Clinical, Cosmetic and Investigational Dentistry

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REVIEW

Marginal bone loss 1 year after implantation: a systematic review for fixed and removable restorations

This article was published in the following Dove Press journal:
Clinical, Cosmetic and Investigational Dentistry

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Abstract: This systematic review analyses the difference of the mean marginal bone loss (MBL) 1 year after implantation depending on the fixation of the restoration. 889 publications on controlled clinical trials were identified, and based on inclusion and exclusion criteria, 22 studies were selected. Related to fixed restorations, the lowest MBL was 0.05 ±0.67 mm and the highest 1.37±0.5 mm. The MBL for removable restorations ranged from 0.13±0.35 mm to 1.03±0.65 mm. Three studies analyzed the MBL around implants of overdentures in the lower jaw. The estimate for this restoration type was 0.476 mm (95% CI: −0.305 to 1.258). 19 randomized controlled studies dealt with restorations which were fixed to the implants. The estimate for the mean MBL was 0.459 mm (95% CI: 0.325–0.593). There was a decrease in 1-year implant survival with an increase of 1 mm MBL (−0.083%; 95% CI: −0.179 to 0.0123; p=0.083) in fixed restorations. The difference in MBL between fixed and removable restorations was 0.363 mm (95% CI: −0.319 to 1.044; p=0.279). This systematic review indicates that implants with fixed and with removable restorations lead to comparable MBL.

Keywords: dental implants, marginal bone loss, fix and removable restorations, systematic review

Introduction

Edentulous patients using a conventional prosthesis suffer the loss of mastication, articulation and insufficient retention. Furthermore, this problem causes pain, loss of soft-tissue support and general dissatisfaction.[1] Masticatory efficiency is restricted to people in possession of complete dentures, namely <20% of the masticatory performance compared to those with natural dentition. One option to overcome this issue is the use of endosseous implants.[2] An established frequently used therapy enables the attachment of the dental implant with a denture.[3] Van Blarcom[4] defined dental implant as

> A prosthetic device made of allo-plastic material(s) implanted into the oral tissues beneath the mucosal or/and periosteal layer, and on/or within the bone to provide retention and support for a fixed or removable dental prosthesis; a substance that is placed into or/and upon the jaw bone to support a fixed or removable dental prosthesis.

By connecting the overdenture to the dental implant, the oral health-related quality of life (OHRQoL) improves as well as the masticatory forces increase.[5]

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http://doi.org/10.2147/CCIDE.S208076

The removable fixation of an overdenture on two implants either splinted or unsplinted is a worldwide accepted medical treatment proven by long-term studies.[6,7] Selim et al conclude in their review that the patient satisfaction of implant-supported fixed prostheses in the mandible is higher compared to the implant-supported removable overdentures. In contrast, implant-supported removable overdentures in the maxilla reach higher scores than the implant-supported fixed prostheses. The following factors are discussed: esthetics, stability, mastication performance, and pronunciation. In addition to keeping the prosthesis clean, implant-supported removable overdentures in the maxilla and mandible show favorable results.[8] Strietzel et al check the implant loss of many different types of restorations, for example, single-tooth replacement, fixed partial denture, removable partial denture and overdenture. There is no statistically significant difference between the various types of restorations with respect to implant loss.[9] For this reason, it is important to choose carefully which restoration is the most beneficial for the patient. Therefore, the clinician has to consider many factors before starting treatment, such as expenses, amount, arrangement and implant location, existing bone quality and quantity, maxilla–mandibular relationship, condition of the opposing dentition and time frame.[10,11]

To date, there is little evidence about the relation between marginal bone loss (MBL) and implant-supported fixed or removable prostheses in medical publications.

This systematic review was conducted to evaluate the outcome of the mean MBL, implant and prosthesis success 1 year after implantation depending on the fixation of the restoration.

Materials and methods

The present review and meta-analysis were performed according to the PRISMA guidelines.[12] To define the research question clearly and to facilitate the process of performing the review, the PICOS approach was used. This approach is based on five components: population, interventions, comparator, outcomes and study design. The specific components for this review are:

P (Population): patients need at least one implant

I (Interventions): fixed-removable restorations

C (Comparator): the comparator groups were unattended

O (Outcomes): mean MBL

S (Study design): randomized controlled studies

Search strategy

The prevailing literature overview was based on a literature search in PubMed via MEDLINE, EMBASE and Cochrane library – the Cochrane Central Register of Controlled Trials (CENTRAL) to identify relevant publications to answer the research question. The studies could be written in any language and should be published between January 2000 and February 2017. The last search was on March 3, 2017, by using MeSH (Medical Subject Heading) and [ALL FIELDS] terms. The following search terms and combinations were used: "bone loss" AND "dental implantation"[MeSH Terms] AND "follow up"; OR ("bone resorption"[MeSH Terms] AND "dental implantation"[MeSH Terms] AND "follow up"); OR ("bone loss" AND "dental implants"[MeSH Terms] AND "follow up"); OR ("bone resorption"[MeSH Terms] AND "dental implants"[MeSH Terms] AND "follow up"). The search was limited to the following filters: Humans; Randomised controlled studies.

Inclusion criteria

The following study design criteria were included in the publications search: "randomised controlled study" and "follow-up one year after implantation". Criteria used to compare the test and control groups: mean age of groups, number of inserted implants, group size, loading protocol (further details see[13]), fixed or removable restoration, implant manufacturer, treatment of implant surface (additive, subtractive, combination of additive and subtractive, combination of different subtractive treatments), survival rate based on implants and mean MBL were further requirements for inclusion.

Exclusion criteria

Exclusions to the trail were: "studies on animals or in vitro"; "reviews"; "case reports" and "clinical trials"; "follow-up one year post-loading"; and "missing data on the above-mentioned groups".

Data extractions

Two independently working reviewers (JZ and MS) extracted the data from the full text for analysis. Both reviewers double-checked the acquired information. Discrepancies were solved by mutual agreement. While reviewing the publications a chart was created and consecutively updated. The following parameters were extracted and inserted in a chart:

Title
Author
Year of publication
Topic of the publication
Number of implants
Mean age of groups
Number of patients participating
Number of patients subdivided into groups
If fixed or removable restoration
Loading protocol (immediate loading, immediate non-occlusal loading, early loading, conventional loading)
Implant manufacturer
Treatment of implant surface (additive, subtractive, combination of additive and subtractive, combination of different subtractive treatments)
Survival and success rate 1 year after implantation
Mean MBL with SD
Complications of the inserted implants and restorations

Definitions

In the literature, fixed restorations are described as screwed or cemented connection of the abutment to the implant body. Removable prostheses are fixed using a specific retention element to the implant.[14]

Statistical analysis

In this review, language bias is non-existent, because the identified studies are written exclusively in English. Moreover, the authors tried to minimize the risk of bias by only including randomized controlled studies.

Publication bias might exist because there was no access to unpublished studies.

The overall MBL estimates for fixed and removable restorations were calculated using DerSimonian–Laird models random-effects meta-analysis. The Egger's test was performed to check for publication bias and the Cochran Q for heterogeneity. The association between 1-year implant survival and MBL was examined using metaregression models. The difference in meta-analytic estimates between removable and fixed restorations was tested with a metaregression including all studies using a dichotomous indicator to distinguish both restoration types. Because of the lack of information on implant success or complications in most of the studies, it was not possible to determine their relationship with MBL. Meta-analysis and metaregression were performed using STATA v.14.0 (StataCorp LP, 2015, College Station, TX, USA).

Results

For creating the review, the authors used the same data referring to the searching of the three databases as shown in a previous review "Marginal bone loss one year after implantation – A systematic review for different loading protocols" (Figure 1).[13] 22 studies (240 implants for removable restorations and 2,096 implants for fixed restorations) were included in this review.

Description of studies

All listed studies had an observation period of 1 year after implantation using intraoral periapical radiographs (Table 1).[13]

Alsabeeha et al[15] estimated the success rate of the different implant systems on removable restorations. Overdentures connected by Southern Regular Implants (Southern Implants, Irene, South Africa) had the lowest implant success rate of 75% and Neoss Regular (Neoss Ltd., Harrogate, UK) and Southern Wide Implants (Southern Implants, Irene, South Africa) reached 100%. Concerning the different attachment types, overdentures with large ball attachment had the highest success rate of 83.3%, followed by overdentures with locator, 66.7%, and overdentures with standard ball attachment, 63.6%.

The estimated implant success rates for the fixed restorations range between 94.7%[33] and 100%.[31,33] None of the authors mentioned the prosthesis success rate concerning fixed restorations.

There are also biological and prosthetic complications listed. The most often mentioned complications concerning the biological tissue were severe MBL and periimplant mucositis. Prosthetic complications included abutment screw loosening and fracture of the restoration.

Three randomized controlled clinical studies analyzed the MBL of implants which serve for better retention of overdentures. These results are illustrated in Table 2. All of them conducted examinations in the lower jaw. Alsabeeha et al[15] placed one mini implant (Southern Implants (Southern Implants, Irene, South Africa), or Neoss Ltd. (Neoss Ltd., Harrogate, UK)) per patient for supporting the mandibular overdenture, while for the same treatment Maryod et al[16] used four mini implants (3M ESPE, Seefeld, Germany). Schincaglia et al[17] tested two OsseoSpeed Implants (AstraTech AB, Molndal, Sweden) per patient. Each study dealt with different types of implant surfaces: Alsabeeha et al[15] decided to insert implants with a combination of subtractive methods (Southern Implants (Southern Implants, Irene, South Africa) [abraded rough surface of rutile titanium]

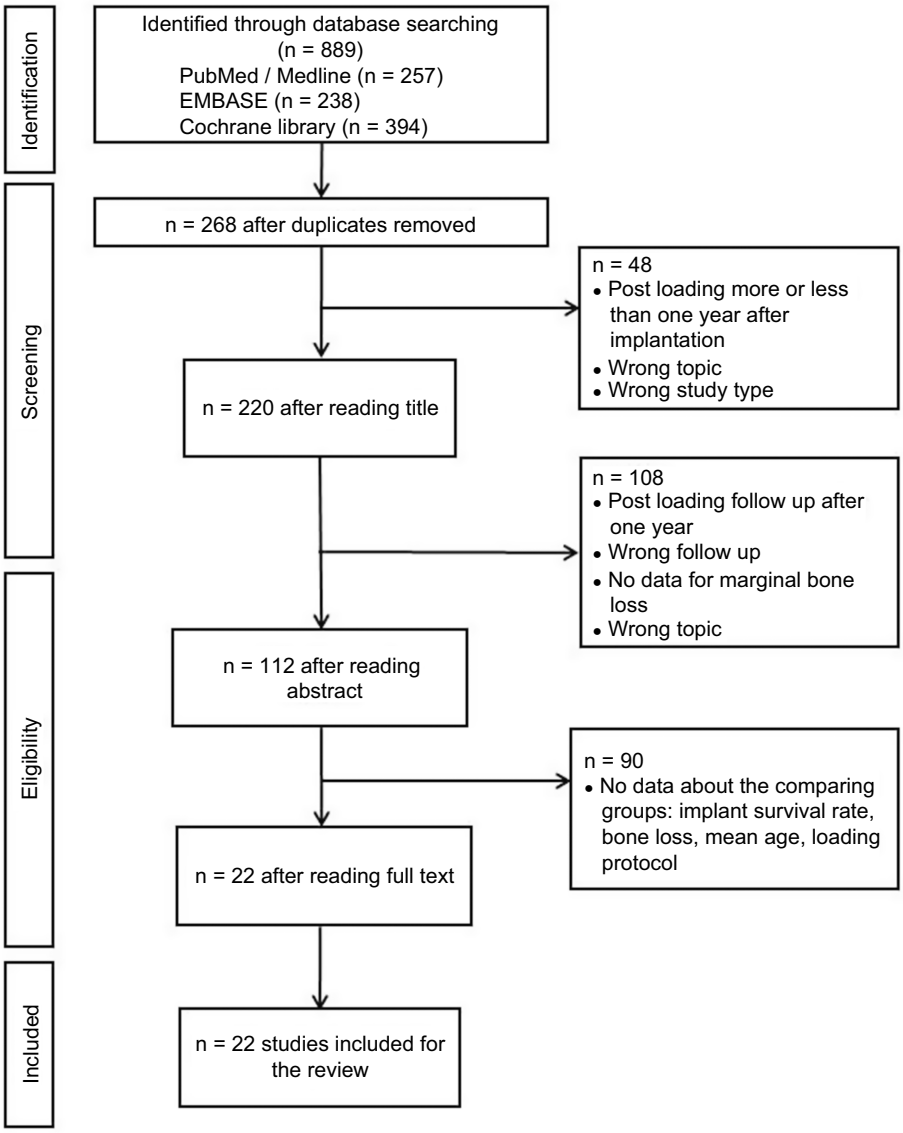

Figure 1 Search strategy.
Note: The article was published in *Int J Oral Maxillofac Surg*, Sommer M, Zimmermann J, Grize L, Stubinger S, Marginal bone loss one year after implantation – a systematic review for different loading protocols, Copyright Elsevier 2019.[13]

and Neoss Ltd. (Neoss Ltd., Harrogate, UK) [sand-blasted and acid-etched and not a clearly described company-specific treatment]), the subtractive implant surface (blasted) was checked by Maryod et al,[16] the OsseoSpeed Implants (OsseoSpeed, AstraTech AB, Molndal, Sweden) appearing in the study of Schincaglia et al[17] were made of a combination of subtractive and additive techniques. Alsabeeha et al[15] divided the patients into three equal groups: every group received a different type of implant and attachment system, but all the implants were connected to the overdenture also using the early loading protocol. Southern 8-mm-wide Implant and large ball attachments showed the best results with a measurement of MBL 0.13 mm. Neoss Regular Implants (Neoss Ltd., Harrogate, UK) and locator attachments had an MBL of 0.23 mm. The group with the Southern Regular Implants and standard ball attachments had the lowest survival rate of 90.9%, but an MBL of only 0.2 mm. The other two studies compared the immediate and early loading protocol. The groups with the immediate-loaded implants had a lower survival rate ranging between 91.7% and 93%. The MBL of overdentures loaded immediately by Maryod et al[16] showed a higher MBL compared to the early loaded in this study, 1.03 mm±0.61 mm versus 0.93 mm±0.52 mm. In comparison, in the study of Schincaglia et al,[17] the results were even better, 0.25 mm±0.5 mm versus 0.54 mm±0.5 mm. Figure 2 shows the Forest plot on the MBL around implants supporting removable restorations a year after implantation. The

Table 1 List of selected studies[13]

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2011	Alsabeeha NH[15]	Neoss Regular Implants and locator attachment	12	70 (NR)	12	Removable	Early loaded (>2 days to <3 months)	Neoss Regular (Neoss Ltd., Harrogate, UK)	Combination of subtractive methods	100%	Overdenture with locator: 66.7%,	NR
2011	Alsabeeha NH[15]	Southern Regular Implants and standard ball attachment	12	64 (NR)	12	Removable	Early loaded (>2 days to <3 months)	Southern Regular (Southern Implants, Irene, South Africa)	Combination of subtractive methods	75%	Overdenture with standard ball attachment: 63.6%	NR
2011	Alsabeeha NH[15]	Southern 8-mm-wide Implants and large ball attachment	12	69 (NR)	12	Removable	Early loaded (>2 days to <3 months)	Southern wide (Southern Implants, Irene, South Africa)	Combination of subtractive methods	100%	Overdenture with large ball attachment: 83.3%,	NR
2008	Cannizzaro G[30]	Flapless placed implants immediately loaded with full-arch prostheses	90	62 (NR)	15	Fixed	Immediately loaded (<48 hrs)	SwissPlus Tapered (Zimmer Dental, Carlsbad, USA)	Subtractive method	98.88%	NR	Soft-tissue ulcers induced by provisional, fracture or loosening of the provisional, fracture of the ceramic of final prosthesis, temperomandibular joint/ occlusal/mastication problems, peri-implant tissue complications (total: 8)

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2008	Cannizzaro G[30]	Flapless placed implants early loaded at 2 months with full-arch prostheses	87	56 (NR)	15	Fixed	Early loaded (>2 days to <3 months)	SwissPlus Tapered (Zimmer Dental, Carlsbad, USA)	Subtractive method	96.66%	NR	Fracture or loosening of the provisional, temporomandibular joint/ occlusal/mastication problems, periimplant tissue complications, esthetic problems (total: 5)
2013	Cannizzaro G[37]	2 implants placed flapless in fully edentulous mandibles and immediately restored with metal-resin screw-retained cross-arch prostheses	60	63 (37–83)	30	Fixed	Immediately loaded (<48 hrs)	Tapered NT Full Osseotite (Biomet 3i, Palm Beach Gardens, USA); ExFeel (MegaGen Implant Co. Limited, Gyeongbuk, South Korea)	Subtractive and additive method/subtractive method	NR	NR	Metal framework not fitting, occlusion to be adjusted, abutment screw loosening, resin tooth detachment/ fracture, distal extension framework fracture, patient unsatisfied (total: 16)
2013	Cannizzaro G[37]	4 implants placed flapless in fully edentulous mandibles and immediately restored with metal-resin screw-retained cross-arch prostheses	120	56 (39–71)	30	Fixed	Immediately loaded (<48 hrs)	Tapered NT Full Osseotite (Biomet 3i, Palm Beach Gardens, USA); ExFeel (MegaGen Implant Co. Limited, Gyeongbuk, South Korea)	Subtractive and additive method/subtractive method	NR	NR	

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2015	Cannizzaro G[41]	Prostheses supported by super-short (5 mm) implants: maxilla	90	58.9 (44–78)	15	Fixed	Immediately loaded (<48 hrs)	NanoTite (Biomet 3i, Palm Beach Gardens, USA)	Subtractive and additive method	NR	NR	Prosthesis screw loosening, hypoplastic soft tissue with ulcers, fracture of long distal cantilever, detachment of central incisors
2015	Cannizzaro G[41]	Prostheses supported by super-short (5 mm) implants: mandible	60	62.9 (47–80)	15	Fixed	Immediately loaded (<48 hrs)	NanoTite (Biomet 3i, Palm Beach Gardens, USA)	Subtractive and additive method	NR	NR	
2015	Cannizzaro G[41]	Prostheses supported by long (11.5 mm) implants: maxilla	90	58.5 (43–72)	15	Fixed	Immediately loaded (<48 hrs)	Tapered NT NanoTite (Biomet 3i, Palm Beach Gardens, USA)	Subtractive and additive method	NR	NR	
2015	Cannizzaro G[41]	Prostheses supported by long (11.5 mm) implants: mandible	60	58.8 (38–72)	15	Fixed	Immediately loaded (<48 hrs)	Tapered NT NanoTite (Biomet 3i, Palm Beach Gardens, USA)	Subtractive and additive method	NR	NR	
2015	Cooper LF[18]	Conical implant–abutment interface	53	43 (18–70)	48	Fixed	Immediately nonocclusally loaded	OsseoSpeed (Astra Tech AB, Molndal, Sweden)	Subtractive and additive method	NR	NR	NR

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2015	Cooper LF[18]	Flat to flat implant–abutment-interface	53	46 (19–78)	49	Fixed	Immediately nonocclusally loaded	Nobel Speedy Replace (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	NR
2015	Cooper LF[18]	Platform-switched implant–abutment interface	50	46 (18–81)	44	Fixed	Immediately nonocclusally loaded	NanoTite Certain Prevail (Biomet 3i, Palm Beach Gardens, USA)	Subtractive and additive method	NR	NR	NR
2010	Cooper LF[21]	Single implants placed in fresh extraction sockets	58	45.1 (NR)	55	Fixed	Immediately nonocclusally loaded	OsseoSpeed (Astra Tech AB, Molndal, Sweden)	Subtractive and additive method	NR	NR	NR
2010	Cooper LF[21]	Single implants placed in healed ridges	65	42.1 (NR)	58	Fixed	Immediately nonocclusally loaded	OsseoSpeed (Astra Tech AB, Molndal, Sweden)	Subtractive and additive method	NR	NR	NR
2015	Esposito M[42]	Implant surface roughened with sandblasting and double etching	137	63.6 (47–80)	25	Fixed	Immediately loaded (<48 hrs)	iRES iPerio (iRES SAGL, Lugano, Switzerland)	Combination of subtractive methods	NR	NR	None
2015	Esposito M[42]	Machined, turned implant surface	163	60.84 (38–81)	25	Fixed	Immediately loaded (<48 hrs)	iRES iPerio (iRES SAGL, Lugano, Switzerland)	Machined surface	NR	NR	None

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2012	Grandi T[35]	Implants immediately loaded and restored using definitive abutments	28	53.2 (43–64)	14	Fixed	Immediately nonocclusally loaded	JDEvolution (JDental Care S.r.l., Modena, Italy)	Subtractive method	NR	NR	NR
2012	Grandi T[35]	Implants immediately loaded and restored using provisional abutments later replaced by custom-made abutments	28	50.3 (39–60)	14	Fixed	Immediately nonocclusally loaded	JDEvolution (JDental Care S.r.l., Modena, Italy)	Subtractive method	NR	NR	NR
2012	Grandi T[36]	Immediately non-occlusally loaded implants	81	51.8 (39–65)	40	Fixed	Immediately nonocclusally loaded	JDEvolution (JDental Care S.r.l., Modena, Italy)	Subtractive method	NR	NR	None
2012	Grandi T[36]	Early-loaded implants	80	55.3 (43–65)	40	Fixed	Early loaded (>2 days to <3 months)	JDEvolution (JDental Care S.r.l., Modena, Italy)	Subtractive method	NR	NR	None
2014	Grandi T[38]	Immediately loaded single implants using a definitive abutment	12	56 (39–70)	12	Fixed	Immediately nonocclusally loaded	JDEvolution (JDental Care S.r.l., Modena, Italy)	Subtractive method	NR	NR	Periimplant mucositis, abutment screw loosening (total: 2)
2014	Grandi T[38]	Immediately loaded single implants using a provisional abutment	13	57.08 (43–74)	13	Fixed	Immediately nonocclusally loaded	JDEvolution (JDental Care S.r.l., Modena, Italy)	Subtractive method	NR	NR	

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2005	Horwitz J[29]	Chlorhexidine mouthwash	28	57.27 (NR)	15	Fixed	Conventionally loaded (>3 months)	Osseotite TG (Biomet3i, Palm Beach Gardens, USA)	Subtractive method	NR	NR	NR
2005	Horwitz J[29]	Amine fluoride/ stannous fluoride mouthwash	33	51.83 (NR)	18	Fixed	Conventionally loaded (>3 months)	Osseotite TG (Biomet3i, Palm Beach Gardens, USA)	Subtractive method	NR	NR	NR
2013	Kim YK[20]	Osstem TSIII HA Implants immediately loaded	52	51.6 (NR)	26	Fixed	Immediately loaded (<48 hrs)	Osstem TSIII HA (Osstem Implant Co., Seoul, Korea)	Subtractive method	98.1%	NR	Severe marginal bone loss (total: 2)
2013	Kim YK[20]	Zimmer TSV Implants immediately loaded	48	49.6 (NR)	24	Fixed	Immediately loaded (<48 hrs)	TSV (Zimmer Dental, Carlsbad, USA)	Subtractive method	97.9%	NR	
2014	Maryod WH[16]	Immediately loaded mini-implants supporting mandibular overdentures	72	63.4 (NR)	18	Removable	Immediately loaded (<48 hrs)	MDI (3M ESPE, Seefeld, Germany)	Subtractive method	NR	NR	Pain and mobility, with and without suppuration
2014	Maryod WH[16]	Early-loaded mini-implants supporting mandibular overdentures	72	64.8 (NR)	18	Removable	Early loaded (>2 days to <3 months)	MDI (3M ESPE, Seefeld, Germany)	Subtractive method	NR	NR	

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2014	Meloni SM[39]	Platform-switching implants: split mouth	18	48 (28–70)	18	Fixed	Conventionally loaded (>3 months)	Nobel Replace Tapered Groovy, (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	Periimplant mucosal inflammation (total: 1)
2014	Meloni SM[39]	Regular platform implants: split mouth	18	48 (28–70)	18	Fixed	Conventionally loaded (>3 months)	Nobel Replace Tapered Groovy, (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	
2015	Meloni SM[43]	Socket sealing with epithelial connective tissue graft	15	49.7 (NR)	15	Fixed	Conventionally loaded (>3 months)	Nobel Replace (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	None
2015	Meloni SM[43]	Socket sealing with porcine collagen matrix	15	46.8 (NR)	15	Fixed	Conventionally loaded (>3 months)	Nobel Replace (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	None

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2015	Merli M[40]	Bone mineral of bovine origin (Bio-Oss, Geistlich Biomaterials AG, Wolhusen, Switzerland) and collagen porcine membranes (Bio-Gide, Geistlich Biomaterials AG, Wolhusen, Switzerland)	32	56 (31–76)	25	Fixed	Conventionally loaded (>3 months)	Element RC Inicell Implants (Thommen Medical AG, Grenchen, Switzerland)	Combination of subtractive metods	NR	NR	Dehiscence of the mucosa, presence of purulent exsudate, tingling sensation and hyposensitivity (for both groups)
2015	Merli M[40]	Synthetic resorbable bone graft substitute (Ceros TCP, Thommen Medical AG, Grenchen, Switzerland) and porcine pericardium collagen membranes (Jason, Bottis AG, Bettlach, Switzerland)	29	53.4 (30–76)	25	Fixed	Conventionally loaded (>3 months)	Element RC Inicell Implants (Thommen Medical AG, Grenchen, Switzerland)	Combination of subtractive methods	NR	NR	
2001	Paolantonio M[19]	Implant placed in a fresh extraction socket: maxilla, split mouth	24	41 (24–66)	48	Fixed	Immediately nonocclusally loaded	Titanium plasma-sprayed solid screwed implants (PHI, Legnano, Italy)	Additive method	NR	NR	None

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2001	Paolantonio M[19]	Implant placed in a fresh extraction socket: mandible, split mouth	24	41 (24–66)	48	Fixed	Immediately nonocclusally loaded	Titanium plasma-sprayed solid screwed implants (PHI, Legnano, Italy)	Additive method	NR	NR	None
2001	Paolantonio M[19]	Implant placed contralateral in a mature bone: maxilla, split mouth	24	41 (24–66)	48	Fixed	Immediately nonocclusally loaded	Titanium plasma-sprayed solid screwed implants (PHI, Legnano, Italy)	Additive method	NR	NR	None
2001	Paolantonio M[19]	Implant placed contralateral in a mature bone: mandible, split mouth	24	41 (24–66)	48	Fixed	Immediately nonocclusally loaded	Titanium plasma-sprayed solid screwed implants (PHI, Legnano, Italy)	Additive method	NR	NR	None

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2010	Park JC[31]	Nonsubmerged dental implants (Osstem SSII Implant System)	36	49.5 (NR)	28	Fixed	Conventionally loaded (>3 months)	Osstem SSII Implant System (Osstem Implant Co., Seoul, Korea)	Subtractive method	100%	NR	Severe marginal bone loss due to inflammation (total: 2)
2010	Park JC[31]	Nonsubmerged dental implants (Standard Straumann Dental Implant System)	39	46.84 (NR)	28	Fixed	Conventionally loaded (>3 months)	Standard Straumann Dental Implant System (Straumann AG, Basel, Switzerland)	Combination of subtractive methods	100%	NR	
2011	Pieri F[33]	Abutments with morse taper connection and a platform switch	20	45.8 (26–67)	20	Fixed	Immediately nonocclusally loaded	Samo Smiler System (Samo Biomedica SpA, Cadriano, Italy)	Additive method	94.7%	NR	Abscess associated with a fistula, abutment screw loosening, fracture of the provisional crown (2 prosthetic, 1 biological)
2011	Pieri F[33]	Conventional abutments with an internal connection and a matching diameter	20	46.6 (32–65)	20	Fixed	Immediately nonocclusally loaded	Samo Smiler System (Samo Biomedica SpA, Cadriano, Italy)	Additive method	100%	NR	

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2016	Schincaglia GP[17]	Immediately loaded implants supporting a locator-retained mandibular overdenture	30	66.6 (53–79)	15	Removable	Immediately loaded (<48 hrs)	OsseoSpeed (Astra Tech AB, Molndal, Sweden)	Subtractive and additive method	NR	NR	Denture fractures, insert change, abutment loosening, denture adjustment
2016	Schincaglia GP[17]	Delayed loaded implants supporting a locator-retained mandibular overdenture	30	66.2 (57–85)	15	Removable	Early loaded (>2 days to <3 months)	OsseoSpeed (Astra Tech AB, Molndal, Sweden)	Subtractive and additive method	NR	NR	

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/ removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2011	Tallarico M[32]	One-stage-early-loaded implants	38	46.71 (26–76)	29	Fixed	Early loaded (>2 days to <3 months)	TiUnite Branemark System Implants (41 MKIII Groovy or Nobel 48 Speedy Groovy) (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	Mobility without pain and swelling (total: 2)
2011	Tallarico M[32]	Two-stage early-loaded implants	51	48.39 (27–65)	18	Fixed	Early loaded (>2 days to <3 months)	TiUnite Branemark System Implants (41 MKIII Groovy or Nobel 48 Speedy Groovy) (Nobel Biocare AB, Goteborg, Sweden)	Subtractive and additive method	NR	NR	
2012	Vandeweghe S[34]	Within comparison of platform-switching implants: switch	15	57 (32–75)	15	Fixed	Conventionally loaded (>3 months)	Max (Southern Implants, Irene, South Africa)	Combination of subtractive methods	NR	NR	NR

(*Continued*)

Table 1 (Continued).

Year	First author	Control/test group	Number of implants	Mean age in years (range)	Number of patients in groups	Fixed/removable	Loading protocol	Implant type	Implant surface	Success rate implants	Success rate prostheses	Reported complications
2012	Vandeweghe S[34]	Within comparison of platform-switching implants: nonswitch	15	57 (32–75)	15	Fixed	Conventionally loaded (>3 months)	Max (Southern Implants, Irene, South Africa)	Combination of subtractive methods	NR	NR	NR

Note: The article was published in *Int J Oral Maxillofac Surg*, Sommer M, Zimmermann J, Grize L, Stubinger S, Marginal bone loss one year after implantation – a systematic review for different loading protocols, Copyright Elsevier 2019.[13]
Abbreviation: NR, not reported.

estimate for the mean MBL was 0.476 mm (95% CI: −0.305 to 1.258), and heterogeneity was not significant (p=0.714). The Egger's test for freedom of publication bias had a p>0.1 (p=0.252). It was not possible to quantify the association between 1-year implant survival and MBL because only 3 studies were available to perform the metaregressions.

The 19 randomized controlled clinical studies dealing with the fixed restored implants are shown in Table 3. The study of Cooper et al,[18] dealing with the replacement of single teeth by implants in the anterior maxilla, showed the lowest survival rate of 85.7%. Implants inserted in the trial of Paolantonio et al[19] reached the maximum MBL of 1.37 mm. In contrast to this high value, the lowest MBL was found by Kim et al[20] dealing with two consecutive implants restored with splinted crowns. Conspicuously, the study of Cooper et al[21] measured a bone gain of 1.3 mm. The authors did not mention the possible reasons for this deviation. Figure 3 shows the Forest plot on the MBL around implants supporting fixed restorations a year after implantation. The estimate for the mean MBL was 0.459 mm (95% CI: 0.325–0.593), and heterogeneity was not significant (p=0.955). The Egger's test for freedom of publication bias had a p>0.1 (p=0.302). A decrease of −0.083% (95% CI: −0.179 to 0.013 p=0.086) in 1-year implant survival per an increase of 1 mm in MBL was observed in fixed restorations.

The IQR for the 1-year implant survival reported in the considered studies was 97.0–100.0% with a median of 99.2%.

The overall MBL estimates for the fixed and removable restorations did not statistically differ (0.363 mm; 95% CI: −0.319 to −1.044; p=0.279).

Discussion

Patients suffering from partial or total edentulism benefit from the rehabilitation of the situation by inserting dental implants. This process shows a high satisfaction.[22] Several prosthetic reconstructions including either fixed or removable approaches are possible.[23]

While composing this systematic review including a meta-analysis, we only searched for randomized controlled clinical trials in which the MBL was measured 1 year after implantation.

Furthermore, we wanted to assess if there is a difference concerning the MBL between the two prosthetic processes. The meta-analysis showed an overall estimated MBL for the removable prostheses of 0.476 mm and for the fixed restorations of 0.459 mm. There is very little difference between these two values, which means that both prosthetic procedures lead to <0.5 mm MBL 1 year after implantation. We noticed that the randomized

Table 2 Selected studies on removable restorations

Year	First author†	Control/test group	Number of implants	Implant surface	Survival rate after 1 year (%)	Mean bone loss (mm)	SD (mm)
2011	Alsabeeha NH[15]	Southern Regular Implants and standard ball attachment	12	Combination of subtractive methods	90.9	0.2	0.4
2011	Alsabeeha NH[15]	Southern 8-mm-wide Implants and large ball attachment	12	Combination of subtractive methods	100	0.13	0.35
2011	Alsabeeha NH[15]	Neoss Regular Implants and locator attachment	12	Combination of subtractive methods	100	0.23	0.44
2014	Maryod WH[16]	Immediately loaded mini-implants supporting mandibular overdentures	72	Subtractive method	91.7	1.03	0.61
2014	Maryod WH[16]	Early-loaded mini-implants supporting mandibular overdentures	72	Subtractive method	96.7	0.93	0.52
2016	Schincaglia GP[17]	Immediately loaded implants supporting a locator-retained mandibular overdenture	30	Subtractive and additive method	93	0.25	0.5
2016	Schincaglia GP[17]	Delayed loaded implants supporting a locator-retained mandibular overdenture	30	Subtractive and additive method	100	0.54	0.5

Note: †Parameter for studies reporting several groups were summarized.

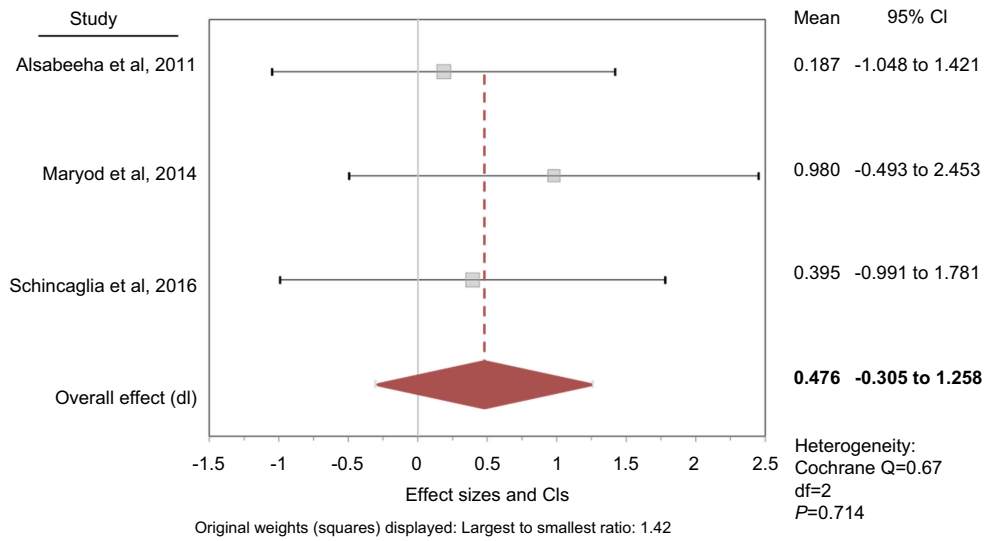

Figure 2 Meta-analysis of the mean marginal bone loss (MBL) 1 year after implantation for removable restorations.
Abbreviations: Mean, mean difference; dl, DerSimonian–Laird random-effects model.

controlled clinical studies in this review assessed many different issues such as different implant lengths, platform-matching/platform-switching implants, different loading protocols, submerged/nonsubmerged implants, different ball attachments and abutment connections. In conclusion, the selected randomized controlled clinical studies in this review did not directly compare MBL around implants of removable and fixed prostheses.

Table 3 Selected studies on fixed restorations

Year	First author†	Control/test group	Number of implants	Implant surface	Survival rate after 1 year (%)	Mean bone loss (mm)	SD (mm)
2001	Paolantonio M[19]	Implant placed in a fresh extraction socket: maxilla, split mouth	24	Additive method	100	1.37	0.5
2001	Paolantonio M[19]	Implant placed in a fresh extraction socket: mandible, split mouth	24	Additive method	100	1.18	0.5
2001	Paolantonio M[19]	Implant placed contralateral in a mature bone: maxilla, split mouth	24	Additive method	100	1.18	0.3
2001	Paolantonio M[19]	Implant placed contralateral in a mature bone: mandible, split mouth	24	Additive method	100	1.12	0.4
2005	Horwitz J[29]	Chlorhexidine mouthwash	28	Subtractive method	92.9	1.06	0.13
2005	Horwitz J[29]	Amine fluoride/stannous fluoride mouthwash	33	Subtractive method	100	1.27	0.25
2008	Cannizzaro G[30]	Flapless placed implants immediately loaded with full-arch prostheses	90	Subtractive method	98.9	0.55	0.22
2008	Cannizzaro G[30]	Flapless placed implants early loaded at 2 months with full-arch prostheses	87	Subtractive method	96.7	0.62	0.25
2010	Park JC[31]	Nonsubmerged dental implants (Osstem SSII Implant system)	36	Subtractive method	100	0.79	0.42
2010	Park JC[31]	Nonsubmerged dental implants (Standard Straumann Dental Implant System)	39	Combination of subtractive methods	93.9	1.07	0.46
2010	Cooper LF[21]	Single implants placed in fresh extraction sockets	58	Subtractive and additive method	94.5	−1.30	2.52
2010	Cooper LF[21]	Single implants placed in healed ridges	65	Subtractive and additive method	98.3	0.4	1.43
2011	Tallarico M[32]	One-stage early-loaded implants	38	Subtractive and additive method	94.7	0.86	0.37
2011	Tallarico M[32]	Two-stage early-loaded implants	51	Subtractive and additive method	100	0.77	0.28
2011	Pieri F[33]	Abutments with morse taper connection and a platform switch	20	Additive method	94.7	0.19	0.17
2011	Pieri F[33]	Conventional abutments with an internal connection and a matching diameter	20	Additive method	100	0.49	0.25
2012	Grandi T[35]	Implants immediately loaded and restored using definitive abutments	28	Subtractive method	100	0.09	0.03
2012	Grandi T[35]	Implants immediately loaded and restored using provisional abutments later replaced by custom-made abutments	28	Subtractive method	100	0.44	0.03
2012	Grandi T[36]	Immediately nonocclusally loaded implants	81	Subtractive method	100	0.42	0.01
2012	Grandi T[36]	Early-loaded implants	80	Subtractive method	100	0.47	0.01
2012	Vandeweghe S[34]	Within comparison of platform-switching implants: switch	15	Combination of subtractive methods	100	0.66	0.47
2012	Vandeweghe S[34]	Within comparison of platform-switching implants: nonswitch	15	Combination of subtractive methods	100	0.94	0.42
2013	Cannizzaro G[37]	2 implants placed flapless in fully edentulous mandibles and immediately restored with metal-resin screw-retained cross-arch prostheses	60	Subtractive and additive method/ subtractive method	100	0.74	0.54
2013	Cannizzaro G[37]	4 implants placed flapless in fully edentulous mandibles and immediately restored with metal-resin screw-retained cross-arch prostheses	120	Subtractive and additive method/ subtractive method	100	0.58	0.38
2013	Kim YK[20]	Osstem TSIII HA Implants immediately loaded	52	Subtractive method	100	0.05	0.67
2013	Kim YK[20]	Zimmer TSV Implants immediately loaded	48	Subtractive method	100	0.63	0.61
2014	Grandi T[38]	Immediately loaded single implants using a definitive abutment	12	Subtractive method	100	0.11	0.06

(*Continued*)

Table 3 (Continued).

Year	First author†	Control/test group	Number of implants	Implant surface	Survival rate after 1 year (%)	Mean bone loss (mm)	SD (mm)
2014	Grandi T[38]	Immediately loaded single implants using a provisional abutment	13	Subtractive method	100	0.58	0.11
2014	Meloni SM[39]	Platform-switching implants: split mouth	18	Subtractive and additive method	100	0.5	0.27
2014	Meloni SM[39]	Regular platform implants: split mouth	18	Subtractive and additive method	100	0.56	0.22
2015	Cooper LF[18]	Conical implant–abutment interface	53	Subtractive and additive method	100	0.22	0.28
2015	Cooper LF[18]	Flat to flat implant–abutment interface	53	Subtractive and additive method	85.7	1.2	0.64
2015	Cooper LF[18]	Platform-switched implant–abutment interface	50	Subtractive and additive method	86.4	1.32	1.01
2015	Esposito M[42]	Implant surface roughened with sandblasting and double etching	137	Combination of subtractive methods	100	0.64	0.2
2015	Esposito M[42]	Machined, turned implant surface	163	Machined surface	98.8	0.68	0.23
2015	Cannizzaro G[41]	Prostheses supported by supershort (5 mm) implants: maxilla	90	Subtractive and additive method	97.8	0.15	0.04
2015	Cannizzaro G[41]	Prostheses supported by supershort (5 mm) implants: mandible	60	Subtractive and additive method	100	0.08	0.03
2015	Cannizzaro G[41]	Prostheses supported by long (11.5 mm) implants: maxilla	90	Subtractive and additive method	100	0.62	0.12
2015	Cannizzaro G[41]	Prostheses supported by long (11.5 mm) implants: mandible	60	Subtractive and additive method	98.3	0.51	0.1
2015	Meloni SM[43]	Socket sealing with epithelial connective tissue graft	15	Subtractive and additive method	100	0.9	0.18
2015	Meloni SM[43]	Socket sealing with porcine collagen matrix	15	Subtractive and additive method	100	0.84	0.21
2015	Merli M[40]	Bone mineral of bovine origin (Bio-Oss, Geistlich Bio- materials AG, Wolhusen, Switzerland) and collagen porcine membranes (Bio-Gide, Geistlich Biomaterials AG, Wolhusen, Switzerland)	32	Combination of subtractive methods	100	0.77	0.36
2015	Merli M[40]	Synthetic resorbable bone graft substitute (Ceros TCP, Thommen Medical AG, Grenchen, Switzerland) and porcine pericardium collagen membranes (Jason, Bottis AG, Bettlach, Switzerland)	29	Combination of subtractive methods	100	0.54	0.45

Note: †Parameter for studies reporting several groups were summarized.

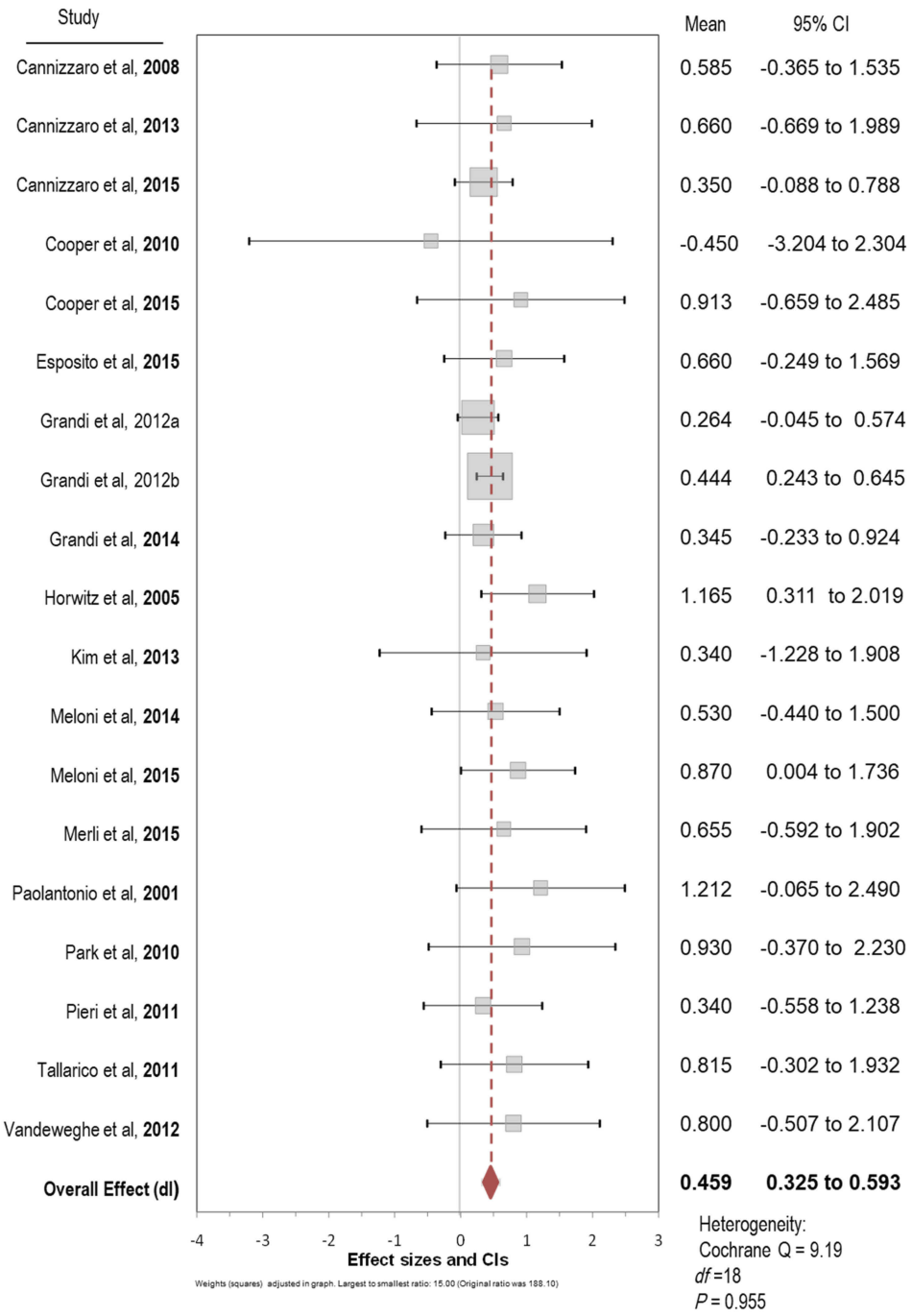

Figure 3 Meta-analysis of the mean marginal bone loss (MBL) 1 year after implantation for fixed restorations.
Abbreviations: Mean, mean difference; dl, DerSimonian–Laird random-effects model.

Regarding the studies dealing with the MBL of removable prostheses, two of three trials compared the immediate and early loading. In both controlled clinical trials, the survival rate of the immediate-loading protocol was lower. The MBL of the immediate-loading protocol measured by Schincaglia et al[17] was statistically significant (p-value <0.02) lower than the value of the early loading protocol. Comparably, Maryod et al[16] proved a statistically significant (p-value <0.011) higher MBL after 6 months of the immediate-loaded implants. But after 6 months, there was no statistically significant difference concerning MBL between the two loading protocols.

To come to a decision which might be the most advantageous approach for patients in need of implant-supported overdentures, Ma et al[24] compared different loading protocols, surfaces and attachment systems for mandibular two-implant overdentures. They came to the conclusion that different attachment systems do not significantly influence the MBL. Furthermore, machined implant surfaces showed statistically significant (p-value <0.05) more MBL than subtractive methods. For the subtractive methods, they used Southern,[5] Straumann (Straumann Group, Basel, Switzerland) and Steri-Oss (Nobel Biocare, Goteborg, Sweden) Implants. In our review, we included one study of Alsabeeha et al[15] where they inserted Neoss Implants (Neoss Ltd., Harrogate, UK) between Southern Implants (Southern Implants, Irene, South Africa). Both came to similar results concerning MBL of Southern Implants. Ma et al[24] lost 0.16 mm and Alsabeeha et al[15] lost 0.13 mm in one group and 0.2 mm in the other group. MBL was statistically significantly higher (p-value <0.05) for implants loaded 2 weeks after insertion in comparison to the implants loaded 12 weeks after implantation in the study of Ma et al.[24] The difference of MBL of implants loaded 6 or 12 weeks after implantation was not statistically significant (p-value >0.05). Concerning the implant success rate, they had comparable values to Alsabeeha et al.[15] The measurements stayed constant after 1 year until 10 years after loading.

To evaluate if there is a difference between overdentures supported by one or two implants, Tavakolizadeh et al[25] developed a study design on this topic. Twenty unsatisfied patients received either one or two interforaminal implants. After implant surgery, implants were immediately loaded. The outcome of the MBL was 0.6 mm±0.67 mm for one implant group and 0.6 mm±0.51 mm for the other. These results as well as those of Cordioli et al[26] correlate with our results.

To compare this review, for the fixed prostheses, we calculated a mean MBL of 0.459 mm considering no subgroups of the fixed prostheses. The review of Firme et al[27] describes the MBL around implants supporting single fixed prostheses and multiple-unit screw-retained prostheses. They included 17 clinical trials, 7 were related to single-implant prostheses and 10 to multiple-unit screw-retained prostheses. The mean MBL and the implant success rate for the single-implant prostheses was 0.58 mm and 100%, respectively, and for the multiple-unit screw-retained prostheses the respective values were 0.9 mm and 89.1–98.9%. They showed no statistical difference (p-value >0.05) between the two types of prostheses. In this case, it has to be considered that it was not clear when the follow-up was done, 1 year after implantation or 1 year after loading. The long-term study of Lai et al[28] showed less MBL. The authors analyzed 231 short dental implants supporting single crowns in 168 patients using a follow-up of 1, 5 and 10 years. The MBL measured 1 year after implantation was 0.55 mm±0.45 mm. This value is comparable to our results. During the time period of 1–5 years and 5–10 years, the MBL slightly increased, with the values being 0.05 mm±0.10 mm and 0.03 mm±0.14 mm, respectively. These results indicate that most bone remodeling occurs 1 year after implantation.

This systematic review and meta-analysis indicate that both the implants with fixed and with removable restorations lead to low respectively comparable MBL. However, there is a lack of clinical trials which compare these two types of restoration to each other. Further information in studies about the implant and prosthesis success rates are needed to make a clear statement. Other factors may influence the marginal bone more than the type of restoration, namely the loading protocol, or the implant surface. There is a need for further clinical trials to find the factors which lead to MBL in fixed and removable restorations supported by implants.

Disclosure

The authors report no conflicts of interest in this work.

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