Concise Review

Influence of Implant Surfaces on Peri-Implant Diseases – A Systematic Review and Meta-Analysis

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ARTICLE INFO

Article history:
Received 29 July 2024
Received in revised form
27 September 2024
Accepted 9 October 2024
Available online 12 November 2024

Key words:
Rough surface implant
Machined surface implant
Smooth surface implant
Peri-implantitis
Implant failure

ABSTRACT

Objectives: The aim of this systematic review and meta-analysis was to evaluate the current literature on the effect of implant surface characteristics on peri-implant marginal bone levels (MBL), soft tissue periodontal parameters, peri-implantitis, and implant failure rates.
Materials and Methods: Randomized controlled trials were searched in electronic databases. Risk of bias within the selected studies was assessed using the Risk of Bias Tool 2. Meta-analyses were performed using Review Manager software for studies with similar comparisons reporting same outcome measures.
Results: Ten randomized control trials were included in the present review. The primary outcome of changes in peri-implant MBL favoured implants with machined surfaces, however, the difference was not statistically significant ($P = .18$). The changes in probing pocket depths significantly favoured the use of machined surfaces ($P = .01$), while the implant failure rates favoured roughened surface implants. However, the difference was not statistically significant ($P = .09$).
Conclusion: Machined surface implants were favoured in terms of lesser peri-implant MBL, though the difference was not significant. The analysis also demonstrated limited favourable outcomes in terms of periodontal parameters for machined surfaces, with slightly significantly better outcomes in terms of probing pocket depths. However, rough surface implants tended to display a lower implant failure.

Introduction

The 2017 World Workshop for the Classification of Periodontal and Peri-implant Diseases, has defined peri-implantitis, as a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.[1] Systematic reviews commissioned during the XI European Workshop in Periodontology (2014) highlighted increased variations in the prevalence of peri-implant mucositis and peri-implantitis. While 30.7% of implants showed indications of peri-implant mucositis and around 9.6% showed peri-implantitis at an implant level h,[2] multiple meta-analyses have indicated a patient-level prevalence of 43% for peri-implant mucositis and 22% for peri-implantitis.[3] Similarly, other authors have also reported incidence of 46.83% for peri-implant mucositis and of 19.83% for peri-implantitis.[4] This prevalence is certainly due to the rise, taking into consideration the increased

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https://doi.org/10.1016/j.identj.2024.10.007

number of implant and implant supported prostheses conducted by dentists across the world. In addition, demands and awareness of an aging patient population leads to chronic illness of the oral tissues and need for longer maintenance of the already functioning implants.[5]

Similar to the biofilm formation on natural teeth, bacterial colonization occurs within minutes after the implantation procedure and throughout the life cycle of an implant.[6] The etiological factor influencing the initiation and progression of peri-implant diseases has been well documented.[7] Although the primary etiological factor is the aggregation of dental biofilm around abutment/implant surfaces; other patient-related, and site-specific factors may contribute towards progression of inflammation around dental implants.[8] Moreover, adverse immune reactions to placement of dental implant in bone may lead to aseptic early marginal bone loss, attributed as 'osteoimmunological remodeling'.[9]

The initial implants placed evaluated in 1990 were mainly machined surfaces with minimal surface roughness (Sa 0.5-1.0 μm).[10] However, substantial roughness of implant surfaces were later introduced, such as acid etching, sandblasting and plasma spray treatments, leading to improved bone-implant interactions and increased long term stability of implants.[11] The introduction of moderately rough surfaces with Sa values of 1 to 1.5 μm increases textured surface area of implants that, in turn, increases direct bone-to-implant contact and ultimately leads to effective stress distribution. Invitro studies have also shown a positive influence on surface roughness in enhancing soft tissue and osteoblasts cell response that considerably impacts the immediate stability of implants.[12] These surface modifications have also demonstrated better long-term success/survival of dental implants in comparison to machined surfaces.[12] More recent evidence evaluating 133 moderately rough implants (TiUnite surface) with a follow-up of 20 years, have also shown a high survival of 94.7% with only nine implants demonstrating marginal bone loss of over 2 mm.[13]

However, debates around benefits of roughened implant/abutments have re-emerged due to possibilities of increased retention of oral microbiota around exposed rough surfaces of abutment/implant surfaces. There are conflicting views related to progression of peri-implant mucositis and peri-implant bone loss around roughened versus machined surface implants.[14] The equilibrium to provide greater surface roughness for better direct bone-to-implant contact without promoting biofilm formation is difficult to achieve. Consequently, the complexity of maintaining roughened implant surfaces once exposed to oral environment and its increased risk of inducing biofilm-induced inflammatory reaction has led the investigators to reconsider the application of machined/polished surfaces, especially at the implant/abutment interface.[15] The development of novel surface texture at different levels of an implant surface may address the needs related to maintenance of implants along with stable tissue integration.

Quirynen et al[16] examined whether variations in surface roughness influences plaque formation and inflammation of gingival tissues around implants over a period of 1 year. Their results indicated that implant surface roughness below a threshold value of <0.2 μm did not influence the quality and quantity of microbial aggregation on the implant surfaces. In addition, authors also suggest that a certain degree of surface roughness appears to be important to ensure resistance to clinical probing around the implants.[16] Limited evidence suggests no conclusive correlation between different implant roughness and its effect on peri-implant tissue parameters.[17]

It is important to evaluate the effects of implant surface modifications on the soft and hard tissue parameters and eventual survival of implants. This systematic review and meta-analyses are aimed to collate information and present an overview if modifications in implant surface roughness influence tissue responses, affect the presence and severity of peri-implant diseases, and implant failure rates.

Materials and methods

The current systematic review was conducted in accordance to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses and the Cochrane collaboration guidelines and the reporting used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses checklist.[18]

The eligibility criteria for the present review attempted to clearly answer a focused question using Population, Intervention, Comparison, Outcome framework.[19] Population, Intervention, Comparison, Outcome framework was identified as follows:

Population (P): partially dentate patient receiving single or multiple implant-supported prostheses for a minimum of 2 years

Intervention (I): dental implants with roughened surface

Comparison (C): dental implants with machined/smoothened surface

Outcome (O): primary outcome: peri-implant marginal bone levels (MBL) around implants; secondary outcomes: bleeding on probing, probing pocket depths (mm), incidence of peri-implant mucositis, incidence of peri-implantitis and percentage of implant failure.

The current review has been registered at the National Institute for Health Research (NHR) under the PROSPERO ID CDR42023412147. Ethical approval was not required for this systematic review.

Inclusion criteria: This review included randomized controlled trials (RCTs), with minimum follow-up of ≥2 years, that compared dental implants with smooth surface with those with rough surface. The included studies must report on changes in peri-implant marginal bone loss and may also include soft tissue periodontal parameters around dental implants. No language restrictions or publication status were employed.

Exclusion criteria: Studies other than RCTs and RCTs that did not provide sufficient information were excluded. RCTs with less than 2 years follow-up were excluded.

Type of participants: Partially dentate patients who received single or multiple dental implants.

Types of interventions: The intervention and the control groups involved use of roughened surface implants and machined/smoothened surface, respectively.

Outcome measures: Primary outcome: peri-implant MBL around implants and secondary outcomes: Bleeding on Probing, Probing pocket depth (mm), incidence of peri-implant mucositis, incidence of peri-implantitis, and percentage of implant failure.

Search strategy and study selection: The electronic databases PubMed, Embase, and Scopus were reviewed up to January 2024, to identify relevant studies. The search was conducted by two independent reviewers (A.H. and M.S.) independently and in duplicate; examined the retrieved studies based on the title, abstract, and keywords (Table S1). Studies which were irrelevant were excluded, and the remaining studies were reviewed after obtaining full text. Any disagreements were resolved by discussion to reach a consensus or by consultation with a third reviewer (H.E.). In the event of duplicate papers, the one with the most relevant, and sufficient information with the longest follow-up period was selected. Reasons for exclusion were reported.

Data extraction: The following information were extracted from the included studies: (1) Study characteristics: title, authors' names, study location, year of publication, (2) Participants: demographic characteristics, number of participants in both treatment groups, and number of implants placed. (3) Interventions: number of smooth surface implants. (4) Comparison: number of rough surface implants. (5) Outcomes: changes in periodontal parameters and implant failure. (6) Length of the observation period. Any disagreements between reviewers were resolved by discussion to reach a consensus or by consultation with a third reviewer (H.E.). Corresponding authors were contacted for additional information if required.

Quality assessment of included studies: The quality of the included studies was assessed using Cochrane Risk of Bias tool 2 (RoB 2).[20] Two independent reviewers assessed the quality of each study (A.H. and M.S.), and disagreements were resolved by consensus or a third reviewer (H.E.). The RoB 2 tool was used to assess bias related to randomization process, bias related to aberrations in primary and secondary outcomes, bias due to missing outcome data, and selection of the repeated result. An overall score for each study was applied based on: (1) low risk of bias, (2) some concerns expected in at least one domain, but not to the extent that indicates a study with a high risk of bias for any domain, (3) high risk of bias in at least one domain or issues related to multiple domains in a study such that these issues significantly affected certainty in the study results.

Data synthesis: A statistical software program (Review Manager [RevMan] software, version 5.3, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) was used to conduct meta-analyses for studies of similar comparisons reporting the same outcome measures. Random-effects model was used to pool the results from more than one study as heterogeneity between studies was expected. The statistical heterogeneity across different studies was assessed by means of Cochran's test for heterogeneity and I^2 statistic.[20] An I^2 value of >50 indicated a substantial heterogeneity. The participant was considered as the statistical unit of analysis. A leave-one study-out sensitivity analysis was conducted to check source of heterogeneity, stability of results, and influence of studies.

Results

Characteristics of study design: A total of 2394 studies were retrieved from the databases. After titles and abstracts were examined independently and in duplicate by two review authors (A.H. and M.S.), 24 studies were eligible for full-text review. Fourteen studies were subsequently excluded and as a result, 10 studies[21-30] were included in the present systematic review (Figure 1). Two of the selected studies[21,28] were conducted in multiple centres while the others were conducted either in a private practice setting or a university hospital setting. The majority of the included studies,[22,23,25,26,28-31] received partial funding and/or received implant components from the implant systems/companies as indicated in the studies.

Risk of bias: Overall, only one study[23] was rated to have a low risk of bias, four studies[22,26,29,30] demonstrated a moderate risk with some concerns, while five studies[24,25,27,28,31] were graded as high risk of bias (Figure S1, Table S2).

Bias based on randomization and allocation concealment: Five studies[22,23,26,29,30,32] were considered at a lower risk of bias in this category as there was adequate information highlighted; however, remaining five studies[24,25,27,28,31] were judged at a higher risk of bias due to insufficient information (Figure S1, Table S2).

Bias due to missing outcome data, and selection of the repeated results: All the studies demonstrated no selective reporting, and all outcomes appear to be documented. Thus, they were rated at low risk for those domains (Figure S1, Table S2).

Effects of intervention: In total, 472 participants with 1463 dental implants were included in the present review. Of these, 689 implants presented with a machined surface while the remaining implants had roughened surface. All the studies reported the data at the implant level (Table).

Primary outcome: Changes in peri-implant MBL

The changes in peri-implant MBL were reported in seven studies.[22,23,26-29,31] The changes were in favour of implants with machined surfaces. However, the difference was not statistically significant (mean difference [MD] 0.14; 95% confidence intervals [CI] −0.06 to 0.34; $P = .18$, Figure 2). Substantial heterogeneity was detected ($\chi^2 = 76.27$, $df = 6$ ($P < .00$); $I^2 = 92\%$).

Secondary outcome

Changes in bleeding on probing (BOP)

The changes in BOP were reported in three studies.[22,25,26] The changes were in favour of implants with machined surfaces. However, the difference was not statistically significant (MD 0.06; 95% CI −0.12 to 0.23; P = .53, Figure 3A). Substantial heterogeneity was detected ($\chi^2 = 6.10$, df = 2 ($P = .05$); $I^2 = 67\%$).

Changes in probing pocket depth (mm)

The changes in probing pocket depth were reported in four studies.[22,23,25,26] The changes were in favour of implants with machined surfaces and the difference was statistically significant (MD 0.38; 95% CI 0.08-0.69; $P = .01$, Figure 3B). There was no heterogeneity detected ($\chi^2 = 4.96$, df = 3 ($P = .17$); $I^2 = 40\%$).

Prevalence of peri-implant mucositis

The prevalence of peri-implant mucositis was reported in one study.[28] The prevalence was in favour of implants with machined surfaces. However, the difference was not

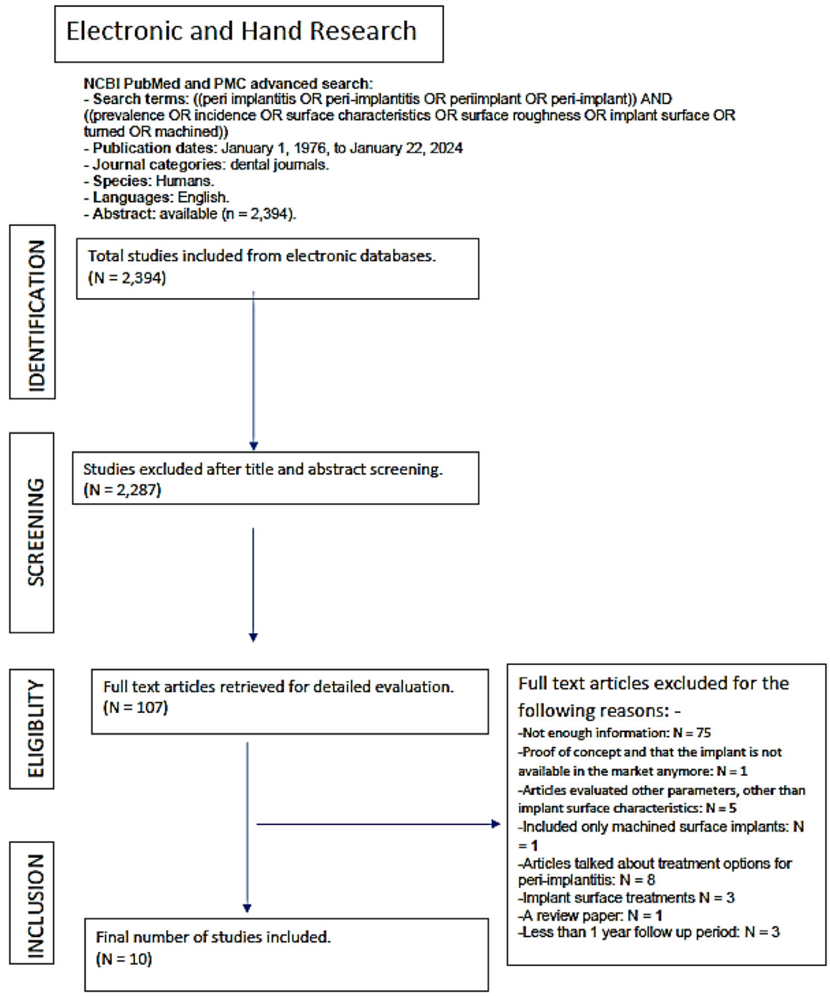

Fig. 1 – Flowchart of the search process. Sample size calculation: **Only five[23,25,28,29,31] out of 10 studies reported on the sample size calculation.**

statistically significant (MD 1.11; 95% CI −0.49 to 2.53; P = .8, Figure 3C). The heterogeneity was not applicable.

Prevalence of peri-implantitis

The prevalence of peri-implantitis was reported in five studies.[22,23,26,28,29] The prevalence was in favour of implants with machined surfaces. However, the difference was not statistically significant (MD 0.99; 95% CI −0.39 to 2.47; P = .97, Figure 3D). There was no heterogeneity detected (χ^2 = 4.06, df = 4 (P = .40); I^2 = 2%).

Implant failure

The implant failure was reported in seven studies.[22,24,26-29,31] The prevalence was in favour of implants with roughened surfaces. However, the difference was not statistically significant (MD 0.48; 95% CI −0.21 to 1.11; P = .09, Figure 3E). There was no heterogeneity detected (χ^2 = 1.44, df = 5 (P = .92); I^2 = 0%).

Sensitivity analyses: The leave-one-study-out sensitivity analysis was conducted to assess the robustness of the meta-analysis on overall effect-size estimate for peri-implant MBL changes (primary outcome) (Table S3). Excluding individual studies resulted in minor variations in the overall MD, with most 95% CI crossing zero and P values above 0.05, indicating a lack of significant changes (Table S3). However, substantial heterogeneity persisted throughout (I^2 > 90%), suggesting high variability across the included studies. These findings confirm that no single study disproportionately influenced the overall primary outcomes related to peri-implant MBL.

Discussion

The aim of the current systematic review was to evaluate the effect of implant surface modifications on the prevalence of MBL, soft tissue parameters, peri-implant diseases, and implant failure. The follow-up period of the included studies ranged from 24 to 290 months.

Primary outcomes

The primary outcome of present analysis was to compare the peri-implant MBL, regardless of the follow-up period, demonstrated a favourable but insignificant benefit to machined surfaced implants in terms of peri-implant MBL. Among the included studies, seven of them have reported mean of MBL.

Table – Characteristics of the included studies.

Articles	Donati[23]	Zetterqvist[30]	Rocci[27]	Tirone[29]	Rothamel[28]	Astrand[31]	Camarda[22]	Moberg[24]	Nicu[25]	Raes[26]
Follow-up period (in mo)	240	60	108	36	24	36	290	36	36	60
Number of participants	25	112	44	114	58	28	22	40	14	15
Age: Mean (range)	59.5 (36-80)	59.1 ± 8.2 (22.6-80.3)	51 (20-69)	59.7	(18-85)	61.7 (36-76)	71.1 ± 1.2	Machined: 62.6 (44.2-75.2) Roughened: 64 (40.2-77.2)	62.1	64 (46-72)
Number of implants	64	304	121	228	116	150	110	208	78	84
Implants system	Osseospeed, Astra Tech	Osseotite, Biomet 3i	Brånemark System (Nobel Biocare)	Nobel Biocare MkIII and Sweden & Martina Outlink2	BEGO Implant Systems (RSX)	Branemark, ITI	Branemark Swede-vent Screw-vent	Brånemark System (Nobel Biocare) and ITI	Branemark	Branemark
Machined – no. of implants	32	139	55	114	58	73	35	102	39	42
Machined surface characteristics	Turned	Hybrid – Machined coronal third	Machined	Machined	Machined	Turned	Machined external hex	Machined	Turned	Turned
Sa (roughness value in microns)	Sa – 0.7	Sa – 0.78	Sa – 0.7	Sa – 0.7	Sa – 0.7	Sa – 0.7	Sa – 0.5-1.0	Sa – 0.7	Sa – 0.78 ± 0.35	Sa – 0.78 ± 0.35
Roughened – no. of implants	32	165	66	114	58	77	36 screw-vent and 36 swede-vent	106	39	42
Roughened surface characteristics	TiOBlast	Continuous acid etched	TiUnite (oxidized)	TiUnite (oxidized) & Outlink	TiPure surface	ITI TPS surface (Titanium-Plasma – Sprayed)	Swede-vent & Screw-vent	ITI TPS surface (Titanium-Plasma – Sprayed)	TiUnite (oxidized)	TiUnite (oxidized)
Sa (roughness value in microns)	Sa – 1.1	Sa – 0.436	Sa – 1.35	TiU Sa – 1.35 Outlink Sa >2	Sa – 1.6	Sa >2	Sa 1-2	Sa >2	Sa – 1.35	Sa – 1.35
Method of assessment	Clinical and Radiographic	Radiograph and Mobility Assessment	Clinical and Radiographic	Clinically and Radiographic	Clinically and Radiologic	Clinical and Radiographic	Clinical and Radiographic	Clinical and Radiographic	Clinical and Radiographic	Clinical and Radiographic
Implant location	52% – maxilla 48% – mandible	Randomly Assigned	N/A	Left and right sides of the same arch	Opposite or next to each other	Maxilla	Mandible: 5 implants between the mental foramen	Mandible edentulism	Maxilla and Mandible	Maxilla and Mandible
Implant diameter	3.5 mm	60% – 4 mm; 40% – 3.75 mm	N/A	N/A	3.0, 3.75, 4.1, 4.5, 5.5 mm	Branemark: 3.3-3.75 mm ITI: 3.3-4.1 mm	3.75 mm	N/A	N/A	N/A

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Table. (Continued)

Articles	Donati[23]	Zetterqvist[30]	Rocci[27]	Tirone[29]	Rothamel[28]	Astrand[31]	Camarda[22]	Moberg[24]	Nicu[25]	Raes[26]
Implant length (mm)	8-19 mm	35% <10 mm, 33% – 11.5 mm, 22% – 13 mm, 10% – 15 mm or more	7-18 mm	N/A	7, 8.5, 10, 11.5, 13, 15 mm	Branemark: 8-18 mm ITI: 8-14 mm	Branemark: 15.83 ± 0.39 (10-20 mm) Swede-vent: 14.84 ± 0.41 (10-18 mm) Screw-vent: 14.42 ± 0.33 (10-16 mm)	N/A	N/A	N/A

The highest MBL mean was 1.65 ± 1.65 mm[26] and the lowest was 0.1 ± 0.4 mm[27] for the rough surface implant group. On the other hand, the MBL for machined implant surface group ranged between 0.1 ± 0.09 mm[21] and 1.56 ± 0.91 mm.[29] Although there is a difference between the two groups, the MD was not statically different (P = .22). These findings are in contrast with those reported in previous systematic reviews.[17,33] Doornewaard et al[33] conducted an exhaustive review that compiled data from RCTs and other prospective as well as retrospective studies; and as per surface roughness, the MBL amounted to 1.04, 1.01, and 0.86 mm for the rough, moderately, and minimally rough surfaces, respectively. Furthermore, there was a statistically significant difference observed between minimally and moderately rough, but not between moderately rough and rough surfaces.[33] Meta-analysis of the data showed a significant difference in MBL between minimally rough and moderately rough implant surfaces with less bone loss for the former.[33] On the other hand, Saulacic et al[17] also confirmed higher MBL on turned implant surface at baseline, 1 and 3 years (P > .05), at 7-year (P = .003), from 6 to 10 years (P = .006) and at 13-year following loading (P = .015) form various studies that constituted their data analysis.[21,24,34-36] The authors also highlighted that significantly different MBL was detected after long-term follow-up of the included studies indicating that implants with turned surfaces may be more prone to peri-implantitis with increasing timelines. For these reasons, modern oral implants are generally preferred over the old implant systems due to the superior osseointegration properties of moderately roughened implants. Besides plaque accumulation, the triggering mechanism behind bone loss may include foreign body reaction to cement and prostheses-loading conditions. Nevertheless, although rough surface implants induce statistically significant more bone loss according to the previous meta-analysis,[33] the clinical impact of surface roughness on bone loss is limited. While the evidence on marginal bone remodelling is still very inconsistent; some authors have described a rather positive influence using roughened neck implants. Koodaryan et al,[37] in their systematic review, included 12 studies, concluded that insertion of implants with rough and rough-surfaced microthreaded neck design influenced the rate of bone loss and favoured lesser MBL compared to machined neck implants. The diverse causes of bone loss and the variability among studies, including the inclusion of at-risk patients and inadequate data reporting, complicate the ability to draw definitive conclusions about the impact of implant surface roughness on bone loss over time.

Secondary outcomes

Changes in soft tissue parameters – BOP and PDs

Among the 10 included studies that reported on BOP, three presented BOP in the form of mean with standard deviations,[22,25,26] while five studies have presented BOP as a % of sites in the two groups.[23,24,28,30,31] In the current meta-analysis, only those presented BOP in form of mean with standard deviations were involved. The difference in terms of BOP favoured machined surfaces; however, there was no statistical difference observed. The percentage range of BOP in the remaining studies ranged from 7.9% to 14% in the

Study or Subgroup	Roughened Mean	Roughened SD	Roughened Total	Machined Mean	Machined SD	Machined Total	Weight	Mean Difference IV, Random, 95% CI
Astrand 2004	0.2	0.25	77	0.1	0.09	73	19.1%	0.10 [0.04, 0.16]
Camarda 2020	1.39	0.43	72	0.85	0.18	35	18.3%	0.54 [0.42, 0.66]
Donati 2018	0.83	1.59	32	0.41	1.25	32	5.9%	0.42 [−0.28, 1.12]
Raes 2018	1.65	1.65	42	1	0.9	42	7.7%	0.65 [0.08, 1.22]
Rocci 2013	0.1	0.4	66	0.2	0.5	55	17.3%	−0.10 [−0.26, 0.06]
Rothamel 2022	0.58	0.24	58	0.61	0.28	58	18.7%	−0.03 [−0.12, 0.06]
Tirone 2021	1.32	0.85	57	1.56	0.91	57	13.0%	−0.24 [−0.56, 0.08]
Total (95% CI)			**404**			**352**	**100.0%**	**0.14 [−0.06, 0.34]**

Heterogeneity: $Tau^2 = 0.06$; $Chi^2 = 76.27$, df = 6 ($P < 0.00001$); $I^2 = 92\%$

Test for overall effect: Z = 1.33 (P = 0.18)

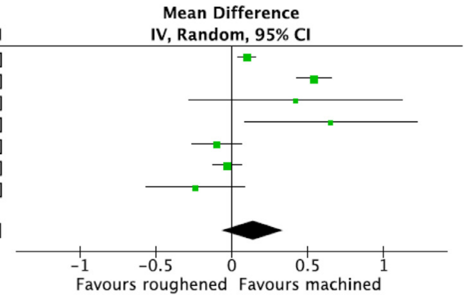

Fig. 2 – Comparison: roughened versus machined surface dental implants; primary outcome: changes in peri-implant marginal bone level (mm). CI, confidence interval; IV, inverse variance; SD, standard deviation; z, z test; τ, Kendall tau.

machined group, as compared to 9.1% to 25.9% in the roughened group. In terms of evaluating the PD changes, out of the 10 included studies, four of these studies reported changes in pocket probing depth.[22,23,25,26] These changes in probing depth measurements significantly favoured machined surfaces. While Saulacic et al[17] could not identify any significant differences in terms of deeper probing depths around either surfaces; the frequency of implants with BOP was higher on turned implant surfaces during first 3 years ($P > .05$) as well as at 7-year ($P = .01$) and 13-year follow-up ($P > .05$). More BOP was also found on rough implant surfaces ($P > .05$) with increasing periods of follow-up. Moreover, Dierens et al[38] highlighted BOP as a poor predictor for bone loss or peri-implantitis in a 18-year observational study. Retrospective evaluation of prevalence of suppuration and its relationship to surface modifications have demonstrated more frequent detection of suppuration on rough surfaces at a 6 to 10 years follow-up ($P > .05$), however, it was more prevalent on turned surfaces at 13 years ($P > .05$).[35,36] Interestingly, the lowest probing depth measurements were presented at the 25 years follow-up by Camarda et al,[22] wherein no significant differences were noticed between the two implant surfaces ($P = .42$), while Raes et al[26] that evaluated influence of implant surface modifications (turned vs TiUnite) in patients with a history of severe periodontitis over 5 years, demonstrated deeper PDs for both groups (Turned: 3.1 versus TiUnite: 4.2 mm, $P = .09$).

Although a meta-analysis was not conducted to evaluate plaque scores around different implant surfaces, regardless of the follow-up period, five RCTs presented this parameter.[23,24,29-31] Plaque scores around machined surfaces ranged from 11.9% to 37%; versus 7.5% to 36% for the roughened surfaces. Other systematic reviews have demonstrated that turned implant surfaces were in favour of lower plaque accumulation at the prosthesis delivery, after 1 and 13 years of loading.[17] Nevertheless, more plaque was found on turned from 6 to 10 years, at 7 years, and from 12 to 15 years following loading. However, none of these differences were statistically significant.[17] Serrano et al[32] directed their clinical trial in patients with a history of periodontitis, where there is a higher risk of exposure of the coronal portion of the implant to the oral environment. The investigators evaluated different coronal surfaces such that hybrid-designed implants were compared to the conventional moderately rough implants with the hypothesis that less biofilm accumulation and, reduced progressive marginal bone loss with improved clinical and microbiological outcomes were related to hybrid-designed implants. Since the follow-up period was only up to 1 year, the RCT could not confirm this hypothesis as both groups showed minimal bone remodelling process and hence the coronal third of the implant surface was not exposed to the oral environment. These results are in agreement with those reported during the first year in function by Wennström et al[39] comparing machined and moderately rough surface implants in a population of previously treated periodontitis patients but did not find significant differences between these implants with different surface microtopographies.

Changes in prevalence of peri-implant mucositis and peri-implantitis

The hypothesis that machined implants show less tendency for peri-implantitis but a relatively longer healing period, led to an advent of roughened surfaces, however with an adjunct possibility of increased risk of complications. Moreover, severe discrepancies have been detected while addressing the case definitions for peri-implant mucositis and peri-implantitis. Out of the five RCTs that reported peri-implantitis; two[28,29] were conducted after the new case definition of peri-implantitis was published by the EFP-AAP.[1] Regardless of the follow-up period, the prevalence of peri-implant mucositis and peri-implantitis did not favour one type of surface over another. Using the most recent definition of peri-implantitis recommended by the American Academy of Periodontology and the European Federation of Periodontology,[1] the participant-level prevalence for peri-implantitis over a period of 25 years[22] was 9% (2 out of 22 participants). This prevalence appeared lower than the peri-implantitis rates reported in two long-term studies, which found prevalence rates of 29.7% and 16% among edentulous participants who were rehabilitated with implant-supported mandibular prostheses.[40,41] Saulacic et al evaluated the prevalence of peri-implantitis within the two groups. While the majority of the studies reported similar survival rates, only one study, Polizzi et al[36] reported significantly more implant failures with machined surfaces ($P = .005$). This split mouth-designed study reported a higher incidence of peri-implantitis in rough surfaces, as well as on turned implant surfaces, without statistically significant difference ($P > .05$). According to Saulacic et al,[17] it does not seem that the use of minimally instead of moderately rough surfaces would help to prevent peri-implantitis; however, this may be attributed to a lack of adequate studies on the impact of implant surface on the development of peri-

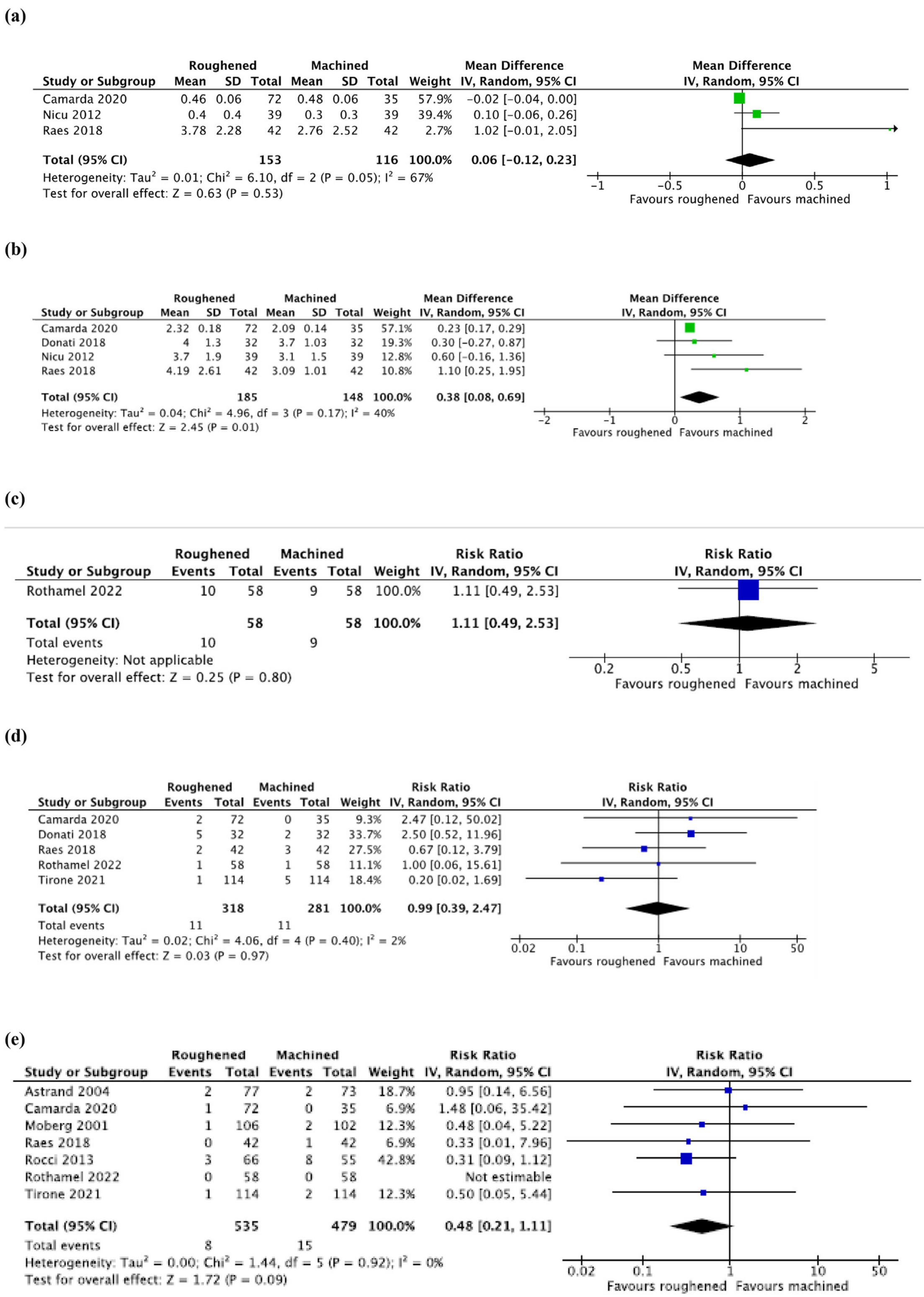

Fig. 3 – Comparison: roughened versus machined surface dental implants; secondary outcome: (A) changes in bleeding on probing. (B) Changes in probing pocket depth (mm). (C) Prevalence of peri-implant mucositis. (D) Prevalence of peri-implantitis. (E) Implant failure rate. CI, confidence interval; IV, inverse variance; SD, standard deviation; z, z test; τ, Kendall tau.

implantitis. The limited evidence suggested no strong correlation between rough surface implants and incidence of peri-implantitis when compared to turned implant surfaces. Serrano et al,[32] focused on selected patients with history of periodontitis since these patients have shown significantly higher bone loss when comparing anodized surface implants to hybrid and turned implants. The patients demonstrated a higher incidence and progression of peri-implantitis for roughened surface implants. While evaluating prevalence of peri-implantitis in comparing minimally with moderately rough implants in patients with severe periodontitis, Raes et al,[26] confirmed the TiUnite surface was more prone to peri-implant disease (in terms of increased bone and attachment loss) than the turned surfaces. Additionally, for patients with active or stable periodontitis, this increased risk of peri-implant disease might be detrimental and may contribute to an increased risk of early implant failure. Finally, lower incidence of peri-implantitis (1.9%) on a long term was demonstrated for implants with oxidized surfaces when the patients with acceptable hygiene were scheduled for regular professional cleaning.[42] Interestingly, biofilm removal at machined implant surfaces has been depicted to be easier when exposed to the oral environment, which could also result in lesser risk of peri-implantitis.[43] This fact is especially relevant for patients with a history of periodontitis, as they present an intrinsic risk of developing peri-implantitis.[7,44] Additionally, the long-term results (20 years) from Donati et al[23] comparing implants with the same microthread design but different surface microtopography (turned vs. moderately rough) (Astra Tech Dental Implant System, Mölndal, Sweden) in a population with history of periodontitis reported limited, although higher MBL changes around modified surface implants (approx. 0.8 mm) compared to nonmodified ones (approx. 0.4 mm). In spite of these differences, the long-term bone level stability demonstrated the importance of strict supportive peri-implant care measurements in these patients as the key factor to preserve peri-implant health over time, irrespective of the implant surface characteristics.

Changes related to implant failure rate

In terms of implant failure, the cumulative analysis showed favourable results for roughened implant surfaces; however, the differences were insignificant. Doornewaard et al,[33] summarized the percentage of implant survival from 79 publications constituting 107 study groups, that ranged from 73.4% to 100%, regardless of the surface characteristics. Further subanalyses showed that the average weighted implant survival was 96.4% for rough, 98.4% for moderately rough, and 97.6% for minimally rough implants. Additionally, in a 10-year retrospective study Aglietta et al[45] found lower implants survival rate and higher MBL in periodontally compromised than periodontally healthy tobacco smokers, regardless of the implant system used. While smoking was initially related to the early healing events on implants with turned surface, later studies confirmed its impact irrespective of the type of implant surface.[46,47] The relation between smoking and type of implant surface cannot be confirmed from the present review, as the analysed studies varied in defining the criteria for smokers (ie, number of cigarettes a day).

Limitations: There are general limitations of two-dimensional radiological measurements provided in most studies. Unfortunately, two-dimensional conventional radiographs only monitor the mesial or distal aspect of bone loss around the implant body. Additionally, issues pertaining to case definition of peri-implantitis and under or over-estimation of peri-implant diseases may hamper the readers' understanding of inferences drawn from this study. Also, it is impossible to control patient and site-related confounders, that may affect bone loss such as implant design, insertion site, need for augmentation, different surgeons with variations in level of expertise performing the operations, prosthetic treatment protocols and follow-up timeline, and measurement methods might limit conclusions derived from these meta-analyses.

Conclusion

Within the limitations of this systematic review and meta-analysis, machined surface implants showed less peri-implant marginal bone loss, though the difference was not significant. The analysis also demonstrated limited favourable periodontal parameters for machined surfaces, particularly in terms of probing pocket depths. However, rough surface implants displayed a lower prevalence of implant failure, although, this difference was not significant.

Conflict of interest

All authors of the current manuscript hereby declare that there are no conflicts of interest.

Data availability statement

The data that support the findings of this study are available on the request from the corresponding author. The data are not publicly available due to privacy.

Acknowledgements

None.

Funding

None.

Author contributions

Ahmad Hussein and Maanas Shah: Data curation; investigation; methodology; writing – original draft; writing – review and editing. Momen A. Atieh: Formal analysis; investigation; methodology; software; writing – original draft; writing – review and editing. Sara Alhimairi and Fatemeh Amir-Rad: Investigation; resources; software; writing – original draft; writing – review and editing. Haitham Elbishari: Conceptualization; data curation; writing – original draft; writing – review and editing.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.identj.2024.10.007.

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