Periimplantitis and Implant Body Roughness: A Systematic Review of Literature

Fabienne Jordana, MSc, DDS, PhD,* Léa Susbielles, DDS,† and Jacques Colat-Parros, MSc, DDS, PhD‡

Purpose: *The aim of this systematic review was to evaluate whether implant roughness is associated with periimplantitis in humans.*

Materials and Methods: *An electronic search of 3 databases (MEDLINE, Web of Knowledge, and the Cochrane Library) was undertaken until October 2017 and was supplemented by manual searching. Prospective studies were included if they met the following criteria: (1) give a clear definition of periimplantitis and (2) contain outcome data (clinical and radiological data) considering the periimplantitis rate. A systematic review was carried out to evaluate the impact of roughness on the periimplantitis rate.*

Results: *Of 4690 potentially eligible articles, 22 were included in the qualitative analysis and quantitative synthesis.*

Conclusions: *This systematic review suggests that roughness and surface treatment of dental implants are important factors associated with periimplantitis. (Implant Dent 2018;27:672–681)*

Key Words: periimplant disease, surface roughness, implant surface

Periimplantitis is an infectious process that occurs after osseointegration of the implant, thus after the formation of a functional interface between the bone and the implant.[1] Periimplant inflammation affects the surrounding hard and soft tissue.[2] Periimplantitis develops progressively from inflammation around the implant, which will increase in the soft tissues, eventually causing marginal bone loss.[3] Periimplantitis affects 16% to 28% of patients implanted, in the short or long term.[4,5] Bacteriologically, many germs are found in the infected periimplant site but they are mainly anaerobes (*Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, *Prevotella intermedia*, *Tannerella forsythia*, *Treponema denticola*, etc).[6–10] Some authors think that this disease entity is a foreign body reaction rather than an infective process.[11,12] The multiple causes of periimplantitis warrant better analysis.

An important parameter for the clinical success of dental implants is the formation of a direct bone-implant contact (BIC) that is directly influenced by the implant's surface roughness.[13] Implant surface topography at the micrometer level of resolution has been regarded as the most important factor for successful implant treatment.[14] Surface topography influences wound healing after implantation and also affects osseointegration.[15,16] Surface roughness measurement is the measurement of the small-scale variations in the height of a physical surface.[17] Some parameters, such as arithmetic mean surface roughness (Sa), that is, the average height of the analyzed area (micrometer), were used to describe the surface topography. Sa represents the arithmetic mean of the roughness area from the mean plane, for the height of the peaks and valleys according to the ISO 25178 standard.[18] Sa expresses, as an absolute value, the difference in height of each point compared to the arithmetical mean of the surface. According to Albrektsson and Wennerberg,[19] implants may be classified into 4 types according to surface roughness: smooth (Sa < 0.5 μm); minimally rough (Sa between 0.5 and 1.0 μm), moderately rough (Sa between 1.0 and 2.0 μm), and rough (Sa > 2.0 μm).

The aim of this review was to examine whether implant roughness is associated with periimplantitis in humans through a literature review.

*Associate Professor, Dental Faculty, University of Nantes, Nantes, France; Hospital Practitioner, Dentistry Department, University Health Centre, Nantes, France.
†Private Practice, Pau, France.
‡Hospital Practitioner, Dentistry Department, Pellegrin Hospital, University Health Centre, Bordeaux, France; Associate Professor, Dental Faculty, University of Bordeaux, Bordeaux, France.

Reprint requests and correspondence to: Fabienne Jordana, MSc, DDS, PhD, University of Nantes, 1 Place Alexis Ricordeau, BP 84215, 44042 Nantes cedex 1, France, Phone: +33670580024, Fax: +332 40 20 18 67, E-mail: fabienne.jordana@univ-nantes.fr

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MATERIALS AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses system[20,21] was adopted for this systematic review.

Study Protocol and Criteria

The protocol was designed to answer the following question: "In subjects with dental implants, do the implant surface treatment or surface roughness characteristics lead to periimplantitis?" It included studies reporting on at least 15 participants, randomized clinical trials, prospective cohort studies, retrospective studies, case-control studies, and cross-sectional studies in humans after implantation. Periimplantitis was defined by Heitz-Mayfield[22] as the radiographic presence of bone loss $\geq$2 mm since the time of prosthetic replacement, positive bleeding on probing, and probing depth $\geq$4 mm.

Inclusion criteria. Only studies published in English in an international peer-reviewed journal were included. The studies had to describe surface treatment or surface roughness characteristics that can lead to periimplantitis. They also had to give a clear definition of periimplantitis or contain clinical and radiological data, which the reviewers could reliably relate to periimplantitis.

Exclusion criteria. In vitro studies and animal studies were excluded. The following PECO (Population, Exposure to risk factor, Comparison, Outcome) definitions were considered for systemic search:

- Population: studies had to include systemically healthy patients with implant treatment;
- Exposure: periimplant disease diagnosed under a clinical and radiographic examination and adhered to a previously described definition;
- Comparison: the specific comparisons investigated were differences either in implant surface characteristics or in implant roughness;
- Outcome measures: the primary outcome variable was periimplantitis.

Search Strategy

A literature search was performed in MEDLINE via the PubMed database of the US National Library of Medicine, in the Web of Science, and Cochrane Library databases as well as a hand search of other literature to identify articles of potential relevance. The search included articles accepted for publication from 2000 up to October 2017. Previously published review articles on similar topics were also analyzed to assess potentially relevant publications.

The following keywords were used for this purpose:

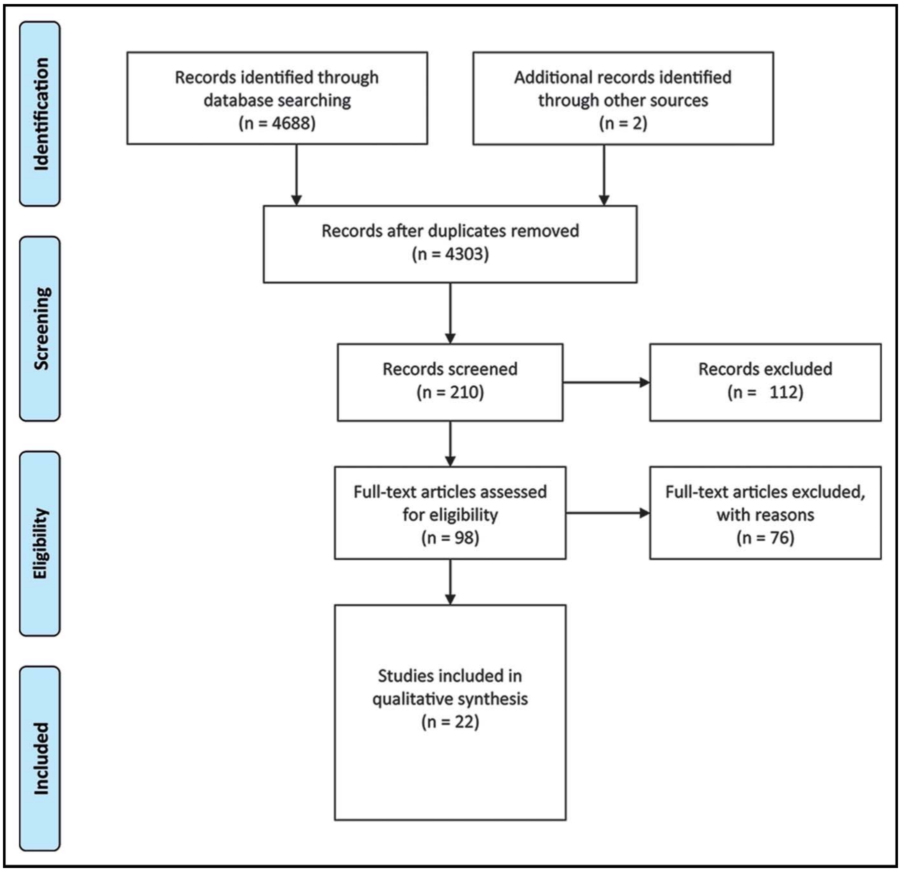

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram demonstrating the results of the systematic literature search.

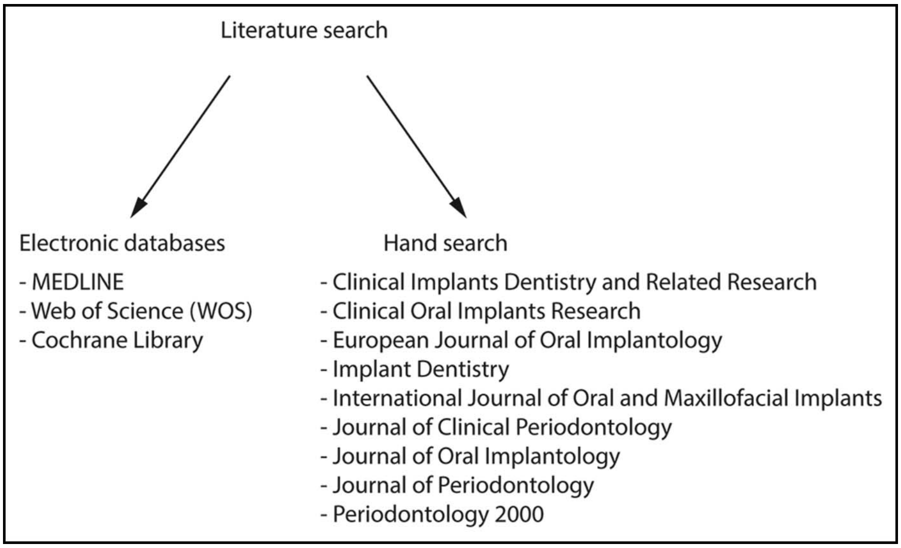

Fig. 2. Electronic databases used and journals searched manually for the systematic literature search.

Table 1. Design of Selected Publications[24–45]

			Studied Implants				
Authors	Follow-up Period (y)	Patient Number	Manufacturer	Surface Treatment	Roughness	Implant Number at Inclusion	
Behneke et al[24]	5	55	ITI TPS (Straumann)	TPS	Rough	114	
Eliasson et al[25]	5	119	Brånemark Systeme (Nobel Biocare)	Machined	Minimally rough	476	
Astrand et al[26]	3	28	ITI TPS (Straumann)	TPS	Rough	77	150
			Brånemark Systeme (Nobel Biocare)	Machined	Minimally rough	73	
Astrand et al[27]	5	68	TiOblast (Astra Tech)	Sandblasted	Moderately rough	184	371
			Brånemark Systeme (Nobel Biocare)	Machined	Minimally rough	187	
Karoussis et al[28]	10	89	ITI TPS (Straumann)	TPS	Rough	179	
Vroom et al[29]	12	20	TiOblast (Astra Tech)	Sandblasted	Moderately rough	40	80
			Dental system (Astra Tech)	Machined	Minimally rough	40	
Jacobs et al[30]	16	18	TiOBlast (Astra Tech)	Sandblasted	Moderately rough	50	95
			Brånemark System MK II (Nobel Biocare)	Machined	Minimally rough	45	
Buser et al[31]	10	303	Straumann Dental Implant System (Straumann)	Sandblasted + acid-etched	Moderately rough	511	
Charyeva et al[32]	6	108	MIS System (MIS)	Sandblasted + acid-etched	Moderately rough	324	
Degidi et al[33]	10	59	TiUnite (Nobel Biocare)	Anodic oxidation	Moderately rough	210	
Fischer and Stenberg[34]	10	24	SLA dental implant system (Straumann)	Sandblasted + acid-etched	Moderately rough	142	
Gotfredsen[35]	10	20	TiOBlast (Astra Tech)	Sandblasted	Moderately rough	20	
Mertens et al[36]	11	17	TiOBlast (Astra Tech)	Sandblasted	Moderately rough	94	
Östman et al[37]	11	46	TiUnite (Nobel Biocare)	Anodic oxidation	Moderately rough	121	
Schliephake et al[38]	5	44	Osseospeed (Astra Tech)	Sandblasted + acid-etched	Moderately rough	143	
Chappuis et al[39]	20	98	Bonefit (Straumann)	TPS	Rough	145	
Polizzi et al[40]	6–10	122	Brånemark System (Nobel Biocare)	Machined	Minimally rough	257	500
			TiUnite (Nobel Biocare)	Anodic oxidation	Moderately rough	243	
Ravald et al[41]	12–15	66	TiOblast (Astra Tech)	Sandblasted	Moderately rough	184	371
			Brånemark System (Nobel Biocare)	Machined	Minimally rough	187	
Jungner et al[42]	5	103	TiUnite (Nobel Biocare)	Anodic oxidation	Moderately rough	154	287
			Brånemark MKIII (Nobel Biocare)	Machined	Minimally rough	133	
van Velzen et al[43]	10	250	Soft-Tissue Level SLActive (Straumann)	Sandblasted + acid-etched	Moderately rough	506	
Becker et al[44]	12–23	92	ITI TPS (Straumann)	TPS	Rough	388	
Glauser[45]	11	38	TiUnite MK IV (Nobel Biocare)	Anodic oxidation	Moderately rough	102	

Table 2. Implant Systems Used in the Literature: Morphology and Topography[24–45]

Implants	Design	Connection	Titanium	Sa (μm)	Roughness	Surface Treatment
Dental Implant System Astra Tech (Astra Tech)*,[29]	Cylindrical	Internal	Grade 4	0.5 < Sa < 1	Minimally rough	Machined
Osseospeed (Astra Tech)*,[38]	Conical or cylindrical	Internal	Grade 4	1.5	Moderately rough	Sandblasted + acid-etched
Astra TiO_2-Blast (Astra Tech)*,[27,29,30,35,36,41]	Cylindrical	Internal	Grade 3	1.1	Moderately rough	Sandblasted
MIS Seven dental implant system (MIS implant technologies)†,[32]	Conical	Internal	TA_6V_4	≈1.7	Moderately rough	Sandblasted + acid-etched
Brånemark Standard (Nobel Biocare)‡,[40]	Cylindrical	External	Grade 1	0.5	Minimally rough	Machined
Brånemark MarkII (Nobel Biocare)‡,[27,30,40,41]	Cylindrical	External	Grade 1	0.7	Minimally rough	Machined
Brånemark MarkIII (Nobel Biocare)‡,[40,42]	Cylindrical	External	Grade 4	0.9	Minimally rough	Machined
Brånemark MarkIV (Nobel Biocare)‡,[40]	Cylindrical	External	Grade 4	0.9	Minimally rough	Machined
Brånemark MarkIII TiUnite (Nobel Biocare)‡,[33,37,40,42,45]	Cylindrical	External	Grade 4	1.1	Moderately rough	Anodic oxidation
Brånemark MarkIV TiUnite (Nobel Biocare)‡,[37,40,45]	Cylindrical	External	Grade 4	1.1	Moderately rough	Anodic oxidation
ITI TPS (Straumann)§,[24,26,28,44]	Cylindrical	Internal	Grade 4	>2	Rough	TPS
Bonefit TPS (Straumann)§,[39]	Cylindrical	Internal	—	>2	Rough	TPS
ITI SLActive (Straumann)§,[31,34]	Cylindrical	Internal	Grade 4	1.75	Moderately rough	Sandblasted + acid-etched
Soft Tissue-Level SLActive (Straumann)§,[43]	Cylindrical	Internal	Grade 4	1.75	Moderately rough	Sandblasted + acid-etched

*Astra Tech AB, Mölndal, Sweden.
†MIS Implant Technologies Ltd, Israël.
‡Nobel Biocare AB, Göteborg, Sweden.
§Straumann AG, Waldenburg, Switzerland Brånemark System (Nobel Biocare)‡ machined (MK not identified).[25,26]

periimplantitis OR peri-implantitis OR peri implantitis OR peri-implant OR periimplant diseases OR peri-implant disease OR peri implant disease
AND titanium OR dental implant OR implant
AND
1. surface characteristic OR surface roughness OR material characteristic OR titanium surface OR implant type OR implant surface OR surface decontamination OR surface topography.
2. surface treatment OR TPS OR titanium plasma-sprayed OR anodic oxidation OR SLA OR machined surface OR turned surface OR sandblasted and acid-etched surface OR sandblasted surface OR acid-etched surface.

Quality Assessment

Quality assurance was developed by independent screening by 2 reviewers (L.S., F.J.) according to Khan et al.[23] When disagreement arose in the selection and eligibility, it was resolved by discussion between the 2 reviewers.

Data Extraction and Synthesis

The search gave 4690 results. Two independent reviewers (L.S., F.J.) analyzed titles and abstracts during the first stage of screening. Irrelevant articles were discarded. Additional manual searching of reference lists in the articles selected and in a number of review articles was performed to source further relevant publications (Fig. 1). The implantology and periodontology journals were searched manually between 2000 and 2017: *Clinical Implants Dentistry and Related Research*, *Clinical Oral Implants Research*, *European Journal of Oral Implantology*, *Journal of Oral Implantology*, *Implant Dentistry*, *International Journal of Oral and Maxillofacial Implants*, *Journal of Periodontology*, *Journal of Clinical Periodontology*, *and Periodontology 2000* (Fig. 2). Ninety-eight full-text articles were assessed for eligibility. The full texts of the articles were read to determine whether the studies fulfilled the predetermined inclusion criteria. Twenty-two studies fulfilled the inclusion criteria and 76 were excluded (Fig. 1).

Table 3. Periimplantitis Rates (%) Depending on the Roughness[24–45]

Implant Roughness	Authors	Periimplantitis Rate (%)	Periimplantitis Rate Depending on the Roughness (%)
Minimally rough	Eliasson et al[25]	0.00	0.57
	Astrand et al[26]	0.00	
	Astrand et al[27]	0.00	
	Vroom et al[29]	0.00	
	Jacobs et al[30]	0.00	
	Polizzi et al[40]	0.39	
	Ravald et al[41]	3.20	
	Jungner et al[42]	0.65	
Moderately rough	Astrand et al[27]	1.09	3.43
	Vroom et al[29]	0.00	
	Jacobs et al[30]	0.00	
	Buser et al[31]	1.76	
	Charyeva et al[32]	3.70	
	Degidi et al[33]	6.20	
	Fischer and Stenberg[34]	3.92	
	Gotfredsen[35]	5.00	
	Mertens et al[36]	2.13	
	Östman et al[37]	1.65	
	Schliephake et al[38]	6.29	
	Polizzi et al[40]	3.70	
	Ravald et al[41]	4.30	
	Jungner et al[42]	2.26	
	van Velzen et al[43]	4.20	
	Glauser[45]	7.56	
Rough	Behneke et al[24]	12.28	12.86
	Astrand et al[26]	11.69	
	Karoussis et al[28]	15.40	
	Chappuis et al[39]	20.00	
	Becker et al[44]	9.76	

Data were collated into tables (Tables 1–5) and grouped according to implant roughness and surface treatment. Data synthesis was performed based on the evidence tables alone, and the data were further interpreted. Statistical analyses (Chi2) were carried out using XLStat (Addinsoft).

RESULTS

The initial search of the literature up to October 2017 yielded 4690 potentially suitable articles. After the exclusion of reviews, animal and *in vitro* studies, and studies that inappropriately identified periimplantitis or surface treatment or roughness characteristics, 22 publications remained fully eligible for this review. A meta-analysis could not be performed because of the heterogeneity of the reviewed studies.

The κ value for interviewer agreement for study inclusion was 0.92 for titles and abstracts and 1.00 for full-text articles, indicating strong agreement.

Periimplantitis Rate and Implant Survival Rate According to Roughness

For the minimally rough surfaces, the Sa is between 0.5 and 1 μm. The mean periimplantitis rate observed is 0.57% (Table 3). Of 8 studies referenced,[25–27,29,30,40–42] five[25–27,29,30] do not present periimplantitis. Two studies[40,42] present a low rate between 0.39% and 0.65%. Finally, the study by Ravald et al[41] indicates a maximum rate of 3.20% for 184 implants.

For the moderately rough surfaces, the Sa is between 1 and 2 μm. Our literature review covered 16 studies; periimplantitis rates are between 0.00% and 7.56%, with a mean rate of 3.43%. There is a high dispersion of results.

For the rough surfaces, the Sa is greater than 2 μm. The mean periimplantitis rate is 12.86%, with rates ranging between 9.76% and 20.00% according to the studies.

Therefore, the minimally rough surfaces have very low periimplantitis rates. The periimplantitis rate increases with the moderately rough surfaces according to their roughness and to the technique used to obtain the roughness. The rough surfaces have the highest periimplantitis rates, which can reach 20.00%.

The statistical analysis is statistically significant ($P < 10^{-6}$) and allows us to say that the higher the roughness is, the higher is the periimplantitis rate.

Periimplantitis Rate According to Surface Treatment

The minimally rough surfaces are obtained by machining. The moderately rough surfaces are obtained by sandblasting, sandblasting + acid etching, or by anodic oxidation (Table 4). The rough surfaces are obtained by titanium plasma-sprayed (TPS). There is a statically significant difference in the frequency of periimplantitis between the different surface treatments ($P = 10^{-6}$).

In our literature review, all the minimally rough surfaces are machined. The periimplantitis rates are between 0.00% and 3.20% with the machined surfaces.[25–27,29,30,40–42] The mean periimplantitis rate with the machined surfaces is 0.57%.

For the moderately rough implant surfaces, a relative heterogeneity of the periimplantitis rates can be noted. The lowest rates are observed with the sandblasted surfaces with an Sa of 1.1 μm. The mean periimplantitis rate with the sandblasted surfaces is 2.38% with rates ranging between 0.00% and 5.00%. These surfaces seem clinically favorable. When the surface is obtained by anodic oxidation, however, the Sa is also 1.1 μm. The mean periimplantitis rate is 4.14%, with rates ranging between 1.65% and 7.56%.[33,37,40,42,45]

The surfaces obtained by sandblasting + acid etching (SLA) have an Sa of 1.75 μm. The mean periimplantitis rate is 3.41%, with rates ranging from 1.76% to 6.29%.

Table 4: Periimplantitis Rates (%) According to Surface Treatment[24–45]

Surface Treatment	Authors	Sa (μm)	Periimplantitis Rates (%)	Periimplantitis Rates According to Surface Treatment (%)
Machined	Eliasson et al[25]	0.9	0.00	0.57
	Astrand et al[26]	0.9	0.00	
	Astrand et al[27]	0.9	0.00	
	Vroom et al[29]	0.9	0.00	
	Jacobs et al[30]	0.7	0.00	
	Polizzi et al[40]	0.5–0.9	0.39	
	Ravald et al[31]	0.7	3.20	
	Jungner et al[42]	0.9	0.65	
Sandblasted	Astrand et al[27]	1.1	1.09	2.38
	Vroom et al[29]	1.1	0.00	
	Jacobs et al[30]	1.1	0.00	
	Gotfredsen[35]	1.1	5.00	
	Mertens et al[36]	1.1	2.13	
	Ravald et al[41]	1.1	4.30	
Anodic oxidation	Degidi et al[33]	1.1	6.20	4.14
	Östman et al[37]	1.1	1.65	
	Polizzi et al[40]	1.1	3.70	
	Jungner et al[42]	1.1	2.26	
	Glauser[45]	1.1	7.56	
Sandblasted + acid-etched	Buser et al[31]	1.75	1.76	3.41
	Charyeva et al[32]	1.75	3.70	
	Fischer and Stenberg[34]	1.75	3.92	
	Schliephake et al[38]	1.75	6.29	
	van Velzen et al[43]	1.75	4.20	
TPS	Behneke et al[24]	>2	12.28	12.86
	Astrand et al[26]	>2	11.69	
	Karoussis et al[28]	>2	15.40	
	Chappuis et al[39]	>2	20.00	
	Becker et al[44]	>2	9.76	

The highest periimplantitis rates are found with the surfaces treated by TPS. Their Sa is higher than 2 μm. The mean periimplantitis rate is 12.86%, with rates ranging from 9.76% to 20.00%.

These studies confirm that the periimplantitis rate increases with surface roughness. The results differ, however, for the moderately rough surfaces. The sandblasted surfaces have an Sa close to that of the minimally rough surfaces. The surfaces treated by sandblasting + acid etching have higher periimplantitis rates than the sandblasted-only surfaces. Their Sa is 1.75 μm. It is close to that of the rough surfaces. However, the surfaces treated by anodic oxidation, with an Sa of 1.1 μm, have high periimplantitis rates, with a mean rate of 4.14%.

Periimplantitis Rate According to Follow-up

Six studies were carried out over periods ranging from 1 to 5 years (Table 5).[24–27,38,42] All the studies observe a periimplantitis rate of 0.11% with theminimally rough surfaces over periods of 1 to 5 years, from 1.09% to 6.29% for moderately rough implants and from 11.69% to 12.28% for rough implants.

Eight studies[28,31–35,40,43] present a follow-up of between 6 and 10 years. The periimplantitis rates are higher than for the studies carried out over a 5-year period. The periimplantitis rates observed with machined surfaces are 0.39% and with rough surfaces treated by TPS are 15.40%.[28] The periimplantitis rates range from 1.76% to 6.20% with the moderately rough surfaces.

Eight studies[29,30,36,37,39,41,44,45] presenting a follow-up of more than 11 years were included in this literature review. The longest is that of Chappuis et al,[39] with a 20-year follow-up of TPS rough surfaces. This study indicates a 20.00% periimplantitis rate.[39] The minimally rough surfaces have periimplantitis rates that vary from 0.00% to 3.20%. The moderately rough surfaces give results ranging from 0.00% to 7.56%, with mean rate of 3.21%. The mean periimplantitis rate is less than that of the 5- to 10-year studies. The studies carried out over more than 11 years concern implants with surfaces treated by sandblasting or by anodic oxidation. No significant difference was found with respect to the moderately rough surfaces according to follow-up time ($P = 0.81$). For the moderately rough surfaces, a periimplantitis rate of 3.04% is observed, and then stabilization is observed over time.

The periimplantitis rate with the rough surfaces increases with the study time. The rate of occurrence of periimplantitis is 12.04% between 1 and 5 years, 15.40% between 6 and 10 years. At 20 years, the periimplantitis rate is 20% in the study by Chappuis et al.[39] For the minimally rough surfaces, however, the results of the 1- to 5-year studies and the 6- to 10-year studies are comparable, but there is a statistically significant increase in the periimplantitis rate after 11 years ($P = 1.2 \times 10^{-4}$). However, the periimplantitis frequency remains low.

DISCUSSION

There is no consensual definition of periimplantitis or of its clinical parameters. The 6th European Consensus Conference (2008) gave the following definition: "the lesion of periimplant mucositis resides in the soft tissues, periimplantitis also affects the supporting bone."[3] Definitions of periimplantitis, which may include different clinical and radiological thresholds, vary because of the various thresholds of bone loss and pocket depths used in the literature.[46] Correct diagnosis of periimplant disease is essential to appropriately manage periimplant disease.[32] We used this definition of

Table 5. Periimplantitis Rates (%) According to Follow-up Period and Roughness[24–45]

Follow-up Period (y)	Authors	Minimally Rough		Moderately Rough		Rough	
0–5	Behneke et al[24]	—	0.11	—	3.04	12.28	12.04
	Eliasson et al[25]	0.00		—		—	
	Astrand et al[26]	0.00		—		11.69	
	Astrand et al[27]	0.00		1.09		—	
	Schliephake et al[38]	—		6.29		—	
	Jungner et al[42]	0.65		2.26		—	
6–10	Karoussis et al[28]	—	0.39	—	3.59	15.40	15.40
	Buser et al[31]	—		1.76			
	Charyeva et al[32]	—		3.70		—	
	Degidi et al[33]	—		6.20		—	
	Fischer and Stenberg[34]	—		3.92		—	
	Gotfredsen[35]	—		5.00		—	
	Polizzi et al[40]	0.39		3.70		—	
	van Velzen et al[43]			4.20		—	
11–20	Vroom et al[29]	0.00	2.40	0.00	3.21	—	12.06
	Jacobs et al[30]	0.00		0.00		—	
	Mertens et al[36]	—		2.13		—	
	Östman et al[37]	—		1.65		—	
	Chappuis et al[39]	—		—		20.00	
	Ravald et al[41]	3.20		4.30		—	
	Becker et al[44]	—		—		9.76	
	Glauser[45]	—		7.56		—	

periimplantitis: radiographic presence of bone loss ≥2 mm since the time of prosthetic replacement, positive bleeding on probing, and probing depth ≥4 mm.[22] According to Albrektsson and Wennerberg,[19] implants may be classified into 4 types according to surface roughness: smooth (Sa < 0.5 μm); minimally rough (Sa between 0.5 and 1.0 μm), moderately rough (Sa between 1.0 and 2.0 μm), and rough (Sa > 2.0 μm). Sa represents the arithmetic mean of the roughness area from the mean plane, for the height of the peaks and valleys.[18]

The first implants to be produced (machined or turned) are still considered the gold standard for implant surfaces. Their minimally rough surfaces (Sa typically ranging from 0.4 to 0.8 μm) have periodic grooves. In the 2000s, rougher surfaces were sought to increase the BIC, improve implant stability, and allow earlier implant loading.[47,48] Some authors considered that the increased surface roughness of commercially pure titanium implants would improve BIC and the mechanical properties of the interface[49–53] and that the improved platelet activation could positively regulate the osteogenic responses.[54]

The majority of currently marketed implants are moderately rough (Sa between 1.0 and 2.0 μm).[22] Albrektsson and Wennerberg[19] showed that there is an optimum surface roughness window from 1 to 1.5 μm, for which there is a compromise between engineering and clinical practice. They consider that a higher value leads to a loss of bone anchoring.[19] Quirynen et al[55] report that implants with relatively smooth surfaces must be used to prevent biological complications. Many studies[56–58] show that rough implants develop significantly more periimplantitis. Esposito et al[59] showed that the use of machined implants (minimally rough surfaces) instead of rough implants could bring a 20% reduction in the periimplantitis rate. These authors confirm the results of our literature review.

Surface treatments influence implant roughness. Machined implants have a relatively smooth surface.[60] Sandblasting consists of forcing small grits of chosen shape and size across implant surfaces, usually by compressed air.[60] Acid etching by immersion in strong acids creates a microroughness with irregular pits of varying depths on the surface.[60] With the SLA method, the implant surface is first sandblasted with large grit, then the acid etching forms micropits on its surface. The rough implants are all produced using the TPS technique. TPS dental implants have a complex surface; the particle density in the valleys normally appears higher than those on the thread peaks.[61] We have not included hydroxyapatite-coated implants in our literature review because there are many controversies about their long-term prognosis.

The sandblasted + acid-etched surfaces have an Sa of 1.75 μm, and the rough surfaces have an Sa greater than 2 μm. In our literature review, the mean periimplantitis rate with surfaces treated by sandblasting + acid etching is 3.41%. The bone loss observed with the machined or sandblasted implants is equivalent, as with the occurrence of periimplantitis according to several authors.[62–64] BIC is even greater with sandblasted surfaces than with machined surfaces.[19,65–67]

In our systematic review of literature, 2 studies[29,30] compare sandblasted surfaces and machined surfaces. No significant difference is observed. The periimplantitis rate is 0% in both these studies. The mean periimplantitis rate with surfaces treated by anodic oxidation (moderately rough surfaces) is 4.14%. The study by Polizzi et al[40] concludes that these surfaces have a higher periimplantitis rate (3.7%) than the machined surfaces (0.39%). The surfaces treated by anodic oxidation have an Sa equivalent to the sandblasted surfaces (1.1 μm); their periimplantitis rate is, however, higher. The difference is due to their surface treatment. The sandblasted surface is obtained by subtraction, and the surface treated by anodic oxidation is obtained by addition. Finally, implants with a very rough TPS surface have periimplantitis rates that can reach 20.00%. It should be noted that the periimplantitis rates observed with TPS surfaces (12.86%) are, in our literature review, lesser to those of the study by Dam et al[68] (18.00%).

Periimplantitis is one of the major problems in implantology. Many uncertainties remain regarding its etiopathogenesis. Bacterial infection is an aggravating factor. Also, the role of the operator and the host's response cannot be excluded. Our literature review shows that surface roughness plays a major role in the occurrence of periimplantitis.

CONCLUSION

Periimplantitis is clearly linked with surface roughness according to the results of our systematic review of literature. The higher the surface roughness, the higher the mean periimplantitis rate. Up to an arithmetic mean surface roughness (Sa) of 1 μm, there is little periimplantitis. Periimplantitis appears for Sa values greater than 1.2 μm.

Considering the reviewed studies as a whole, it is evident that implant roughness is associated with periimplantitis. Although a comparison of the published results was limited due to the lack of homogeneity of the studies, it is clear that clinicians should give priority to the use of implants with machined or even sandblasted surfaces.

DISCLOSURE

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

ROLES/CONTRIBUTIONS BY AUTHORS

F. Jordana made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; drafted or critically revised the manuscript for important intellectual content; and provided final approval of the manuscript. L. Susbielles made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; drafted or critically revised the manuscript for important intellectual content; and provided final approval of the manuscript. J. Colat-Parros made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; drafted or critically revised the manuscript for important intellectual content; and provided final approval of the manuscript.

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F. Jordana and L. Susbielles contributed equally to this work.

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