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Prevalence of peri-implantitis and peri-mucositis in pristine and augmented bone in periodontally compromised patients. A literature review

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SUMMARY

Aim. The aim of this systematic literature review is to analyze the literature about the prevalence of peri-implantitis and peri-implant mucositis in patients with periodontal diseases and compare their prevalence in pristine and augmented sites.

Material and methods. A systematic literature review was performed of clinical trials, controlled clinical trials, comparative studies, and clinical studies. In the studies, patients who have periodontal diseases and need a dental implant with or without bone grafts were selected. Records about peri-implantitis and peri-implant mucositis, implant survival and success rates were extracted.

Results. 19 studies with 3049 patients were selected. X had a periodontal disease. After analysis, peri-implant mucositis was more prevalent in augmented sites (19% – 74.0% on patient level, 10.2% – 62,5% on implant level). Prevalence of peri-implantitis was not apparent because of missing data and heterogeneity of records. Implant survival and success rates were lower in augmented sites.

Conclusion. When alveolar ridge augmentation is needed for dental implant in patients with periodontal diseases, dentists must evaluate the risk of long term biological complications.

Key words: periodontal disease, periodontitis, dental implant, alveolar ridge augmentation, peri-implantitis, complications.

INTRODUCTION

Periodontitis is a periodontal disease affecting periodontal tissues and bone. The prevalence of severe periodontal diseases is around 19% of the global adult population, representing more than 1 billion cases worldwide (1). If left untreated, it leads to functional and psychological problems including tooth loss and edentulism (2). Dental implants have become a routine for replacing untreatable and missing teeth and are highly predictable and reliable. A good dental implant positioning is mandatory to achieve satisfactory functional and aesthetical outcomes and sufficient amount of soft and hard tissues is needed (3).

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Periodontitis and loss of tooth both lead to disruption of the alveolar bone and bone augmentation is usually necessary in restoring missing teeth in periodontally compromised patients with dental implants. Autogenous bone is the gold standard in bone augmentation although because of its invasiveness or lack of autogenous bone it is replaced by synthetic or xenogenic bone. Regardless of the high reliability of the dental implants and bone augmentation procedures, it is known that augmented bone differs from alveolar bone histologically, the number of osteoclasts is higher compared to pristine bone (4). This leads to the conclusion that biological complications are more common in augmented bone compared to the pristine bone. It is also known that people with the history of periodontitis are at higher risk of biological implants complications because of its similar pathogenesis and risk factors (5).

So the aim of this systematic review is to analyze the present literature on biologic dental implants complications-peri-implantitis (PI) and peri-implant

mucositis (PIM)- in patients with periodontitis comparing augmented bone to pristine.

MATERIALS AND METHODS

This systematic review was registered within the Lithuanian University of Health Sciences bioetic center and the permit was obtained (permit number BEC-LSMU(R)-14). Methodic principles of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and Cochrane Handbook for Systematic Reviews of Interventions were adopted for this systematic review (6).

P (Population), I (Intervention), C (Comparison), O (Outcome)

- Population – periodontally compromised patients with osseointegrated titanium or titanium alloy dental implants;
- Intervention – dental implants, placed in augmented sites prior or simultaneous to implantation (vertical ridge augmentation, horizontal ridge augmentation, alveolar socket preservation, open or closed sinus lift);
- Comparison – dental implants, placed in pristine sites;
- *Outcome – primary outcome:* prevalence of peri-implant mucositis and peri-implantitis; secondary outcome: prevalence of implant success and survival.

Primary and secondary focus questions

Primary outcome

Will patients with periodontal diseases, who have osseointegrated dental implants placed in augmented sites, have more biological complications than those who have osseointegrated dental implants placed in pristine sites?

Secondary outcome

Will dental implant survival and success rate be worse in patients with periodontal diseases with dental implants placed in augmented sites, than patients with dental implants placed in pristine sites?

Search strategy

Electronic search

An electronic search of MEDLINE via PubMed was conducted from October 2022 to December 2022. Last date of the search was December 10th, 2022.

For the electronic search, MeSH and and EMTREE controlled keywords and terms or combinations were used when possible:

((((((((((periodontal disease) AND (dental implant)) AND (alveolar ridge augmentation)) OR (pristine bone)) AND (prevalence)) AND (biological complications)) OR (peri-implantitis)) OR (peri-implant mucositis)

Manual search

Manual literature search was also conducted via PubMed, using keyword combinations. Electronic journals such as "Journal of Periodontology", "Journal of Clinical Periodontology" and "International Journal of Oral and Maxillofacial Implants" were searched for articles published no later than December 2012.

Study Selection

The selection process was performed by two reviewers (U.M. and A.B.A.). All articles were screened by both reviewers for consistency. Studies were firstly selected by name and abstract of the article; later, full text articles were read for data extraction. In case of disagreement, a discussion was held between reviewers.

Inclusion Criteria

- Full text studies with humans
- Literature up to 10 years old
- Clinical studies, controlled clinical trials, comparative studies, observational studies, randomized controlled clinical trials
- Studies, reporting on titanium or titanium alloy implants in periodontally compromised patients
- Studies, reporting on whether or not any type of bone regeneration / preservation was conducted prior or simultaneous with implantation
- Studies with clear definitions for peri-implant health, peri-implant mucositis and peri-implantitis, or, studies with comprehensive clinical data, such as bleeding on probing, periodontal probing depth, radiographic bone loss and suppuration.

Exclusion criteria

- Studies reporting on small (less than 20) number of cases
- Preclinical studies, studies on animals or in vitro studies
- Studies failing to report on periodontal status of the patients
- Studies on patients with systemic diseases
- Studies with any other kind of implant than endosseous implants
- Studies failing to report on augmentation procedures
- No author response for further details on results

Data collection

Data was collected using a table from Salvi G. E. *et al.* (7) article as an example with some additional information:

- Type of study
- Mean follow-up time

- Number of patients, their age, gender, periodontal status, smoking habits
- Number of implants and implant system used
- Type of augmentation, time of augmentation, materials used
- Peri-implant health, peri-implant mucositis and peri-implantitis case definitions and prevalence
- Implant survival and success rates
- Clinical data such as bleeding on probing, suppuration, mean bone level changes and probing depth.

Quality assessment

Since all articles, except one, were non-randomised retrospective or prospective studies, The Newcastle-Ottawa Scale (NOS) was applied for assessing the quality of publications (8). Each study was assessed by two reviewers and received a maximum of 9 points which are submitted in Table 1.

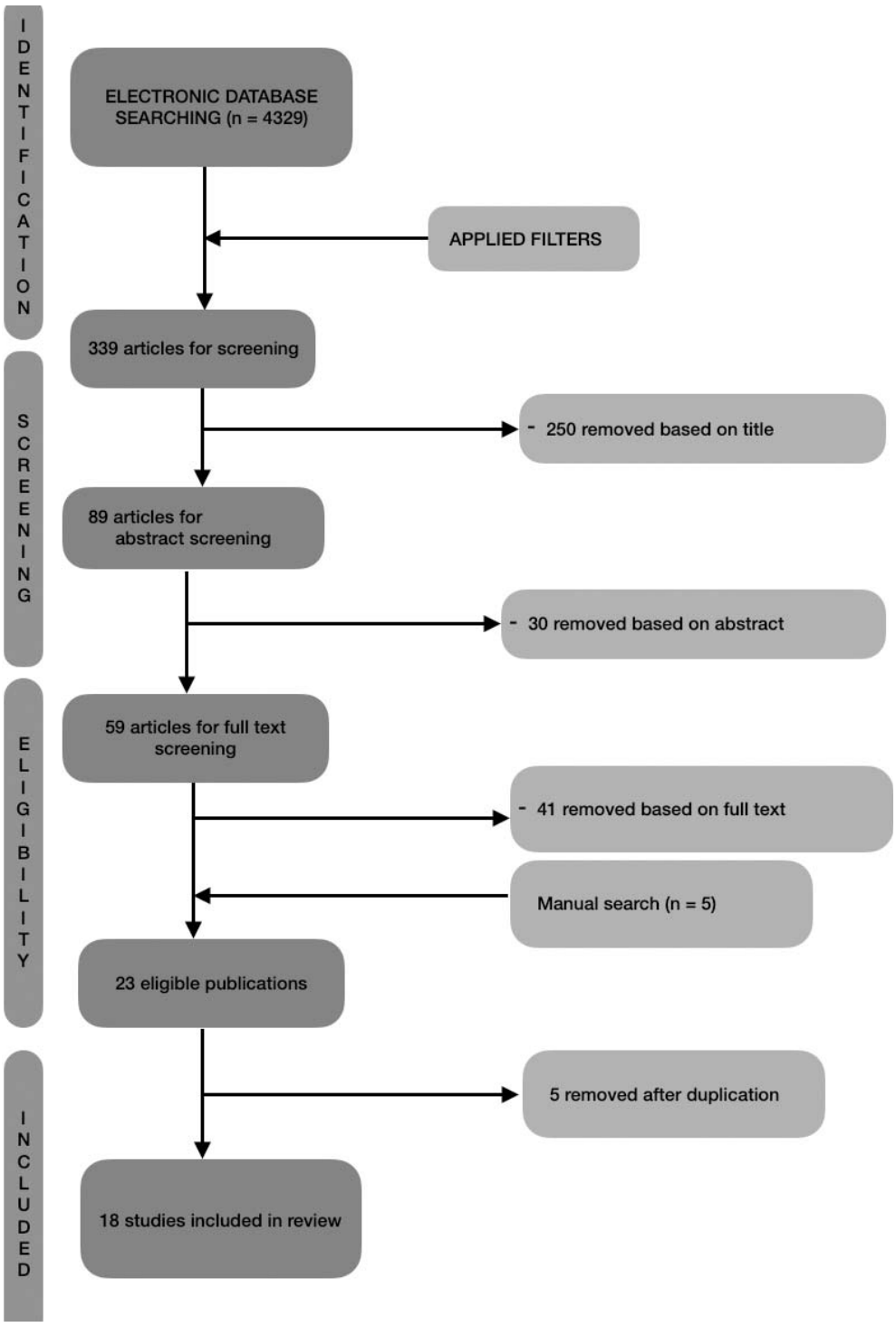

Fig. Flowchart of Selection of Articles

Meta-analysis

Meta-analysis was not performed due to the difference in how authors provided their data.

RESULTS

Study selection

4329 articles were found in PubMed database using the combination of keywords. After filters were applied, 339 articles were identified. 250 articles were excluded based on their title; 30 based on their abstract. Finally, the remaining 59 full text articles were read by two reviewers (U.M. and A.B.A) and 41 were excluded. 5 articles were found by manually searching electronic journals; 5 were removed because of duplication yielding 18 remaining studies for systematic review (Figure). Of those 18, 5 of the studies, reported on implants, placed in pristine alveolar bone only. Other 14 studies reported on pristine as well as augmented sites.

Study population

The characteristics of the study population are summed up in Table 2. Overall, 3049 patients were included in the studies. Most of the studies included gender in their study population; Roccuzzo et al (16, 18) and Atieh *et al.* (23) did not. More than 8239 implants were studied, although the exact number cannot be counted as one author did not state how many implants were included in their study (18).

Only one study in this review had smoking habits as an exclusion criteria (26). One author did not state whether smokers were included in their study (17). Some studies reported on the percentage of smoking patients that varied from 3.1% to 32.7%. (9, 11, 12, 14-16, 18, 19, 21, 22, 26). The rest reported on the number of smoking patients, which varied from 2 to 40 (10, 13, 20, 23, 24, 26).

All studies included in this review reported on patients with periodontal diseases, although not all patients studied in the publications had periodontal diseases. Two authors reported that all study subjects are periodontally compromised (9, 11).

One publication (13) did not state what implant systems were used in the study. The most popular implant systems used were Straumann, Nobel Biocare, AstraTech and Branemark (9-12, 14-18, 20, 22-25).

Five authors did not include patients who required alveolar bone augmentation (9, 10, 12, 16, 18). 5 publications reported on the number of implants who were placed in augmented sites (12, 14, 19, 20, 22), the rest reported on the number, technique and / or materials used (11, 13, 15, 17, 21, 23, 24). More than 1523 patients had implants placed in augmented sites. The exact number cannot be counted as some authors did not in-

Table 1. Quality assessment of studied articles, according to NOS

Author (year)	SELECTION				COMPARABILITY		EXPOSURE			TOTAL
	Adequate case definition / representativeness of the exposed cohort	Representativeness of the cases / Selection of external control	Selection of controls / Ascertainment of exposure	Definition of controls / Outcome of interest not present at the start of study	Comparability of cases and controls / cohorts		Ascertainment of exposure / Assessment of outcome	Same method of ascertainment for cases and controls / Assessment of outcome	Non - Response rate / Adequacy of follow-up	
			Main factor	Additional factor	Main factor	Additional factor				
Aguirre-Zorzano *et al.* (2014)	*	*	0	*	*	*	*	*	*	8/9
Arunyanak *et al.* (2019)	*	*	*	0	*	*	0	*	*	7/9
Pandolfi at al. (2019)	*	*	*	*	*	0	*	0	*	7/9
Daubert *et al.* (2015)	*	*	0	*	*	*	0	*	*	7/9
Swierkot *et al.* (2012)	*	*	*	0	*	0	*	*	*	7/9
Meyle *et al.* (2014)	*	0	0	*	*	*	*	*	0	6/9
Derks *et al.* (2015)	*	*	*	0	*	0	*	*	*	7/9
Simion *et al.* (2016)	*	0	0	*	*	0	*	*	*	6/9
Roccuzzo *et al.*(2011)	*	0	0	*	*	*	*	*	*	7/9
Roccuzzo *et al.* (2016)	*	0	0	*	*	*	*	*	*	7/9
Roccuzzo *et al.* (2013)	*	*	0	*	*	*	*	*	0	7/9
Obreja et al (2021)	*	0	*	*	*	0	*	*	*	7/9
Zhao et al (2022)	*	*	0	*	*	*	*	*	*	8/9
Atieh M. A. et al (2019)	*	0	0	*	*	0	*	*	*	6/9
De Ry S. P. et al (2021)	*	*	0	*	*	0	*	*	*	7/9
Pieri F. et al (2017)	*	*	0	*	*	0	*	*	0	6/9
Guarnieri R. et al (2021)	*	*	0	0	*	0	*	*	*	6/9
Velasco-Ortega E et al (2021)	*	*	0	0	*	*	*	*	*	7/9

Table 1. Quality assessment of studied articles, according to NOS

Author (year)	Study type	Mean follow-up time±SD (years or months)	Number of patients	Mean age±SD (years)	Sex	Smokers (%)	Periodontal disease	Number of implants (n)	Implant system	Augmentation	Time of augmentation	Augmentation materials	Barrier material
Aguirre – Zorzano *et al.* (2014)	Cross-sectional study	63±41 months	239	53±9	Female-156 Male – 83	31.4	Aggresive periodontitis – 69 patients (28,9%) Chronic periodontitis – 170 (71,1%)	786	678 AstraTech, 90 Nobel Replace Straight, 16 Nobel Replace, 2 Steri-Oss	Not augmented	-	-	-
Arunyanak *et al.* (2019)	Cross-sectional study	62,58 months from implantation; 52,79 months from final restauration	200	57,3	Female – 117 Male – 83	Former smokers – 10 Current smokers – 2	Healthy – 1 % Gingivitis – 63% Treated chronic periodontitis – 36%	412	149 Straumann, 136 AstraTech, 53 Zimmer, 20 Nobel Replace, 16 Intra-lock, 38 other	Not augmented	-	-	-
Pandolfi *et al.* (2019)	Retrospective cohort study	10 years yearly	475	15,8% – 61 y.o.or more; 84,2% 60 y.o.or less	Female – 1087 Male – 904	7,3	All patients enrolled in this study lost teeth due to periodontal disease	1991	Straumann SLA	803 patients (40,3%)	In case of increased pneumatisation of maxillary sinus: 1) Simultaneous sinus floor augmentation (one-step procedure); 2) Previuos sinus floor augmentation with bone grafting; 3) Localised horizontal bone defects – GBR with simultaneous or staged approach.	Autogenous bone in particulate form (mental symphysis and ramus mandibularis) / xenograft material (deproteinized bovine bone) / mix	Degradable bi-layer collagen membrane
Daubert *et al.* (2015)	Cross-sectional analysis	10,9±1,5 years	96	67,7±10,6	Female – 48 Male – 48	3,1	Slight periodontitis Moderate / severe periodontitis	225	69 Straumann, 39 Nobel Biocare, 15 Branemark System, 10 Centerpulse Dental, 6 Astra Tech, 5 Sulcer Dental, 3 Steri-Oss	59 (26,2%)	NS	NS	NS
Swierkot *et al.* (2012)	Prospective longitudinal cohort study	5-16 years	58	39,6	Female – 20 Male – 15	12 previous smokers, 14 current smokers	Generalised aggressive periodontitis – 35	149		7 – GBR (22 implants)	6 months prior to implantation	NS	Expanded politetrafluorethylen membrane and titanium screws
Derks *et al.* (2015)		9 years	588	62,3±9,3	Female – 55,1% Male – 44,9%	20.6	Initial periodontal disease – 10,2% Periodontitis on recall – 24,0%	2277	Straumann – 32.6%; Branemark System – 38.4% Astra Tech – 18.4% Kiti – 9.4%	6,3% implants	NS	NS	NS
Simion *et al.* (2016)	Retrospective clinical study	16 years	33	62	Female – 23 Male – 10	27	Patients with history of periodontitis – 6 pacientai – 18%	91	Branemark – 87. Ebon – 4	Vertical GBR	Bone height >6mm – simultaneous augmentation + implantation. 36 surgical sites 6 simultaneous. If bone height not sufficients – 6-8 months prior to implantation	Blood clot + autogenous bone granules / autogenous bone and deproteinized bovine bone mineral mix	e-PTFE titan reinforced membrane
Roccuzzo *et al.* (2011)	Prospective longitudinal study	10 years	101 PHP – 28 mPCP – 37 sPCP – 36	PHP – 45±13 mPCP – 49±15,3 s PCP – 44±8,6		PHP 11.1% mPCP 27% sPCP 13,9%	Patients classified into 3 groups: 1) PHP (periodontally healthy patients); 2) mPCP (moderatelly periodontally compromised patients); 3) sPHP (severelly periodontally compromised patients)	246	Straumann	Not augmented	-	-	-

Table 1. Quality assessment of studied articles, according to NOS *(continued)*

Author (year)	Study type	Mean follow-up time±SD (years or months)	Number of patients	Mean age±SD (years)	Sex	Smokers (%)	Periodontal disease	Number of implants (n)	Implant system	Augmentation	Time of augmentation	Augmentation materials	Barrier material
Roccuzzo *et al.* (2016)	Prospective longitudinal study	10 years	34	48,5±10,6	Female – 28 Male – 13	NS	Patients classified into 2 groups: 1) PHP (periodontally healthy patients) n=18; 2) PCP (periodontally compromised patients) n=15.	PHP – 18 PCP – 27	Straumann SLA	18 patients – autogenous bone block from mandibular ramus or mental symphysis with titanium screws, granular bone and titanium mesh (Ti-Mesh); 23 patients – control – bone transplant + Ti-Mesh; 12 Bone transplant	NS	Autogenous bone block / bone granules	Ti-Mesh
Roccuzzo *et al.* (2013)	Prospective longitudinal study	10 years	123	PSP – 43.3±12.4 mPCP – 53.3±10.7 sPCP – 52.7±8.4		PHP 15,6% mPCP 13,3% sPCP 22,2%	Patients classified into 3 groups: 1) PHP (periodontally healthy patients) n=32; 2) mPCP (moderately periodontally compromised patients) n=46; 3) sPHP (severely periodontally compromised patients) n=45.		Straumann SLA	Not augmented	-	-	-
Obreja *et al.* (2021)	Cross-sectional analysis	9.36±6.44 years (1-26 years)	200	62.68±14.31	118 Female 82 Male	7 overall; 5,5 with history of periodontitis	112 patients with history of (treated or current) periodontitis	657	Ankylos	Not augmented – 357 Immediate augmentation – 300	NS	NS	NS
Zhao *et al.* (2022)	Retrospective longitudinal case control study	2.52 years	131	48.29±11.85	58 Male 73 Female	22 control group 21case group	Control group – 138 (79 slight periodontitis, 14 moderate periodontitis). Case group – 110 (56 slight, 47 moderate periodontitis).	248	Nobel, Biomet, ITI ir kiti	Control group augmented 86 Case group augmented 63	NS	NS	NS
Mastrangelo F. *et al.* (2018)	Multicenter randomised clinical trial	3 years	102	44 ±6,7	39 females 63 males	24.3%	47 had a history of previously treated periodontitis (54.0%)	115	tioLogic Implant System, Dentaurum, Germany	Filling residual pocket	Immediate	Anorganic bovine bone ((BioOss, Geistlich-Germany)	Resorbable collagen barrier (Osteobiol Evolution, Tecnoss-Italy)
Atieh M. A. *et al.* (2019)	Retrospective analysis	8.1±2.0	188	55.6±14.6		26.1% smokers in peri-implant mucositis group. 21.7% smokers in peri-implantitis group	38,1% peri-implant mucositis in chronic periodontitis patients 17.5% peri-implantitis in chronic periodontitis patients	423	Straumann, Branemark, Nobel Biocare, Neoss, Southern, Biomet 3i, Astra Tech	25.3% peri-implant mucositis had augmentatioin 15.7% periimplantitis had augmentaton	NS	NS	NS

clude how many patients received augmentation – Derks *et al.* reported on the percentage of implants that were placed in augmented sites; Atieh *et al.* reported that 25,3% of patients, who were diagnosed with peri-implant mucositis and 15,7% of patients with peri-implantitis, have had augmentation procedures done prior. Guaernieri *et al.* did not state the number or percentage of augmentation procedures recorded in their study. Overall, at least 60 patients had GBR, 110 had sinus lifts and 40 had autologous bone blocks for vertical augmentation (Table 2). Materials used for augmentation were autogenous bone (blocks or particulated), inorganic bovine bone granules or a mix (11, 15, 17, 21, 24). Barrier materials used were resorbable collagen barrier, titanium mesh or expanded polytetrafluoroethylene membrane with titanium screws (11, 13, 15, 17, 21, 24).

Table 1. Quality assessment of studied articles, according to NOS *(continued)*

Author (year)	Study type	Mean follow-up time±SD (years or months)	Number of patients	Mean age±SD (years)	Sex	Smokers (%)	Periodontal disease	Number of implants (n)	Implant system	Augmentation	Time of augmentation	Augmentation materials	Barrier material
De Ry S. P. *et al.* (2021)	Retrospective study	11.8	79	59.0	36 Female 43 Male	n=8; MR – 1 HR – 7	MR – 34 (moderate risk) HR – 45 (high risk)	79	Straumann SLA	29 augmentations: 9 sinus lifts 20 GBR MR – 3 sinus lift, 1 GBR; HR – 6 sinus lift, 1 GBR.	NS	NS	NS
Pieri F. *et al.* (2017)	Retrospective study	5 years	45	Augmented: 56.4±8.25 Short implant: 57.69±7.93	Augmented: 16 female 6 male Short implant: 19 female 4 male	Augmentation: 5 patients of 22 Short implant: 5 patients of 23	Augmentation: 5 patients of 22 had chronic periodontitis Short implant: 4 patients of 23 had chronic periodontitis	97: Augmentation group – 51; Short implant group – 46	Astra Tech, OsseoSpeed	Vertical alveolar augmentation with autologus bone block: 22 patients / 51 implants augmented	4-5 months prior implantation	Autologous bone (mandibular ramus) and inorganic bovine bone granules (Bio-Oss)	Resorbable collagen membrane (Bio-Gide)
Guarnieri R. *et al.* (2021)	Retrospective study	13.4±2.07	88 CP 42	CP – 58±5.26	CP 22 male, 20 female	0	Moderate-severe periodontitis CP – chronic periodontitis 42 patients / 134 implants HP – healthy 46 patients / 133 implants. CP had two subdivisions: 1. Without recurring periodontitis – 37 patients / 114 implants. 2. With recurring periodontitis – 5 patients / 20 implants	267 CP 134	Branemark, 3i, Calcitek, Biolok	in CP group, 30 implants were placed in augmented sites (out of 133)	NS	NS	NS
Velasco-Ortega E *et al.* (2021)	Long term clinical study	10 years	101	56.9	58 females and 43 males	33 (32.7%)	29 (28.7%) had a previous history of periodontitis	234	Surgimplant® Galimplant®, Sarria, Spain	Maxillary sinus floor augmentation	If ≥5 mm residual bone, a simultaneous implant placement, if < 5 mm residual, a delayed surgical approach was carried	β-TCP (Osteoblast ™, Sarria, Spain)	NS

GBR – guided bone regeneration; e-PTFE – expanded polytetrafluoroethylene membrane; PHP – periodontally healthy patient; PCP – periodontally compromised patient; mPCP – moderately periodontally compromised patient; sPCP – severely periodontally compromised patient; Group A – patients received residual pocket filling materials with implantation; Group B – patients did not receive any type of bone regeneration; CP – chronic periodontitis group; MR – moderate risk group; HR – high risk group.

Case definitions

4 publications had no definitions for neither peri-implant health, peri-implant mucositis or peri-implantitis (17, 18, 21, 26).

Peri-implant health definition

The definition of peri-implant health was given in 5 out of 20 publications (10, 14, 19, 22, 23). In all 5 cases, peri-implant health was

defined as an absence of clinical signs of inflammation, such as bleeding on probing, suppuration and increased probing depth. Two authors stated that no bone loss is also a sign of peri-implant health (10, 19), one author defined that bone loss up to 2 mm was still considered healthy peri-implant tissue (22).

Peri-implant mucositis definition

12 authors had defined peri-implant mucositis in their publications (9, 10, 12-14, 16, 19, 20, 22-25). 7 of them outlined peri-implant mucositis as a soft tissue inflammation around dental implants, with clinical signs of bleeding on probing and / or suppuration without detectable bone loss (9, 10, 12, 14, 16, 24, 25). 4 authors (13, 19, 20, 23) also added increased PD – Swierkot *et al.* defined probing depth up to 5 mm is considered peri-implant mucositis; Zhao *et al.* defined it as 4 mm and more. Two authors (Zhao *et al.* (20); Atieh *et al.* (22)) described peri-implant mucositis as an inflammation in soft tissue around implants with bone loss up to 2 mm.

Peri-implantitis definition

Peri-implantitis was most described in publications, with 14 articles giving a definition (9-16, 19, 20, 22-25). 7 authors defined peri-implantitis as a soft and hard tissue inflammation, with bleeding on probing and / or suppuration, increased PD and supporting bone loss (9, 11, 15, 16, 19, 23, 25). Arunyanak *et al.* described peri-implantitis as presence of soft tissue inflammation with ≥2 mm bone loss; Daubert *et al.* - peri-implant mucositis with 2mm of BL, PD≥4 mm; Swierkot *et al.* PD >5 mm with / without BoP and annual BL >0,2 mm; Derks *et al.* defined it as BL >0,5 mm, where >2 mm BL were considered moderate / severe peri-implantitis; and Zhao *et al.* - PD >4 mm, BL ≥ 2 mm with BoP or periodontal abscess; Atieh *et al.* defined peri-implantitis as BoP and / or suppuration and BL >2 mm.

Prevalence of biological complications in pristine bone

Eight publications reported on peri-implant mucositis and peri-implantitis in only pristine or both pristine and augmented sites (9, 10, 16, 18, 20, 21, 24, 25). All records on the prevalence of biological complications are represented in Table 3.

Peri-implant mucositis

Peri-implant mucositis in pristine bone was recorded in seven publications (9, 10, 12, 20, 21, 24, 25). Peri-implant mucositis at patient level was between 19% (21) and 60% (10). Pieri *et al.* reported 2 patients out of 23 with 4 implants had peri-implant mucositis. On implant level, peri-implant mucositis was found in 12.8% (9) up to 58.3% (10) implant sites. Guarnieri *et al.* also reported that 28 or 70% of implants had peri-implant disease (peri-implant mucositis or peri-implantitis).

Peri-implantitis

Peri-implantitis in pristine bone was recorded in nine publications (9, 10, 12, 16, 18, 20, 21, 24, 25). The prevalence of peri-implantitis on patient level was between 2% (21) and 66.7% (18). On implant level peri-implantitis prevalence was between 7.66% (20) and 50% (25). Pieri *et al.* reported on 1 patient out of 23 with peri-implantitis. Guarnieri *et al.* found that overall, 20% of patients and 35.6% of implants in chronic periodontitis patients had peri-implantitis. The publication also reported that 31 implants (75.6%) placed in pristine bone had peri-implant disease (25). Roccuzzo *et al.* assigned their patients according to the treatment they received for their complications – C was systemic antibiotic treatment or treatment with local delivery device and D was surgical treatment (16, 18). 27% of moderate PCP and 47.2% of severe PCP received C or D treatment (16); In another publication Roccuzzo *et al.* reported 52.2% and 66.7% of moderate PCP and severe PCP respectively received C or D treatment for peri-implantitis (18).

Prevalence of biological complications in augmented bone

13 publications reported on peri-implant mucositis and peri-implantitis placed in augmented sites (11, 13-15, 17, 19-26). All records of biological complications in regenerated bone are listed in Table 3.

Peri-implant mucositis

Peri-implant mucositis in augmented sites was reported in nine publications (13, 14, 19-25). The lowest prevalence of peri-implant mucositis on patient level was reported in study by Mastrangelo *et al.* – 19%, the highest – Swierkot *et al.* – 74.0%. De Ry *et al.* reported that overall, 59% of moderate risk patients and 40% of high risk patients developed peri-implant mucositis. The prevalence on implant level was between 10.2% (22) and 62.5% (19). Pieri *et al.* reported 4 patients out of 22 with 8 implants who developed peri-implant mucositis.

Peri-implantitis

Peri-implantitis in augmented sites was reported in twelve articles (11, 13-15, 19-26). Prevalence of peri-implantitis on patient level varied between 2% (22) and 42.8% (13). On implant level, the prevalence of peri-implantitis was between 5.4% (22) and 35.6% (25). De Ry *et al.* reported that in the moderate risk group and high risk group, respectively 12% and 27% developed peri-implantitis. Pieri *et al.* found that 4 patients out of 22 in augmented sites developed peri-implantitis. Derks *et al.* described their complications in changes in BL: 10,1% patients (4,3% implants) had

Table 3. Prevalence of biological complications *(continued)*

Author (year)	Periodontal health definition	Peri-implant mucositis definition	Peri-implantitis definition	Peri-implant mucositis at patient / implant level (%)	Peri-implantitis at patient / implant level (%)	Implant survival rate patient / implant level (%)	Implant success rate patient / implant level (%)
Aguirre - Zorzano *et al.* (2014)	NS	An inflammatory lesion that affects the soft tissue with bleeding on probing, together with clinical signs of inflammation, with no bone loss around the implant.	Inflammatory lesion often associated with suppuration, increased probing depth and bleeding on probing, with loss of marginal support bone	24.7 / 12.8	15.1 / 9.8	NS	NS
Arunyanak *et al.* (2019)	Absence of soft tissue inflammation and bone loss	Presence of soft tissue inflammation with bleeding on probing at at least 1 aspect of the dental implant (recorded from the mBLI) and no signs of supporting bone loss after initial bone remodeling	Presence of soft tissue inflammation with bleeding on probing at at least 1 aspect of the dental implant (recorded from the mBLI) and bone loss around an osseointegrated implant beyond functional remodeling ≥2 mm from time of loading. When there was no baseline radiograph, a threshold vertical distance of 2 mm from the expected marginal bone level was diagnosed as peri-implantitis	60 / 58.3	16 / 10.7	96 / 97.3	NS
Pandolfi at al. (2019)	NS	NS	Changes in the level of crestal bone, presence of bleeding on probing and/or suppuration; with or without concomitant deepening of the peri-implant pocket	NS	24.4 / 12.9 During first 5 years: 8.42 / 3.19. 5th – 10th year: 16 / 9.72	91.3 / 96.0	72.2 / 82.4
Daubert *et al.* (2015)	NS	The presence of BOP and/or gingival inflammation with no evidence of radiographic bone loss beyond normal remodeling.	The presence of BOP and/or suppuration, with 2 mm of detectable bone loss after initial remodeling, and PD ‡4 mm. The presence of 2 mm of bone loss alone without mucositis symptoms did not count as a case of peri-implantitis.	- / 33.0	-/ 16.0	NS	83.3 / 91.6
Swierkot *et al.* (2012)	NS	Peri-implant mucositis was defined as PD ‡5 mm with BOP and no bone loss.	Peri-implantitis was defined as PD >5 mm with or without BOP and annual bone loss of >0.2 mm.	74.0 / 56.0	42.8 / 26.0	- / 96.0	5.0 / 33.0
Derks *et al.* (2015)	Absence of BoP/suppuration	BoP/suppuration but no detectable bone loss	BoP/suppuration and detectable bone loss (>0.5 mm; exceeding the measurement error). Implant sites presenting with BoP/suppuration and bone loss >2 mm were considered as moderate/severe peri-implantitis.	32.0 / 35.1	Bone level: >0.5mm – 45.0 / 24.9 >1mm – 26.9 / 14.7 >2mm – 14.5 / 8.0 >3mm – 10.1 / 4.3 >4mm – 5.9 / 2.3	NS	NS
Simion *et al.* (2016)	NS	NS	Infection with associated suppuration and clinically significant progressive crestal bone loss after the adaptive phase	NS	- / 9.9	- / 97.0	- / 89.0
Roccuzzo *et al.*(2011)	NS	Inflammatory lesion that resides in the mucosa	Inflammatory lesion that resides in the mucosa and the supporting bone.	NS	CIST C/D treatment: PHP – 0.7%; mPCP – 27%; sPCP – 47.2%. PD ≥ 6mm: PHP – 1.7; mPCP – 15.9; sPCP – 27.2	PHP - - / 96.6 mPCP - - / 92.8 sPCP - - / 90	NS
Roccuzzo *et al.* (2016)	NS	NS	NS	NS	PCP – 40% implants needed C or D treatment	PHP – 97.4 PCP – 90	NS
Roccuzzo *et al.* (2013)	NS	NS	NS	NS	Patients recieving C / D treatment: PHP – 18.8%; mPCP – 52.2%; sPCP – 66.7%	PHP – - / 100 mPCP – - / 96.9 sPCP – - / 97.1	NS

Table 3. Prevalence of biological complications *(continued)*

Author (year)	Periodontal health definition	Peri-implant mucositis definition	Peri-implantitis definition	Peri-implant mucositis at patient / implant level (%)	Peri-implantitis at patient / implant level (%)	Implant survival rate patient / implant level (%)	Implant success rate patient / implant level (%)
Obreja *et al.* (2021)	NS	the presence of BOP and/or SUPP on gentle probing with or without increased PDs compared to previous examinations and an absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling.	Peri-implantitis defined as the presence of BOP and/or SUPP on gentle probing, increased PDs compared to previous examination, and the presence of radiographic bone loss at the final follow-up compared to the baseline (i.e., radiographs taken following the placement of the final prosthetic reconstruction)	66.5 / 62.6 n = 133/411 Out of 300 implants in augmented sites – 197 (n) had peri-implant mucositis	15 / 7.5 n = 30 / 49 Out of 300 implants in augmented sites – 16 (n) had peri-implantitis	NS	Healthy implants: 37/200 patients 197/657 Implants
Zhao *et al.* (2022)	Absence of clinical signs of inflammation, such as BOP/SUPP on gentle probing, no increase in PDs compared to previous examinations, and an absence of bone loss beyond crestal bone level changes resulting from initial bone remodeling	Probing depth ≥4 mm, and bleeding on probing and bone loss <2 mm	Probing depth >4 mm, bone loss ≥2 mm, and the presence of bleeding on probing or periodontal abscess	45.80 / 36.69 Peri-implant disease was found in: 42.73% of control group without bone augmentation 63% of control group with bone augmentation	7.63 / 7.66 Peri-implant disease was found in: 42.73% of control group without bone augmentation 63% of control group with bone augmentation	NS	NS
Mastrangelo F. *et al.* (2018)	NS	NS	NS	19/-	2/-	Survival rate of the implants was 99.1% at 12 months and 98.3% at 36 months.	NS
Atieh M. A. *et al.* (2019)	NS	An osseointegrated functional implant which demonstrated bleeding on probing and/or suppuration and bone loss of ≤ 2 mm	Osseointegrated functional implant with bleeding on probing and/or suppuration and bone loss of > 2 mm.	20.2 / 10.2	10.1 / 5.4	NS	NS
De Ry S. P. *et al.* (2021)	NS	Presence of BoP and/or suppuration with or without increased probing depth compared to previous examinations in conjunction with the absence of bone loss beyond crestal bone level changes resulting from initial bone remodelling.	Presence of BoP and/or suppuration with increased probing depths compared to previous examinations and presence of bone loss beyond crestal bone level changes resulting from initial bone remodelling.	MR group: 5-9 years – 57%; 10-13 years – 58%; 14-22 years- 63% overall 59%. HR group: 5-9 years – 48%; 10-13 years – 47%; 14-22 years – 31% overall 40%.	MR group: 5-9 years – 0%; 10-13 years – 17%; 14-22 years – 25%; overall 12%. HR group: 5-9 years – 0; 10-13 years – 33%; 14-22 years – 44%; overall – 27%.	NS	NS
Pieri F. *et al.* (2017)	An absence of bleeding on probing or suppuration, and with bone loss of ≤ 2 mm	Heavily inflamed soft tissue without bone loss	Bone loss of more than 3mm with suppuration, heavily inflamed tissues or fistulas	Augmentation group: 4 patients / 22 (8 implants) Short implant group: 2 patients / 23 (4 implants)	Augmentation group: 4 / 44 Short implant group: 1 / 23	Augmentation: 95.5 / - Short implant: 95.7 / -	NS
Guarnieri R. *et al.* (2021)	Absence of signs of soft tissue inflammation, that is absence of bleeding on gentle probing (BOP) and suppuration	According to 1999 classification	According to 1999 classification	CP – 46 / 34.7 CP without recurring periodontitis – 14 / 36 CP with reccuring periodontitis – 29 / 37.5 Augmented bone – 12 implants (30%) Pristine bone – 28 implants (70%)	CP – 20 / 35.6 CP without recurring periodontitis – 34 / 20.8 CP with recurring periodontitis – 60 / 50 Augmented bone – 10 implants (24.7%) Pristine bone – 31 implants (75.6%)	CP – 19 implants lost (14,1%). 18 lost because of progressive periimplant bone loss CP withour recurring periodontitis – 7 implants (6,7%) lost CP with recurring periodontitis – 12 implants (60%) lost	Healthy periimplant tissues in CP – 34 impl. (29.5%)
Velasco-Ortega E *et al.* (2021)	NS	NS	NS	NS	14 (13.9%) / 36 (15.3%)	97.2%	NS

PHP – periodontally healthy patient; PCP – periodontally compromised patient; mPCP – moderately periodontally compromised patient; sPCP – severely periodontally compromised patient; Group A – patients received residual pocket filling materials with implantation; Group B – patients did not receive any type of bone regeneration; CP – chronic periodontitis group; MR – moderate risk group; HR – high risk group; BoP – bleeding on probing; PD – probing depth; SUPP – suppuration; NS – not stated.

Table 4. Clinical parameters

Author (year)	Patients recieving supportive periodontal treatment (%)	FMPS (%)	Mean bone level changes±SD (mm)	BoP (%)	Suppuration (%)	PD mm±SD
Aguirre-Zorzano *et al.* (2014)	100 %	≥25% – 20.9 <25% – 79.1	4.3±1.9	NS	NS	NS
Arunyanak *et al.* (2019)	Regular – 18; Irregular – 68; Not documented – 14	Dental hygiene status: good – 17.5; fair – 77.5; poor – 5	0.8±1.08	NS	NS	NS
Pandolfi at al. (2019)	100 %	NS	NS	NS	NS	NS
Daubert *et al.* (2015)	NS	NS	NS	NS	NS	NS
Swierkot *et al.* (2012)	100%	NS	NS	NS	NS	NS
Derks *et al.* (2015)	NS	NS	0.72±1.15 implant level	NS	NS	NS
Simion *et al.* (2016)	30 %	NS	1.02±1.47	NS	NS	NS
Roccuzzo *et al.*(2011)	PHP – 85.7% mPCP – 70.3% sPCP – 80.6%	After 10 years: PHP – 16.1±2.4 mPCP – 29.0±2.4 sPCP – 23.1±2.3	NS	After 10 years PHP – 12.3±2.1 mPCP – 31.0±2.5 sPCP – 30.9±2.6	NS	After 10 years PHP – 3.1±0.5 mPCP – 3.5±0.9 sPCP – 3.9±0.7
Roccuzzo *et al.* (2016)	NS	NS	0.58 ±0.57 mean PHP – 0.43±0.5 PCP – 0.78±0.59	After 10 years: 24.75±23.97 % PHP – 26.4% PCP – 25.0%	No suppuration	3.26±0.91 PHP – 0.08±0.51 PCP – 0.21±0.66
Roccuzzo *et al.* (2013)	PHP – 59.4% mPCP – 54.4% sPCP – 68.9%	After 10 years: PHP – 22.1±10.8 mPCP – 27.7±14.8 sPCP – 30.4±20.6	After 10 years, radiographic bone loss ≥3 mm (%): PHP – 0 mPCP – 9.4 sPCP – 10.8	After 10 years: PHP – 31.8±26.3 mPCP – 34.7±33.0 sPCP – 38.4±28.6	During SPT: PHP – 0 mPCP – 11 sPCP – 8	After 10 years, implants with PD ≥6 mm: PHP – 6 mPCP – 24 sPCP – 36 Deepest PD: PHP – 4.4±1.1 MPCP – 4.6±1.3 sPCP – 4.8±1.4
Obreja *et al.* (2021)	100% of patients with periodontal disease recieved SPP	PI – 0.41±0.37 patient level; 0.48±0.42 implant level	Mean radiographic bone loss – 0.7±1.52 patient level; 0.44±1.18 implant level	31±26 patient level 17.09±31.26 implant level	4%	2.73±0.79 patient level 2.87±0.85 implant level
Zhao *et al.* (2022)	NS	NS	NS	NS	NS	NS
Mastrangelo F. *et al.* (2018)	NS	NS	Group A – 0.25±0.362 Group B – 0.28±0.304	NS	NS	Group A – 1.69±1.345 Group B – 1.4±1.619
Atieh M. A. *et al.* (2019)	12.1% patients recieving SPT had peri-implant mucositis 4.7% recieving SPT had periimplantitis	NS	NS	NS	NS	NS
De Ry S. P. *et al.* (2021)	100 %	10.9	NS	10.9; MR – 8.6 HR – 12.6	NS	NS
Pieri F. *et al.* (2017)	NS	NS	Augmentation group: after 5 years – 1.65±1.13 54.5% lost more than 1 mm Short implant group: after 5 years – 0.7±0.69 17.3% lost more than 1 mm	NS	NS	NS
Guarnieri R. *et al.* (2021)	CP – 100% 62.5% overall patients regullary	NS	NS	44 %	NS	CP group 4.4±0.9
Velasco-Ortega E *et al.* (2021)	NS	NS	1.93±1.03mm	NS	NS	NS

SPT – supportive periodontal treatment; PHP – periodontally healthy patient; PCP – periodontally compromised patient; mPCP – moderately periodontally compromised patient; sPCP – severely periodontally compromised patient; Group A – patients received residual pocket filling materials with implantation; Group B – patients did not receive any type of bone regeneration; CP – chronic periodontitis group; NS – not stated.

lost 2-3 mm of bone; 5,9% of patients (2,3% implants) lost 4 mm or more (14).

Spt and clinical parameters

Twelve authors reported on SPT (9-11, 13, 15, 16, 18, 19, 22, 23, 25). In 5 of them, 100% of study population received regular SPT (9, 11, 13, 19, 23).

At least one of clinical parameters was recorded in 13 publications (9, 10, 14-19, 21, 23-26). Clinical parameters recorded were mean bone level changes (9, 10, 14, 15, 17-19, 21, 24, 26), BoP (16-19, 23, 25), suppuration (17-19,) and PD (16-19, 21, 25). 5 authors did not report any clinical parameters (11-13, 20, 22). All data reported is listed in Table 4.

Implant success and survival rates

11 publications reported on implant survival rate (10, 11, 13, 15-18, 21, 24-26). Lowest survival rate reported on was 91,3% (11) on patient level and 90% on implant level (16, 17). Highest survival rates were 97.2% (26) and 97.3% (10) on patient and implant level, respectively.

Six publications recorded implant success rate (11-13, 15, 19, 25). 5% was the lowest success rate on patient level (13) and 29.5% on implant level (25). Highest success rates reported were 83.3% and 91.6% on patient and implant level respectively (12). Obreja *et al.* reported that 37 patients (out of 200) had 197 (out of 657) healthy implants. All survival and success rates are listed in Table 3.

DISCUSSION

Based on analyzed literature, peri-implant mucositis is diagnosed more often in augmented bone compared to pristine (9, 11, 13, 15, 17, 18), although not all studies have found the difference statistically significant (13, 14). It is also important to highlight that other factors such as smoking, individual oral hygiene, periodontal maintenance therapy can have an impact on the PI and PIM emergence. For example, Atieh MA et al study showed the connection between smoking and PI association exists: patients who smoke were more prone to developing peri-implantitis (26). A higher risk was also observed when smoking is combined with irregular supportive peri-implant maintenance care (22). Periodontitis is also an independent risk factor for biological complications occurrence. Derks *et al.* 2015 have found Significantly higher ORs for moderate/severe peri-implantitis for patients presenting with periodontitis (OR, 4.1) (14). Other studies also reported similar results (22, 23).

The results of PI prevalence are controversial. In two articles the rate of PI was lower in augmented alveolar bone than in pristine. It could be explained by the fact that 84.37% patients in Daubert et al clinical trial and all patients in Swierkot study underwent periodontal maintenance therapy. On the other hand in other studies the prevalence of PI in pristine bone varies between 2.8% and 53% in patient level and between 2% and 42.8% in augmented bone in patient level. However not all studies have found these differences between pristine and augmented bone statistically significant (11). Evaluating these results it is important to emphasize that not all authors presented the results in patient and implant levels so this can influence the results . Different PI definitions, various bone augmentation materials and methods, smoking patients inclusion in common population, lack of patients percentage undergoing maintenance periodontal treatment also can have impact on the results.

Dental implant survival rate was lower in implants placed in augmented bone than in pristine (12, 15-18, 27). These results are similar to other systematic review and meta-analysis published in 2018. Although there was no statistically significant difference between the augmented bone and pristine, the tendency of implant survival rate to be lower in augmented sites (7).

CONCLUSION

Peri-mucositis prevalence is higher in augmented bone compared to pristine, while peri-implantitis prevalence results are controversial. When alveolar ridge augmentation is needed for dental implant in patients with periodontal diseases, dentists must evaluate the risk of long term biological complications.

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