were generally assessed as low risk, ensuring consistency in treatment allocation and participant eligibility.

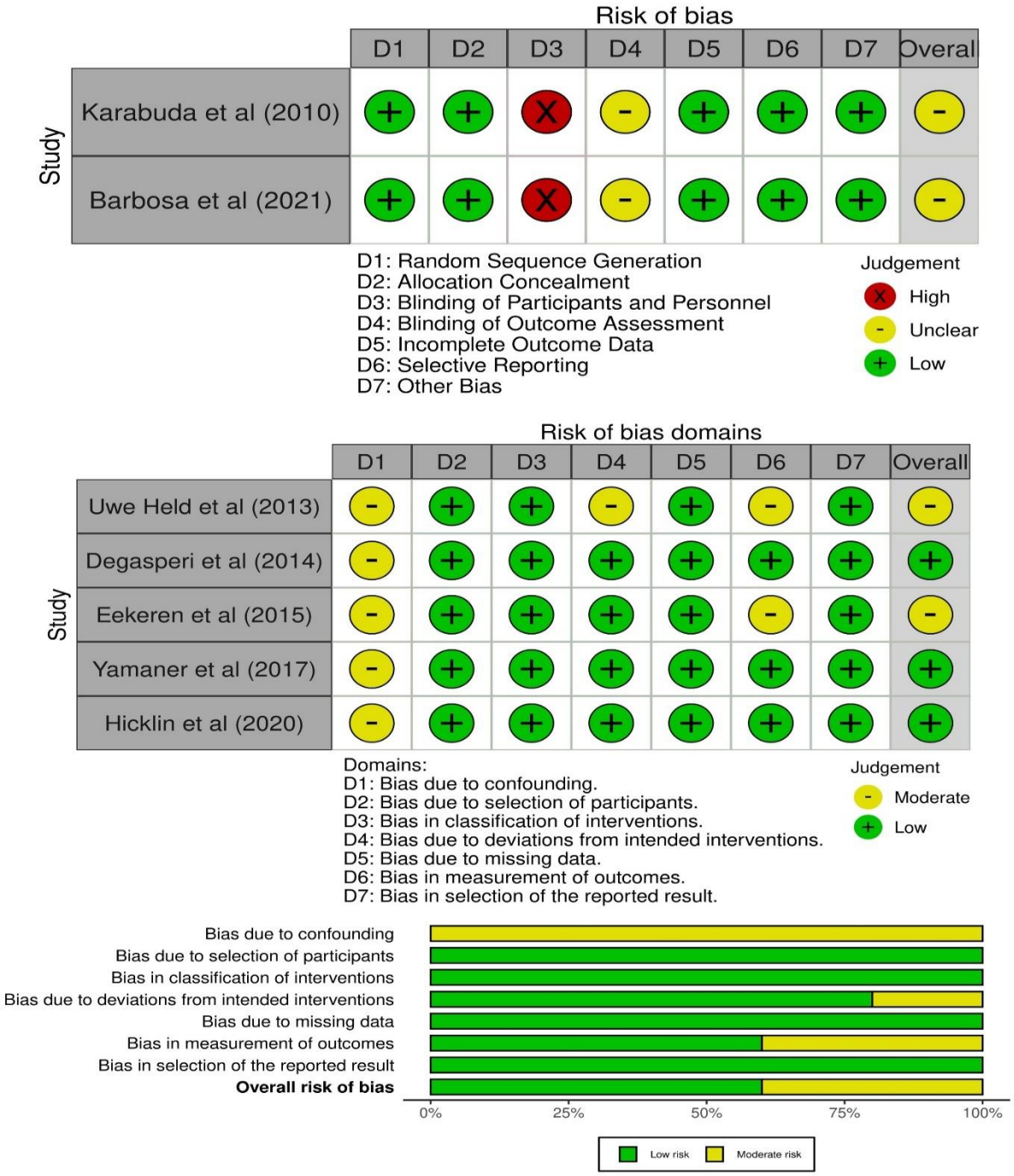

Figure 2: Risk of bias in the randomized and non-randomized clinical trials included in the present systematic review

The Newcastle-Ottawa Scale (NOS) was applied to the cross-sectional studies (Lang et al., 2011; Sartoretto et al., 2017; Trisi et al., 2017) to evaluate selection, comparability, and outcome assessment (Table 2). The studies scored between six and eight stars on a nine-star scale, indicating moderate to high quality. Most studies had robust selection methods and comparability between groups. However, some studies were limited in comparability, typically receiving fewer stars due to not accounting adequately for confounding variables.

Table 2: Risk of bias evaluated using Newcastle-Ottawa Scale for Cross-Sectional Studies

Sr. No.	Author (Year)	Selection (max 4 stars)	Comparability (max 2 stars)	Outcome (max 3 stars)	Total Stars (max 9)
1	Lang et al (2011)	***	**	***	8
2	Sartoretto et al (2017)	***	*	**	6
3	Trisi et al (2017)	***	*	***	7

Across all study designs, the primary sources of bias identified were related to blinding (in RCTs and non-randomized studies) and control of confounding factors (in non-randomized and cross-sectional studies). Despite these limitations, the overall quality of the evidence was adequate, with the majority of studies showing low risk in key domains such as selection and outcome reporting. These findings indicate a moderate risk of bias for some outcomes but generally acceptable quality of evidence across the studies included (Table 3).

Table 3: Quality of evidence in the articles included in the systematic review

Sr. No	Author & Year	Risk of Bias	Inconsistency	Indirectness	Imprecision	GRADE Rating
1	Karabuda et al, 2010	Low	None	Direct	Low	High
2	Lang et al, 2011	Low	None	Direct	Low	High
3	Uwe Held et al, 2013	Moderate	None	Direct	Moderate	Moderate
4	Degasperi et al, 2014	High	None	Direct	Moderate	Low
5	Eekeren et al, 2015	Moderate	None	Direct	Low	Moderate
6	Sartoretto et al, 2017	Low	None	Direct	Low	High
7	Trisi et al, 2017	Low	None	Direct	Low	High
8	Yamaner et al, 2017	Low	None	Direct	Low	High
9	Hicklin et al, 2020	Low	None	Direct	Low	High
10	Barbosa et al, 2021	Low	None	Direct	Low	High

4. Discussion:

This systematic review comprehensively evaluated the outcomes associated with hydrophilic dental implants compared to their non-hydrophilic counterparts, with a focus on bone loss, survival rates, and bone-to-implant contact (BIC). The studies included in this review provide substantial insights into the potential benefits of hydrophilic surfaces, suggesting an enhanced performance in various clinical conditions. Our findings indicate that hydrophilic implants often show comparable or superior results in terms of bone loss when contrasted with non-hydrophilic implants. For instance, Karabuda et al. reported slightly lower bone loss with hydrophilic implants (0.43 mm) compared to non-hydrophilic ones (0.46 mm).[9] Similarly, Degasperi et al. noted a mean bone loss of 0.7 mm with hydrophilic implants, aligning with the hypothesis that these implants may reduce bone resorption in the early post-operative period.[10]

Nevertheless, the study by Uwe Held et al. highlighted a notable exception, where hydrophilic implants experienced a greater bone loss of 1.46 mm, particularly in areas of poor bone quality.[11] This suggests that while hydrophilic implants can be advantageous, their efficacy might be contingent upon the local bone environment. Furthermore, the long-term study by Yamaner et al. showed that the differences in bone loss between hydrophilic and non-hydrophilic implants, while favoring the former, were not statistically significant over extended periods, underscoring the complexity of factors that influence implant success over time.[16]

The survival rates associated with hydrophilic implants were predominantly high across the studies, with many reporting rates exceeding 97%. Notably, Hicklin et al. documented a 100% survival rate for hydrophilic implants in the posterior mandible, reinforcing the potential of these implants for early loading applications without compromising long-term outcomes.[17] This is particularly relevant in clinical practices aiming to shorten the treatment duration and accelerate patient recovery.

In terms of BIC, the review revealed positive outcomes for hydrophilic implants. Trisi et al. and Sartoretto et al. both reported higher BIC percentages for hydrophilic implants than their non-hydrophilic counterparts, indicating superior initial bone integration.[14,15] Such findings suggest that hydrophilic implants could confer a biomechanical advantage by enhancing early bone anchorage, which is critical for the stability and longevity of the implant.

The clinical implications of these findings are significant, suggesting that hydrophilic implants can be especially beneficial for patients undergoing early loading protocols or those with less ideal bone conditions. However, the variability observed in study outcomes and the influence of external factors such as implant design and surface treatments indicate that results should be interpreted with caution. While generally favorable, the performance of hydrophilic implants can vary widely based on specific clinical scenarios and patient factors.

Despite the promising results, this review acknowledges several limitations within the included studies, such as variations in study design, patient populations, and follow-up durations, which could influence the consistency and reliability of the findings. Moreover, the predominance of short- to medium-term data limits the ability to fully assess the long-term efficacy and stability of hydrophilic implants.

To address these limitations, future research should focus on standardizing study protocols and extending the

duration of follow-up to better evaluate the long-term benefits and potential drawbacks of hydrophilic implants. Such studies would help solidify the understanding of when and how hydrophilic implants can be most effectively utilized in dental practice. Ultimately, while the current evidence supports the use of hydrophilic implants in certain clinical contexts, ongoing research is crucial to optimize treatment outcomes and expand the applicability of these findings to a broader range of patient conditions.

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