Influence of marginal bone loss on peri-implantitis: Systematic review of literature

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Abstract
Background: The marginal bone of dental implants is subjected to slight load modifications over time, conditioning implant survival. Objective: Perform a systematic review of the literature analyzing the factors that contribute to marginal bone loss (MBL) and the subsequent development of peri-implantitis.
Material and Methods: Bibliographic research in the databases PubMed, Medline and Scopus between 2010 and 2018 was performed. The inclusion criteria were articles published in the last 10 years and that were in English or Spanish, that were carried out on humans, that were cohort studies, that included cases and controls or that used randomized clinical trials. Exclusion criteria removed articles that contained clinical cases, case series or systematic reviews. Results: A total of 90 articles were analyzed that examined all the factors reported in the literature, such as idiosyncratic factors, toxic habits, systemic drugs and implant characteristics (diameter, length, type surface, implant connection, implant design and type of platform at the moment of the prosthetic load). Discussion: Patient characteristics and associated pathologies must be taken into account when assessing MBL. MBL in all dental implants can be considered independent of the type of prosthetic rehabilitation and the moment of load; this was emphasized. The MBL is smaller in dental implants with rough surfaces, switch platforms and infracrestal localization, as they are of multifactorial origin.
Conclusions: All the reviewed articles maintain a common criterion regarding the concept and measurement of the MBL and highlighting the importance of radiodiagnosis for quantification. Longterm prospective studies with unified criteria are needed to reduce bias by identifying the most relevant factors in MBL.

Key words: Marginal bone loss, dental implant, peri-implantitis.
Introduction
Rehabilitation through dental implants has a long history. Recently, the analysis and relevance of bone remodeling shows that rehabilitation occurs from the moment of dental implant placement and the osseointegration process and from the implant’s subsequent prosthetic re-
habilitation and submission to masticatory loads, as well as the conservation and modification of the soft tissues that surround dental implants to achieve adequate func-
tion (1).
The study of these variables begins with Albrektsson et al. 1986 (2) and continues with Misch 2008 (3), who showed how remodeling of the bone surrounding the crestal area of the implant takes place during the first year after implant placement. A loss of up to 2 mm of bone around the neck has been considered to be normal. However, the subsequent remodeling of the surrounding bone must continue be evaluated, since it can ultimately lead to the loss of the dental implant.

To assess a dental implant’s success, different criteria have been described, some of which are still valid today: absence of peri-implant radiolucency, absence of mobil-
ity, annual bone loss of less than 0.2 mm after the first year and absence of pain, infection and paresthesias (2). However, new criteria have been incorporated in an at-
tem to establish scales of implant quality by establish-
ing groups: Group I includes optimal health conditions, Group II includes satisfactory health with stable implants and a history of clinical problems, Group III includes those who have implants with compromised health and Group IV implants are considered failures (3).

Many factors that may influence marginal bone loss (MBL) have been described in the scientific literature: systemic factors of the patient (patient’s baseline pa-
thology, toxic habits), local factors (history/presence of periodontal disease, poor oral hygiene, quality and bone quantity) and characteristics of the implant (surface, dia-
meter, length and morphology) (4-8).
This systematic review aimed to examine previous ar-
ticles published in the scientific literature that examine which factors contribute to MBL and the development of peri-implantitis.

Material and Methods
This work has been carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) statement published in 2009 (9). The PI-CO question was asked: What factors in-
fluence the initial MBL after the placement of a dental implant and its progression over time? To answer this, a bibliographic search was carried out using PubMed, Medline and Scopus databases and was limited to works published during 2010-2018. The keywords used for the search were “Marginal bone loss,” “dental implant” and “peri-implantitis.”

The inclusion criteria for the research literature were articles published in the last 10 years and that were in English or Spanish, that were carried out on humans and that included the following types of studies: cohort stud-
ies, cases and controls or randomized clinical trials.
Exclusion criteria removed articles that contained clinical cases, case series or systematic reviews.
All the information was obtained from the articles selected by one of the authors (ACG). The variables included general information, such as the author, year of publica-
tion, type of study, sample size, number of patients evaluated and number of implants placed. Specific variables included the definition used by the authors for MBL, which types of radiography were used for the analysis of MBL, which factors were evaluated in the study and the results obtained.

Results
A systematic research of the PubMed database was carry
out with the following research strategies:
1. (marginal[All Fields] AND (“bone diseases, meta-
abolic”[MeSH Terms] OR (“bone”[All Fields] AND “di-
seases”[All Fields] AND “metabolic”[All Fields]) OR
“metabolic bone dis-eases”[All Fields] OR (“bone”[A-
ll Fields] AND “loss”[All Fields]) OR “bone loss”[All Fields]) AND (“peri-implantitis”[MeSH Terms] OR
“peri-implantitis”[All Fields] OR “pe-riimplantitis”[A-
ll Fields]) AND ((Clinical Trial[ptyp] OR Observatio-
nal Study[ptyp] OR Con-trolled Clinical Trial[ptyp]) AND “2008/12/01”[PDat]: “2018/11/27”[PDat] AND
“hu-mans”[MeSH Terms] AND (English[lang] OR Spa-
ish[lang])). A total of 619 articles were obtained, of which, after reading the title and summary, 36 were excluded for not complying with the established inclusion criteria; 13 articles were selected (Fig. 1).
2. (marginal[All Fields] AND (“bone diseases, meta-
abolic”[MeSH Terms] OR (“bone”[All Fields] AND “di-
seases”[All Fields] AND “metabolic”[All Fields]) OR
“metabolic bone dis-eases”[All Fields] OR (“bone”[A-
ll Fields] AND “loss”[All Fields]) OR “bone loss”[All Fields]) AND (“dental implants”[MeSH Terms] OR
(“dental”[All Fields] AND “implants”[All Fields]) OR
“dental implants”[All Fields] OR (“dental”[All Fields] AND “implant”[All Fields]) OR “dental implant”[All Fields]) AND ((Clinical Trial[ptyp] OR Observatio-
nal Study[ptyp] OR Controlled Clinical Trial[ptyp]) AND “2008/12/01”[PDat]: “2018/11/27”[PDat] AND
“hu-mans”[MeSH Terms] AND (English[lang] OR Spa-
ish[lang])). A total of 619 articles were obtained, and after reading the title and abstract, 82 articles were se-
lected (Fig. 2).
After the analysis of the articles obtained from both re-
search attempts, five repeated articles were found, result-
ing in 90 articles being analyzed.
The articles included in the systematic review of the lite-
The dimensional stability of the tissues is analyzed one year after the prosthetic load of the implant, since during the first year, different authors establish MBL limits of 1.5-2 mm (14), determining a single value of 1.8 mm (15) against the 1.5 mm subsequently established (16). Some authors suggested that after the first year, an MBL greater than 0.2 mm per year can take place (2).

-MBL Diagnostic Tests
For the proper assessment of MBL around dental implants, it is essential to go through complementary diagnostic tests (3). Among the most important radiological tests, we observed the panoramic radiography or orthopantomography and the periapical radiography; these tests will only allow researchers to measure the proximal (mesial and distal) MBL of the implant vertically (3). On the other hand, the conical beam tomography (CBCT) offers us transversal cuts, giving us the possibility to obtain a threedimensional evaluation of the MBL and measure the MBL of the vestibular and lingual area of the implant aside from being able to obtain values in the horizontal sense (17). In addition, with respect to axial tomography, the exposure time, radiation dose and economic cost are reduced (18). However, only 4 of the 90 included studies used cone beam tomography, and 8 of them resorted to...
panoramic radiography, whereas the vast majority carried out periapical radiographs of the implants by performing a parallel technique with the help of positioners (Table 1, 1 continue, 1 continue-1-18).

-**MBL Quantification**

When quantifying MBL, some authors used different software (19) and even used magnifying glasses to be more exhaustive with the measurement (20). All the studies included in this review expressed this MBL quantitatively in millimeters, except for the study performed by Corcuera et al. 2016 (21), in which Lagervall and Jansson’s classification was used (22). This classification gives grade 0 if there is no MBL, grade 1 when the loss is equal to or less than 1/3 of the length of the implant, grade 2 if the loss is greater than 1/3 but less than 2/3 of the length of the implant and grade 3 if it suffers 2/3. Corcuera et al. 2016 made a modification to this classification, incorporating a grade 4 that includes implants that were unsuccessful or non-surviving (21).

-**MBL Influential Epidemiological Factors**

The main idiosyncratic patient factors recorded in the studies reviewed were age, gender, toxic habits and systemic pathology (osteoporosis, osteopenia, Interleukin-1b levels), in addition to the medication administered (bisphosphonates) (23-27). Few studies focused on assessing MBL and highlighted the presence of systemic pathology, including a patient’s medication and/or their toxic habits. Although greater MBL has been observed in smoking patients, independently of the type of implant rehabilitation, MBL sometimes duplicates these results independently of the type of implant rehabilitation applied (28). Sayardoust et al. 2017 (25) indicated that MBL was higher in the mechanized implants of smoking patients at 90 days, with a higher expression of the proinflammatory cytokine IL-6 and a lower expression of the osteogenic and osteocalcin gene. Predictors of MBL are reflected in smoking, bleeding as a result of probing at 90 days, an expression of factor 1 alpha and an expression of proinflammatory cytokine at 90 days (25).

Corcuera et al. 2017 (21) concluded that patients with Down syndrome have significantly higher MBL (p < 0.001) if one implant per patient is selected (p < 0.05). They also observed a greater loss of implants, especially in those with greater MBL (p < 0.01). In the case group, an increase in MBL (p < 0.05) and greater implant loss (p < 0.01) was also observed with age.
# Marginal bone loss analysis

| Author et al. | Year | Reference | Study type | Sample size | Criteria used to define MBL | Evaluated variables | Results |
|--------------|------|-----------|------------|-------------|-----------------------------|---------------------|---------|
| Corcuera-Flores et al. | 2017 | Four years of survival and marginal bone loss of implants in patients with Down syndrome and cerebral palsy. | Retrospective | 19 patients | MBL in thirds (Langeland and Jansson's proposed radiological classification; does not specify program used). | Implant length, Radiography | MBL was significantly higher in all samples (p < 0.05) and implants (p < 0.01). MBL of implants increased with age. The three-unit fixed dental prosthesis showed a higher MBL than one implant per patient; p < 0.0001. All patients with Down syndrome saw some damage to bone support (p < 0.005). Implant loss occurred only in Down syndrome patients (p < 0.0001). |
| Cooper et al. | 2016 | Comparison of Marginal Bone Changes with Internal Conus and External Hexagon Design Implant Systems: A Prospective, Randomized Study. | Prospective | 45 patients | MBL in mm (does not specify program used). | Implant connection, Intraoral Rx with paralyzer (parallel technique) | The mean marginal bone level change from implant placement to 3 years was -0.25 ± 0.60 mm and -0.5 ± 0.93 mm for internal conus design implants and external hex design implants, respectively. The change recorded from permanent restoration to 3 years was a gain of 0.31 ± 0.41 mm versus 0.04 ± 0.51 mm for ICI and EXI implants, respectively (P < 0.05). |
| Mendoza-Azpurd et al. | 2016 | Assessment of Marginal Peri-implant Bone-Level Short-Length Implants Compared with Standard Implants Supporting Single Crowns in a Controlled Clinical Trial: 12-Month Follow-Up: Int Periodontics Restorative Dent. 2016 Sep;35(5):631-42 | Clinical trial | 82 patients | MBL in mm measured with ImageJ software (NIH). | Type of implant (shorts vs. conventional), Soft tissue stability | A statistically significant difference was found in favor of the standard-length implants after 12 months, with greater gingival recession around the implant; however, bone loss in the short implants did not exceed 0.53 mm. The treatment with 5.5- to 7-mm-length implants is as reliable as treatment with 10- or 12-mm-length implants. |
| Koutouzis et al. | 2015 | The Effect of Interimplant Distance on Peri-Implant Bone and Soft Tissue Dimensional Changes: A Nonrandomized, Prospective, 2-Year Follow-Up Study. Int J Periodontics Restorative Dent. 2015 Nov-Dec;35(6):679-95. | Prospective | 30 patients | MBL in mm measured with MIPacs, Medicor Imaging (parallelizer) | Marginal and midproximal bone loss between implants | There were no statistically significant differences in marginal and midproximal bone loss and dental implant. |

Table 1: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.
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| Study | Year | Design | Patients | Implants | MBL in mm measured with | Implant location | Implant system | Prosthetic material | Surgical technique | MBL in mm measured with | Implant design | Implant stability | Surgical technique | MBL in mm measured with |
|-------|------|--------|----------|----------|-------------------------|-----------------|----------------|------------------|-------------------|-------------------------|----------------|----------------|-------------------|-------------------------|
| Türk et al. | 2013 | Clinical trial | 33 patients | 77 implants | Scion Image (Scion Corporation, Frederick, MD, USA) software | I,C, PM, M | Prosthetic material with three different superstructure materials: a randomised clinical trial. | J Oral Rehabil. 2013 Jun;40(6):457-63 | Intraoral Rx with parallelizer (parallel technique) | Marginal bone loss measured with RAIN software (v. 12.27) | Implant system Prosthetic material | | | | |
| Bressan et al. | 2017 | Clinical trial | 80 patients | 128 implants | Diagnostic imaging (Sectra PACS; Sectra AB, Linköping, Sweden) software | I,C, PM, M | | | | Intraoral Rx with parallelizer (parallel technique) | Implant location (I,C, PM, M) | Implant system | | | | |
| Pisoni et al. | 2016 | Prospective | 40 patients | 69 implants | Scion Image (Scion Corporation, Frederick, MD, USA) software | I,C, PM, M | | | | Rx does not specify | Implant system | | | | | |
| Abtahi et al. | 2016 | Clinical trial | 32 patients | 56 implants | Diagnostic imaging (Sectra PACS; Sectra AB, Linköping, Sweden) software | I,C, PM, M | Bisphosphonate treatment | | | Measured with diagnostic imaging (Sectra PACS; Sectra AB, Linköping, Sweden) software | Implant system | | | | | |
| Gultekin et al. | 2013 | Clinical trial | 27 patients | 104 implants | Diagnostic imaging (Sectra PACS; Sectra AB, Linköping, Sweden) software | I,C, PM, M | | | | Intraoral Rx with parallelizer (parallel technique) | Implant system | | | | | |
### Table 1: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study Authors                  | Study Title                                                                 | Design                  | Patients/Implants | MBL Measurement Method                                      | Implant Length | Implant Location (I, C, PM, M) | Implant Design | Findings                                                                                         |
|-------------------------------|-----------------------------------------------------------------------------|-------------------------|-------------------|-------------------------------------------------------------|----------------|-------------------------------|---------------|-----------------------------------------------------------------------------------|
| Khorsand et al. 2016          | Effect of Microthread Design on Marginal Bone Level Around Dental Implants Placed in Fresh Extraction Sockets. Implant Dent. 2016 Feb;25(1):90-6 | Clinical trial         | 30/41             | MBL in mm measured with Trophy 2000 software (Trophy windows access software; Paris, France) | Introral Rx with parallelizer (parallel technique) | Implant design | At month 3, the microthread groups have been associated with more MBL than the CG (P = 0.04). At months 6 and 12, both groups had comparable bone levels (P = 0.21). |
| Lee et al. 2016               | A Long-Term Prospective Evaluation of Marginal Bone-Level Change Around Different Implant Systems. Int J Oral Maxillofac Implants. 2016 May-Jun;31(3):657-64 | Prospective             | 54/135            | MBL in mm measured with UTHSCSA Image Tool (version 3.00 for Windows, University of Texas Health Science) | Introral Rx (parallel technique) | Implant system | The rough-surface implants and the machined coronal aspect implants did not exhibit statistically significantly different MBL, whereas the microthreaded coronal aspect implants exhibited significantly less MBL (P = .0015). |
| Schincaglia et al. 2016       | Marginal Bone Response Around Immediate- and Delayed-Loading Implants Supporting a Locator-Retained Mandible Overdenture: A Randomized Controlled Study Int J Oral Maxillofac Implants. 2016 Mar-Apr;31(2):448-58 | Clinical trial         | 30/60             | MBL mm measured with Image J, version 1.42, National Institutes of Health | Introral Rx (parallel technique) | Moment of implant loading (immediate or deferred) | A statistically significant difference was observed at 12 months, with less radiographic bone loss in the immediately implants group. Insertion torque and implant length were not correlated with radiographic bone loss. Also, no difference in frequency of maintenance visits and prosthetic complications was reported between the groups. |
| Elsyad et al. 2016            | Circumferential bone loss around splinted and non-splinted immediately loaded implants retaining mandible overdentures: A randomized controlled clinical trial using cone beam-computed tomography. J Prostheth Dent. 2016 Nov;116(5):741-748 | Clinical trial         | 30/60             | MBL mm Measured with On-Demand3DApp Software; CyberMed Inc | CBCT            | MBL | Vertical bone loss and horizontal bone loss increased significantly at 3 years after insertion (T3) compared with 1 year (T1) for both groups (P < .005). After 3 years, vertical bone loss was 1.36 ± 0.57 mm and 1.0 ± 0.44 mm and horizontal bone loss was 0.88 ± 0.48 mm for with ball attachment (BA) and 0.77 ± 0.53 mm for bar attachment (RA). At T1 and T3, a BA had more significant vertical bone loss than an RA (P < .001), while horizontal bone loss did not differ significantly between groups. For both groups, a significant difference was found in vertical bone loss and horizontal bone loss between implant sites (P < .001). |
### Table 1 continue-2: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study | Description | Patients | Implants | Marginal Bone Loss Measurement | Imaging Technique | Hybrid Prosthesis Details | Findings |
|-------|-------------|----------|----------|--------------------------------|------------------|--------------------------|----------|
| Slot et al. 2016 | Maxillary overdentures supported by four or six implants in the anterior region: 5-year results from a randomized controlled trial. J Clin Periodontol. 2016 Dec;43(12):1180-1187 | Clinical trial 50 patients 250 implants | MBL in mm Intraoral Rx with parallelizer (parallel technique) | Hybrid prosthesis on 4 or 6 implants (number of implants) | In patients with functional complaints of their maxillary denture, bar-supported overdentures on four implants in the anterior maxillary region were not inferior to overdentures supported by six implants after 5 years of function. Clinical function was good, with no difference in clinical parameters between the groups. |
| Negri et al. 2014 | The effect of age, gender, and insertion site on marginal bone loss around endosseous implants: results from a 3-year trial with premium implant system. Biomed Res Int. 2014;2014:369051 | Clinical trial 252 patients 632 implants | MBL in mm measured with OsirIX Imaging Software | OPG | Age Gender Implant location (maxillary mandible) Implant diameter | Overall MBL was 0.8 mm ± 0.03 (mean ± SEM). Higher MBL was observed around implants in the maxilla than in the mandible (P < 0.007). A relationship between implant diameter and MBL (P < 0.0001) was observed in male and, more limitedly, female patients. Older patients had higher MBL in the maxilla, but not in the mandible (P < 0.0001). MBL progressively increased with age in male patients, but reached a peak in the 50- to 60-year age group in the female subset (P < 0.001). |
| Fernández-Formoso et al. 2012 | Radiographic evaluation of marginal bone maintenance around tissue-level implant and bone-level implant: a randomised controlled trial. A 1-year follow-up. J Oral Rehabil. 2012 Nov;39(11):830-7. | Clinical trial 54 patients 114 implants | MBL in mm measured with NHI Image | Intraoral Rx (parallel technique) | Implant platform design | Mean of bone loss with platform-switching implants was -0.01 mm, and the mean of bone loss with standard platform implant was 0.42 mm. Outcomes of this study indicated that the platform-switching design could preserve the crestal bone levels to the 1-year follow-up. There was a statistically significant difference in MBL. |
| Ma et al. 2010 | Marginal bone loss with mandibular two-implant overdentures using different loading protocols and attachment systems: 10-year outcomes. Int J Prosthodont. 2010 Jul-Aug;23(4):321-32. | Retrospective 106 patients 212 implants | MBL in mm measured with x7 magnification, using a peak magnifying glass (which had a scale in tenths of a millimeter) | Intraoral Rx with parallelizer (parallel technique) | Implant surface Attachments (ball retainers vs. locator) | Annual MBL progressed at low levels after the first year with episodes of bone loss and gain. There was stability in marginal bone levels over the long term, with the majority of remodeling occurring during the first year of function. Roughened implant surfaces may be beneficial during the early remodeling period. The amount of MBL in the first year of loading differed significantly by loading protocol and implant surface, whereas the attachment system had only a minor influence. |
| Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. |
|---|
| Hof et al. 2014 | Impact of insertion torque and implant neck design on peri-implant bone level: a randomized split-mouth trial. Clin Implant Dent Relat Res. 2014 Oct;16(5):668-74 |
| Clinical trial | 21 patients | MBL in mm; does not specify program used | Introral Rx (parallel technique) | Implant stability (insertion torque) |
| 84 implants | | | Implant design | Interleukin-1β levels |
| Song et al. 2009 | Comparative analysis of peri-implant marginal bone loss based on microthread location: a 1-year prospective study after loading. J Periodontol. 2009 Dec;80(12):1937-44 |
| Prospective | 20 patients | MBL in mm; does not specify program used | Introral Rx with parallelizer (parallel technique) | Implant design |
| 40 implants | | | | The average bone loss was 0.16 (SD: 0.19) mm in the group with microthreads placed at the implant top and 0.30 (SD: 0.22) mm in the group with microthreads placed 0.5 mm below the implant top after 1 year of functional loading. The paired t test revealed a significant difference in crestal bone loss between groups A and B in individual patients (P = 0.004). No significant differences were found between the two groups for the gingival parameters. |
| Froum et al. 2017 | Survival Rates and Bone and Soft Tissue Level Changes Around One-Piece Dental Implants Placed with a Flapless or Flap Protocol: 8.5-Year Results Int J Periodontics Restorative Dent. 2017 May/Jun;37(3):327-337 |
| Retrospective | 52 patients | MBL in mm; measured with Image-Pro Insight version 8.0.4, Media Cybernetics | Introral Rx (parallel technique) | Surgical technique with or without flap |
| 108 implants | | | Implant and abutment one piece | Analysis suggested decreasing mean levels of bone loss with time (P < .001). Moreover, there was 0.8-1.0 mm of bone loss through year 1.5, which decreased to 0.3 mm at 8.5 years (P < .05). There was no statistically significant difference in probing pocket depth (PPD) or bleeding on probing over time. Similar mean levels of PPD were found in flap and flapless groups (mean [SD] = 2.4 [0.3] and 2.2 [0.4] mm, respectively [P = .18]), as well as similar rates of BOP (22.8% vs. 17.9%, respectively). |
| Ainetti et al. 2015 | Soft tissue and crestal bone changes around implants with platform-switched abutments placed nonsubmerged at subcrestal position: a 2-year clinical and radiographic evaluation. Int J Oral Maxillofac Implants. 2015 Nov-Dec;30(6):1369-77 |
| Retrospective | 40 patients | MBL in mm measured with Image J software | Introral Rx (parallel technique) | Implant location (maxilla or mandible) |
| 58 implants | | | Bone quality (2 or 3) | Number of implants |
| | | | From implant insertion to the 2-year follow-up, the mean bone loss was 0.32 ± 0.37 mm. No significant differences related to sex, implant site and bone density were observed. |
Table 1 continue-4: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study Reference         | Intervention Description                                                                 | Study Design | Patients | Implant/Implants | MBL Measurement Methodology                                                                 | Implant Diameter/Location |
|-------------------------|------------------------------------------------------------------------------------------|--------------|----------|------------------|-----------------------------------------------------------------------------------------------|----------------------------|
| Toljanic et al. 2016    | Immediate Loading of Implants in the Edentulous Maxilla with a Fixed Provisional Restoration without Bone Augmentation: A Report on 5-Year Outcomes Data Obtained from a Prospective Clinical Trial. Int J Oral Maxillofac Implants. 2016 Sep-Oct;31(5):1164-70 | Clinical trial | 51 patients 306 implants | MBL in mm measured with x7 magnification and using software (Illustrator CS, Adobe Systems) | Intraoral Rx (parallel technique) | Implant diameter/Implant location Forty subjects with 232 implants returned for the final follow-up appointment, representing a 5-year implant survival proportion of 93% with a mean MBL of 0.44 ± 1.25 mm for this group |
| Giacomel et al. 2017    | Comparison of Marginal Bone-Level Changes of Immediately Loaded Implants, Delayed Loaded Non-submerged Implants, and Delayed Loaded Submerged Implants: A Randomized Clinical Trial. Int J Oral Maxillofac Implants. 2017 May/June;32(3):661-666 | Clinical trial | 15 patients 45 implants | MBL in mm measured with Cliniview 10.2.2 software (Instru-mentarium) | Intraoral Rx (parallel technique) | Implant location (submerged or not submerged) Moment of implant loading (immediate or deferred) In the 9-month period following the implants, no statistically significant differences were found between immediately and delayed loaded implants or between submerged and nonsubmerged implants in bone level changes in patients with partial posterior mandibular edentulism. |
| Thoma et al. 2014       | Prospective randomized controlled clinical study comparing two dental implant systems: demographic and radiographic results at one year of loading. Clin Oral Implants Res. 2014 Feb;25(2):142-9 | Clinical trial | 60 patients 151 implant | MBL in mm measured with Image J; National Institutes of Health, Bethesda, MD, USA | Intraoral Rx (parallel technique) | Implant design (implant and abutment one piece or two pieces) The changes in mean marginal bone levels on the implant level amounted to -0.05 mm (SD ± 0.32 mm) (2 piece) and to -0.27 mm (± 0.52 mm) (1 piece). Patient-level values were -0.06 mm (± 0.37 mm) (2 piece) and -0.25 mm (±0.35 mm) (1 piece). These differences between the groups reached statistical significance on the patient level with less bone loss in the 2-piece group (P < 0.05). |
| Vigolo et al. 2015      | Clinical evaluation of marginal bone-level change around multiple adjacent implants restored with splinted and nonsplinted restorations: a 10-year randomized controlled trial. Int J Oral Maxillofac Implants. 2015 Mar-Apr;30(2):411-8. | Clinical trial | 44 patients 132 implants | MBL in mm (does not specify program used) | Intraoral Rx (parallel technique) | Prosthetic rehabilitation At 10 years, the splinted group showed a mean of 1.2 mm (interquartile range: 0.2 mm) of bone loss; the nonsplinted group showed 1.3 mm (interquartile range: 0.2 mm). A significant difference in bone loss was seen between the two groups. However, the difference of 0.1 mm was not considered clinically meaningful. |
Table 1 continue-5: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study                  | Description                                                                 | Patients | Implants | MBL measurement                          | Imaging   | Implant length | Regeneration | Results                                                                 |
|------------------------|-----------------------------------------------------------------------------|----------|----------|------------------------------------------|-----------|----------------|--------------|-------------------------------------------------------------------------|
| Bechara et al. 2017    | Short (6-mm) dental implants versus sinus floor elevation and placement of longer (≥10-mm) dental implants: a randomized controlled trial with a 3-year follow-up. Clin Oral Implants Res. 2017 Sep;28(9):1097-1107 | Clinical trial | 53 patients | 90 implants | MBL in mm measured with software (Scion Image; Scion, Frederick, MD, USA) | OPG | At 3 years, the sinus floor elevation with simultaneous placement of standard-length (≥ 10-mm) implants (CG) had a significantly higher mean ISQ than the short (6-mm) implants (TG) (72.4 vs. 71.6, P = 0.004). Mean MBL was significantly higher in the CG than in the TG, both at 1 year (0.14 mm vs. 0.21 mm, P = 0.006) and at 3 years (0.20 mm vs. 0.27 mm, P = 0.01). A few complications were reported. Surgical time and cost were significantly higher in the CG than in the TG (P < 0.0001). |
| Elsyad et al. 2012     | Marginal bone loss adjacent to conventional and immediately loaded two implants supporting a ball-retained mandibular overdenture: a 3-year randomized clinical trial. Clin Oral Implants Res. 2012 Apr;23(4):496-503 | Clinical trial | 36 patients | 60 implants | MBL in mm measured with software (MxLiteView, version 1.24 DICOM viewer) | CBCT | After a 3-year follow-up period, the immediate-loading group recorded more significant vertical bone loss at distal and labial sites than the conventional-loading group, and no significant differences in horizontal bone loss between the groups were observed. The probing depths at the distal and labial sites in the immediate loading group were higher than in the conventional loading group. |
| Temmerman et al. 2017  | An open, prospective, non-randomized, controlled, multicenter study to evaluate the clinical outcome of implant treatment in women over 60 years of age with osteoporosis/osteopenia: 1-year results. Clin Oral Implants Res. 2017 Jan;28(1):95-102. | Clinical trial | 48 patients | 148 implants | MBL in mm measured with software (Illustrator CS; Adobe Systems Inc., San Jose, CA, USA) | Intraoral Rx (parallel technique) | Bone density (osteoporosis osteopenia vs. healthy) | The overall MBL alteration on a subject’s level was -0.04 ± 0.27 mm (osteoporosis group: -0.17 ± 0.30 mm; CG: 0.04 ± 0.23 mm). No statistically significant differences were found between groups. |
| Canullo et al. 2016    | Implant Abutment Cleaning by Plasma of Argon: 5-Year Follow-Up of a Randomized Controlled Trial. J Periodontol. 2016 Apr;87(4):434-42 | Clinical trial | 30 patients | 30 implants | MBL in mm measured with Autocad 2006, v.Z54.10, Autodesk, San Rafael, CA | Intraoral Rx with parallelizer (parallel technique) | Implant location (I.C,PM) | A statistically higher mean MBL occurred in the CG (cleaning protocol by steaming) compared with the TG (plasma of argon treatment) at 6, 24 and 60 months after crown connection. Nevertheless, intragroup comparisons during the entire follow-up demonstrated a statistically significant mean MBL in the CG but not in the TG. |
Table 1 continue-6: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study Description | Clinical trial | Prospective | MBL (in mm) (does not specify the program used) | Intraoral Rx with parallelizer (parallel technique) | Type of implant loading (immediate or deferred) | Implant location | Moment of implant loading (immediate or deferred) | Implant design (cylindrical, conical) | Implant surface | MBL in mm measured with various programs, software, and photogrammetry: | Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. |
|-------------------|---------------|-------------|-----------------------------------------------|--------------------------------------------------|--------------------------------------------------|----------------|-----------------------------------------------|-----------------------------------|----------------|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| Galindo-Moreno et al. 2017 | Clinical trial | Prospective | MBL in mm (does not specify the program used) | Intraoral Rx with parallelizer (parallel technique) | Moment of implant loading (immediate or deferred) | Implant location | Clinical trial | Radiographic evaluation of marginal bone levels around dental implants with different surface characteristics: | Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. |
| Piao et al. 2009 | 69 patients | 97 implants | MBL in mm (does not specify the program used) | Intraoral Rx with parallelizer (parallel technique) | Moment of implant loading (immediate or deferred) | Implant location | Clinical trial | Radiographic evaluation of marginal bone levels around dental implants with different surface characteristics: | Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. |
| Kadkhodazadeh et al. 2013 | 25 patients | 75 implants | MBL in mm (does not specify the program used) | Intraoral Rx with parallelizer (parallel technique) | Moment of implant loading (immediate or deferred) | Implant location | Clinical trial | Radiographic evaluation of marginal bone levels around dental implants with different surface characteristics: | Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. |
| Zuffetti et al. 2016 | A 10-year report from a multicentre randomised controlled trial: Immediate non-occlusal versus early loading of dental implants in partially edentulous patients. | 52 patients | 52 implants | MBL in mm measured with various programs, software, and photogrammetry: | Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. |

Marginal bone loss analysis
Marginal bone loss analysis

Table 1 continue-7: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Clinical trial | Implant design | Type of implant | Bone quality | Implant length | Implant diameter | Implant location | Bone regeneration or not | Surgical technique with or without flap | Prosthetic rehabilitation or screw-retained or not | Implant location | Bone regeneration or not | Implant length | Implant diameter | Prosthetic rehabilitation or screw-retained or not | Postextraction implant or not |
|----------------|----------------|-----------------|--------------|----------------|-----------------|-----------------|------------------------|------------------------------------------|---------------------------------------------|----------------|------------------------|--------------|---------------|---------------------------------------------|--------------------------|
| 64 patients    | 144 implants   | MBL in mm       | (does not specify program used) | Intraoral Rx with parallelizer (parallel technique) | WaterScion Imagent (WaterScion, Frederick, MD, USA) software | Implant type        | Implant design          | Implant length             | Implant diameter              | Implant location | Bone regeneration or not | Implant length | Implant diameter | Prosthetic rehabilitation or screw-retained or not | Postextraction implant or not |
| 18 patients    | 36 implants    | MBL in mm       | (does not specify program used) | Intraoral Rx with parallelizer (parallel technique) | WaterScion Imagent (WaterScion, Frederick, MD, USA) software | Implant type        | Implant design          | Implant length             | Implant diameter              | Implant location | Bone regeneration or not | Implant length | Implant diameter | Prosthetic rehabilitation or screw-retained or not | Postextraction implant or not |
| 80 patients    | 80 implants    | MBL in mm       | (does not specify program used) | Intraoral Rx with parallelizer (parallel technique) | WaterScion Imagent (WaterScion, Frederick, MD, USA) software | Implant type        | Implant design          | Implant length             | Implant diameter              | Implant location | Bone regeneration or not | Implant length | Implant diameter | Prosthetic rehabilitation or screw-retained or not | Postextraction implant or not |
| 16 patients    | 21 implants    | MBL in mm       | (does not specify program used) | Intraoral Rx with parallelizer (parallel technique) | WaterScion Imagent (WaterScion, Frederick, MD, USA) software | Implant type        | Implant design          | Implant length             | Implant diameter              | Implant location | Bone regeneration or not | Implant length | Implant diameter | Prosthetic rehabilitation or screw-retained or not | Postextraction implant or not |

Felice et al., 2014

A comparison of two dental implant systems in partially edentulous patients: 1-year post-loading results from a pragmatic multicentre randomised controlled trial. Eur J Oral Implantol. 2014 Winter;7(4):397-409.

Clinical trial
64 patients
144 implants
MBL in mm measured with Scion Imagent (Scion Corporation, Frederick, MD, USA) software
Intraoral Rx with parallelizer (parallel technique)
Implant type
Implant design
Type of implant
Bone quality
Implant length
Implant diameter
Implant location
Bone regeneration or not
Surgical technique with or without flap
Prosthetic rehabilitation or screw-retained or not
Implant location
Bone regeneration or not
Implant length
Implant diameter
Prosthetic rehabilitation or screw-retained or not
Postextraction implant or not

Vigolo et al., 2012

Cemented versus screw-retained implant-supported single-tooth crowns: a 10-year randomized clinical trial. Eur Oral Implantol. 2012 Winter;5(4):355-64.

Clinical trial
18 patients
36 implants
MBL in mm measured with Scion Imagent (Scion Corporation, Frederick, MD, USA) software
Intraoral Rx with parallelizer (parallel technique)
Implant type
Implant design
Type of implant
Bone quality
Implant length
Implant diameter
Implant location
Bone regeneration or not
Surgical technique with or without flap
Prosthetic rehabilitation or screw-retained or not
Implant location
Bone regeneration or not
Implant length
Implant diameter
Prosthetic rehabilitation or screw-retained or not
Postextraction implant or not

Esposito et al., 2017

Do repeated changes of abutments have any influence on the stability of peri-implant tissues? One-year post-loading results from a multicentre randomised controlled trial. Int J Oral Maxillofac Implants. 2017 May-Jun;28(3):807-14.

Clinical trial
80 patients
80 implants
MBL in mm measured with Scion Imagent (Scion Corporation, Frederick, MD, USA) software
Intraoral Rx with parallelizer (parallel technique)
Implant type
Implant design
Type of implant
Bone quality
Implant length
Implant diameter
Implant location
Bone regeneration or not
Surgical technique with or without flap
Prosthetic rehabilitation or screw-retained or not
Implant location (PM or M)
Definitive implant abutment vs. healing abutment
Prosthetic rehabilitation or screw-retained or not
Postextraction implant or not

Koutouzis et al., 2013

The effect of healing abutment reconnection and disconnection on soft and hard peri-implant tissues: a short-term randomized controlled clinical trial. Int J Oral Maxillofac Implants. 2013 May-Jun;28(3):807-14.

Clinical trial
16 patients
21 implants
MBL in mm measured with ImageJ, version 1.39F (U.S. National Institutes of Health)
Intraoral Rx with parallelizer (parallel technique)
Implant type
Implant design
Type of implant
Bone quality
Implant length
Implant diameter
Implant location
Bone regeneration or not
Surgical technique with or without flap
Prosthetic rehabilitation or screw-retained or not
Implant location (PM or M)
Definitive implant abutment vs. healing abutment
Prosthetic rehabilitation or screw-retained or not
Postextraction implant or not

Marginal bone level changes were not statistically significant different for Way Milano compared to Kentron implants at 4 months (−0.16 mm, 95% CI −0.30, 0.01; P = 0.0606) and at 1 year (−0.09 mm, 95% CI −0.26, 0.09; P = 0.3407) after loading.

There was no evidence of a significant difference in the clinical behavior of the peri-implant marginal bone of the definitive abutment group and 0.23 (0.49) mm for the repeated abutment changes group (difference = −0.66, 95% CI 0.33, −0.99; P = 0.046).

The mean peri-implant MBL at 1 year after loading was 0.06 (0.12) mm for the definitive abutment group and 0.23 (0.49) mm for the repeated abutment changes group (difference = −0.66, 95% CI 0.33, −0.99; P = 0.046).

Two disconnection and two reconnection of the abutment did not cause negative dimensional changes in the peri-implant mucosa.
### Marginal bone loss analysis

| Reference | Study Description | Study Design | Patients | Implants | MBL Measurement | Implant Length | Implant Diameter | Implant Location | Implant Material | MBL Outcome | Implant Stability | Implant Stability Outcome |
|-----------|-------------------|--------------|----------|----------|----------------|---------------|-----------------|-----------------|-----------------|--------------|------------------|-----------------------------|
| Ter-Gunne et al. 2016 | Immediate and Early Loading of Two-Implant-Supported Mandibular Overdentures: Three-Year Report of Loading Results of a Single-Center Prospective Randomized Controlled Clinical Trial. Int J Oral Maxillofac Implants. 2016 Sep-Oct;31(5):1110-6. | Clinical trial | 40 patients | 40 implants | MBL in mm measured with ImageJ software (v1.47, National Institutes of Health) | Implant length | Implant diameter | Implant location | Implant material (zirconia vs. titanium) | MBL in mm measured with ImageJ software (v1.47, National Institutes of Health) | The mean radiographic MBL between the baseline and the 3-year follow-ups was 0.35 ± 0.63 mm for immediately loaded implants and 0.51 ± 0.96 mm for early loaded implants. The difference between the two groups was not statistically significant (p = .26). |
| Borgonovo et al. 2012 | Multiple tooth replacement with endosseous one-piece yttria-stabilized zirconia dental implants. Med Oral Patol Oral Cir Bucal. 2012 Nov 1;17(6):e981-7. | Retrospective | 8 patients | 29 implants | MBL in mm measured with software program (CorelDraw 10; Corel Corp and Coral Ltd, Ottawa, Canada) | Implant length | Implant diameter | Implant location | Implant material (zirconia vs. titanium) | MBL in mm measured with software program (CorelDraw 10; Corel Corp and Coral Ltd, Ottawa, Canada) | Radiographic measurements of MBL did not exceed 1.6 mm during the first year of loading, and further MBL was minimal and not significant 1 to 4 years after surgery. No implant was lost during the study period. The MBL of the fixture and the abutment, as zirconia dental implants are one-piece implants. Moreover, zirconia is characterized by high biocompatibility and accumulates significantly fewer bacteria than titanium. |
| Patil et al. 2014 | Comparison of two different abutment designs on marginal bone loss and soft tissue development. Int J Oral Maxillofac Implants. 2014 May-Jun;29(3):675-81. | Prospective | 26 patients | 52 implants | MBL in mm (does not specify program used) | Implant locations | Implant length | Implant diameter | Implant abutment (conventional vs. circumferential curved) | MBL in mm (does not specify program used) | A titanium abutment with a circumferential curved design did not have a benefit to soft tissue development or to the prevention of soft tissue recession. The findings suggested that implants inserted with high IT (≥50 Ncm) in healed bone ridges showed more peri-implant bone remodeling and less soft tissue recession than implants inserted with a regular IT (50 Ncm) (p < 0.001). |
| Pohl et al. 2017 | Short dental implants (6 mm) versus long dental implants (11-15 mm) in combination with sinus floor elevation procedures: 3-year results from a multicenter, randomized controlled clinical trial. J Clin Periodontol. 2017 Apr;44(4):438-445. | Clinical trial | 101 patients | 137 implants | MBL in mm (does not specify program used) | Implant stability | Implant length | Regeneration (maxillary sinus lift or not) | Implant location | MBL in mm (does not specify program used) | Implant stability | Implant stability (inserted vs. non-inserted) | Implant stability (inserted vs. non-inserted) |
| Barone et al. 2016 | The Effect of Impression Technique on the Clinical Outcome of Single Implants: A Randomized Clinical Trial. Clin Implant Dent Relat Res. 2016 Jun;18(3):S88-S96. | Clinical trial | 16 patients | 116 implants | MBL in mm (does not specify program used) | Implant abutment (conventional vs. circumferential curved) | Implant length | Regeneration (maxillary sinus lift or not) | Implant location | MBL in mm (does not specify program used) | Implant abutment (conventional vs. circumferential curved) | The findings suggested that implants inserted with high IT (≥50 Ncm) in healed bone ridges showed more peri-implant bone remodeling and less soft tissue recession than implants inserted with a regular IT (50 Ncm) (p < 0.001). |
Table 1 continue-9: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study                        | Title                                                                 | Study Design | Number of Patients | Number of Implants | MBL Measurement | Implant Quality | Bone Quality | From Surgery to 36 Months, Mean Bone Loss (± Standard Deviation) |
|------------------------------|-----------------------------------------------------------------------|--------------|--------------------|--------------------|----------------|----------------|--------------|-----------------------------------------------------------------|
| Rocha et al. 2016            | Effect of platform-switching on crestal bone levels around implants in the posterior mandible: 3 years results from a multicentre randomized clinical trial. J Clin Periodontol. 2016 Apr;43(4):374-82 | Clinical trial | 63 patients        | 135 implants       | MBL in mm measured with ImageJ 1.44 | MBLO Implant platform design | Bone quality | From surgery to 36 months, the mean bone loss was 0.28 ± 0.56 mm for the platform-switching group and 0.68 ± 0.64 mm for the platform-matching group. A statistically significant difference was found between groups (p = 0.002) with an estimate of 0.39 mm (0.15-0.64, 95% CI) in favor of platform-switching. |
| Hadzik et al. 2018           | The Influence of the Crown-Implant Ratio on the Crestal Bone Level and Implant Secondary Stability: A 36-Month Clinical Study. Biomed Res Int. 2018 May 16:2018:4246874. | Clinical trial | 30 patients        | 30 implants        | MBL in mm (does not specify program used) | MBL Implant length | MBL Implant length | The MBL was low for short and conventional implants at 0.34 ± 0.24 mm and 0.22 ± 0.46 mm, respectively. No significant correlation was found between the C/I ratio and secondary stability or between the C/I ratio and the MBL. |
| Canullo et al. 2010          | Platform-switching and marginal bone-level alterations: the results of a randomized-controlled trial. Clin Oral Implants Res. 2010 Jan;21(1):115-21 | Clinical trial | 31 patients        | 80 implants        | MBL in mm measured with Autocad 2006, version Z 54.10, Autodesk, San Rafael, CA, USA | MBL Implant length | Bone quality | A radiographic evaluation showed a mean bone loss of 0.99 mm (SD = 0.42 mm) for the 4.3 mm platform diameter, 0.82 mm (SD = 0.36 mm) for the 4.8 mm platform diameter and 0.56 mm (SD = 0.31 mm) for the 5.5 mm platform diameter. These values were statistically significantly lower (P < 0.005) than the control platform diameter of 3.8 mm (1.49 mm, SD = 0.54 mm). Marginal bone level alterations could relate to the extent of implant and abutment mismatching. The marginal bone levels were better maintained at implants restored according to the platform-switching concept. |
| Moergel et al. 2016          | Radiographic evaluation of conical tapered platform-switched implants in the posterior mandible: 1-year results of a two-center prospective study. Clin Oral Implants Res. 2016 Jun;27(6):686-93. | Prospective   | 24 patients        | 52 implants        | MBL in mm measured with ImageJ | MBL Implant connection | From surgery to 36 months, the mean bone loss was 0.28 ± 0.56 mm for the platform-switching group and 0.68 ± 0.64 mm for the platform-matching group. A statistically significant difference was found between groups (p = 0.002) with an estimate of 0.39 mm (0.15-0.64, 95% CI) in favor of platform-switching. |

MBL = Marginal Bone Loss, C/I = Crown-Implant Ratio.
### Table 1 continue-10: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant. | Becker et al. 2013 | Cochran et al. 2009 | Ryu et al. 2016 | Mumcu et al. 2012 |
|---|---|---|---|---|
| Prospective clinical trial evaluating a new implant system for implant survival, implant stability and radiographic bone changes. Clin Implant Dent Relat Res. 2013 Feb;15(1):15-21. | Clinical trial | Prospective | Clinical trial | Clinical trial |
| 66 patients | 192 patients | 30 patients | 48 patients |
| 10 implants | 596 implants | 60 implants | 96 implants |
| MBL in mm measured with ImageJ | MBL in mm (does not specify program used) | MBL in mm (does not specify program used) | MBL in mm measured with software program CorelDraw 11.0 (Corel Corporation and Coral Ltd., Ottawa, Canada) |
| Intraoral Rx with parallelizer (parallel technique) | Intraoral Rx with parallelizer (parallel technique) | Intraoral Rx with parallelizer (parallel technique) | OPG |
| Implant diameter | Implant size | Type of implant | Healing period (implant submerged or not) |
| Implant location | Bone quality | Implant design (solid screw or hollow cylinder) | MBL of the implants at 6 months was found to be significantly higher in the submerged healing group (P < 0.05). No statistically significant relation was found between the MBL of implants left to submerged healing and that of implants left to non-submerged healing in the other follow-up periods. |
| Implant stability | Prosthetic restoration (single or multiple) | Implant stability (insertion torque) | |
| Between examinations, there was an average -0.6 mm of bone loss, which was statistically significant (p = 0.03). On average, 4.0-mm-wide implants lost 0.1 mm of bone when compared with 5-mm-wide implants. These differences were insignificant (p = 0.86). Bone loss was adjusted for implant length, and tooth position and there were small, but clinically insignificant changes. Five-millimeter-wide implants lose 0.2 mm more than 4.0-mm-wide implants (p = 0.7). Maxillary incisors lose the least amount of bone at 0.152 mm (p = 0.33). |
| Clinically significant marginal bone remodeling occurred between the implant placement and the final prosthesis placement around one-stage non-submerged titanium implants with a titanium plasma-sprayed surface. Subsequent to that, bone loss observed around implants up to 5 years postloading was minimal. |
| Both groups exhibited no stability dip during the early phase of healing. The average MBL from the baseline of implant placement for the control and experimental groups was 0.38 and 0.45 mm after 4 weeks and 0.98 and 0.61 mm after 13 months, respectively. |
Table 1: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study                  | Research / Description                                                                 | Clinical / Implant Details                                                                 | Radiographic Method                | Implant Details                                                                 | Results                                                                 |
|------------------------|----------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Palaska et al. 2016    | Influence of placement depth and abutment connection pattern on bone remodeling around 1-stage implants: a prospective randomized controlled clinical trial. Clin Oral Implants Res. 2016 Feb;27(2):e47-56. | Clinical trial 81 patients 105 implants MBL in mm measured with DSR (Vix Win; Gendex Dental System) | Intraoral Rx with parallelizer (parallel technique) | Implant location (crestal vs. subcrestal) (M, PM) Implant connection (Morse type or not) | The mean (± SE) peri-implant bone loss was recorded as follows. Group 1 (sub-crestal, screwed tapered internal connection): 0.68 ± 0.07 mm; Group 2 (crestal, screwed and tapered internal connection): 0.79 ± 0.06 mm; Group 3 (sub-crestal internal conical seal connection): 0.49 ± 0.06 mm; and Group 4 (crestal, internal conical seal connection): 0.40 ± 0.07 mm. The statistical analysis revealed significant differences in bone resorption between groups with different abutment connections. |
| Veis et al. 2010       | Evaluation of peri-implant marginal bone loss using modified abutment connections at various crestal level placements. Int J Periodontics Restorative Dent. 2010 Dec;30(6):609-17. | Prospective 282 implants MBL in mm measured with AxioVision 4.6.3, Carl Zeiss | Does not specify the radiographic method used | Implant location (crestal, sub and supracrestal) Implant platform design | Statistically significant differences were found between subgroups in both straight and platform-switched categories. The only non-statistically significant difference (P = .341) arose when comparing the supracrestal and subcrestal locations in the straight abutment connection group. The platform-switched group exhibited significantly less bone loss (P = .046) only in subcrestal locations. The platform-switched concept was not beneficial during the overall comparison, but it was for the subcrestal location of the abutment connection. The crestal placement of the implant-abutment connection raised the marginal bone resorption in straight and platform-switched abutments. |
| Study | Year | Design | Patients | Implants | MBL in mm | Method of measurement | Results |
|-------|------|--------|----------|----------|-----------|----------------------|---------|
| Cehreli | 2010 | Retrospective | 46 | 105 | Measured with IMAGEJ 1.32j, NIH, Bethesda, MD, USA | Postextraction implants or not, Provisional prosthesis or not | MBL in the early-placed group (Group 1) was higher than in the conventionally placed group (Group 2). The percentage of bone loss was 0.07% in Group 1 and 0.02% in Group 2. The use of a provisional prosthesis did not increase the MBL in Group 1, but it led to a higher MBL in Group 2. The percentage of bone loss in Group 2 (P = 0.007; odds ratio = 11.5). The differences between the groups were significant for both sides in Group 1 (P < 0.05) and the mesial side in Group 2. The percentage of nonexposed implants in Group 1 was higher than in Group 2 (P = 0.007, odds ratio = 7). Group 1 implants had an 11.5 times greater plaque index score of 0 than those in Group 2 (P = 0.007; odds ratio = 11.5). The differences between the groups were significant for both sides in Group 2 and the mesial side in Group 2. |
| Tealdo | 2014 | Prospective | 49 | 260 | Intraoral Rx with parallelizer (parallel technique) | Moment of implant loading (immediate or deferred) | Significantly less bone loss occurred in the immediately loaded implants (mean: 1.62 mm) compared with the control delayed implants (mean: 2.44 mm). Over the study’s 6-year follow-up period, the differences were significant. |
| Karabuda | 2011 | Prospective | 22 | 96 | Measured with software (Diagora for Windows, Sorex, Tuusula, Finland) | Implant surface (SLA or modified sandblasting and acid) | At the loading stage, modSLA implants showed significantly lower MBL (0.18 ± 0.06 mm; P < 0.002) than SLA implants (0.22 ± 0.06 mm). The RFA value of the modSLA implant (60.42 ± 6.82) was significantly higher than that of both implant types in the surgical stage (55.48 ± 8.29 and 56.66 ± 8.19 for SLA and modSLA implants, respectively). |
| Tallarico | 2016 | Prospective | 40 | 98 | Intraoral Rx with parallelizer (parallel technique) | MBL after bisphosphonate intake | Oral bisphosphonate therapy did not appear to significantly affect implant survival and success in cases with an accurate treatment time selection, minimally invasive surgical approach and constant follow-up. |
| Authors               | Year       | Study Design    | Number of Patients | Number of Implants | MBL Measurement Method | MBL Measurement Software/Program | Implant Location | Implant Stability | Implant Connection | Implant Length | Implant Diameter | Bone Density | Surgical Technique | Results/Conclusion                                                                                                                                                                                                                                                                                                                                 |
|----------------------|------------|-----------------|--------------------|--------------------|------------------------|---------------------------------|-----------------|------------------|-------------------|----------------|-----------------|--------------|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Felice et al.        | 2016       | Clinical trial  | 159 patients       | 240 implants       | MBL in mm measured with OsiriX software (Pixmeo Sarl, Bernex, Switzerland) | Intraoral Rx with parallelizer (parallel technique) | One-year post-loading | One-year post-loading | Short and long implants | No statistically significant difference in bone level changes between short and long implants occurred for 1 year (mean difference = 0.038 mm; 95% CI: −0.068 to 0.138; P = 0.198).                                                                                               |
| Lee et al.           | 2016       | Retrospective   | 14 patients        | 18 implants        | MBL in mm (does not specify program used) | Intraoral Rx with parallelizer (parallel technique) | One-year post-loading | One-year post-loading | Short and long implants | No statistically significant differences in bone level changes between short and long implants occurred for 1 year (mean difference = −0.001 mm; 95% CI: −0.03 to 0.029; P = 0.873). |
| Vercruyssen et al.   | 2014       | Clinical trial  | 59 patients        | 314 implants       | MBL in mm measured with the ImageJ software (National Institutes of Health) | Intraoral Rx with parallelizer (parallel technique) | One-year post-loading | One-year post-loading | Coronal and vertical | No statistically significant differences in bone level changes between different implants (CSS vs. conventional) occurred for 1 year (mean difference = 0.023 mm; 95% CI: −0.042 to 0.087; P = 0.464). |
| Esposito et al.      | 2015       | Clinical trial  | 200 patients       | 327 implants       | MBL in mm measured with UTHSCSA Image Tool 3.0 software (The University of Texas Health Science Center, Texas, USA) | Intraoral Rx with parallelizer (parallel technique) | One-year post-loading | One-year post-loading | External vs. internal | No statistically significant differences in bone level changes between different implants (CSS vs. conventional) occurred for 1 year (mean difference = −0.006 mm; 95% CI: −0.03 to 0.018; P = 0.407). |
| Jung et al.          | 2016       | Clinical trial  | 60 patients        | 71 implants        | MBL in mm (does not specify program used) | Intraoral Rx with parallelizer (parallel technique) | One-year post-loading | One-year post-loading | Maxilla or mandible | No statistically significant differences in bone level changes between different implants (CSS vs. conventional) occurred for 1 year (mean difference = −0.03 mm; 95% CI: −0.06 to 0.01; P = 0.156). |

Marginal bone loss analysis
Table 1 continue-14: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Studies included after the research “marginal bone loss and peri-implantitis” | Marginal bone loss and dental implant. |
|---|---|
| Nickenig et al. 2013 | A 5-year prospective radiographic evaluation of marginal bone levels adjacent to parallel-screw cylinder machined-neck implants and rough-surfaced microthreaded implants using digitized panoramic radiographs. J Craniomaxillofac Surg. 2013 Oct;41(7):564-8. | Prospective | 34 patients | MBL in mm measured with Fricomat Dental Office Software 2.4, Friatec AG, Mannheim, Germany | OPG | Implant surface (rugged microtreated, machined neck) | The machined-neck group had a mean crestal bone loss of 0.5 mm (0.0–2.3) after the healing period, 1.1 mm (0.0–3.0) at the 2-year follow-up and 1.4 mm (0.0–2.9) at the 5-year follow-up. The rough-surfaced microthreaded implant group had a mean bone loss of 0.1 mm (−0.4 to 2.0) after the healing period, 0.5 mm (0.0 to 2.1) at the 2-year follow-up, and 0.7 mm (0.0 to 2.3) at the 5-year follow-up. The two implant types showed significant differences in marginal bone levels. |
| Cehreli et al. 2010 | Marginal bone level changes and prosthetic maintenance of mandibule overdentures supported by 2 implants: a 5-year randomized clinical trial. Clin Implant Dent Relat Res. 2010 Jun 1;12(2):114-21. | Clinical trial | 28 patients | MBL in mm measured with ImageJ 1.32j, NIH, USA | Introral Rx with parallelizer (parallel technique) | Type of implant (Brämark vs. Straumann) | The MBL around Brämark implants (1.21 ± 0.1) was higher than around Straumann implants (0.73 ± 0.06) after 5 years of functioning (p = .002). |
| Crespi et al. 2014 | Immediate occlusal loading of full-arch rehabilitations: screw-retained versus cement-retained prosthesis. An 8-year clinical evaluation Int J Oral Maxillofac Implants. 2014 Nov-Dec;29(6):1406-11. | Prospective | 28 patients | MBL in mm measured with software (Schick Technologies) | Introral Rx with parallelizer (parallel technique) | Prosthetic rehabilitation (cemented or screwed) | Within 1 year after implant placement, bone loss was recorded as follows: the cement-retained group (CRG) showed mean bone levels of −1.23 ± 0.45 mm, and the screw-retained group (SRG) showed mean bone levels of −1.01 ± 0.33 mm. A slight increase appeared after a 3-year follow-up (0.30 ± 0.25 mm in CRG and 0.45 ± 0.29 mm in SRG). After that, marginal bone levels remained over time up to the 8-year follow-up. No statistically significant differences were found between groups (P > .05). Definitive cement- and screw-retained ceramic restorations are highly predictable, biocompatible and esthetically pleasing, and the two groups presented no statistically significant differences in bone loss. |
| Simunek et al. 2010 | Changes in stability after healing of immediately loaded dental implants. Int J Oral Maxillofac Implants. 2010 Nov-Dec;25(6):1085-92. | Prospective | 188 patients | MBL in mm (does not specify program used) | OPG | Moment of implant loading (immediate or deferred) | Correlations between the MBL and the final insertion torque and between the MBL and the DISQ values were observed. | 184 implants | }
Table 1 continue-15: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study                        | Clinical type | Patients | Implants | MBL measured with | Intraoral Rx with parallelizer (parallel technique) | Implant location (I, C, PM, M) | Implant diameter Prosthetic rehabilitation (cemented or screwed) | Implant design | Bone regeneration or not | Bone regeneration or not | Marginal peri-implant hard-tissue loss |
|------------------------------|---------------|----------|----------|-------------------|-----------------------------------------------------|--------------------------|-----------------------------------------------------------------|----------------|--------------------------|--------------------------|---------------------------------------|
| den Hartog et al. 2017       | Clinical trial| 93 patients | 93 implants | MBL in mm measured with Adobe Photoshop (Adobe Photoshop CS3 Extended, Adobe Systems Inc., San Jose, California). | Intraoral Rx with parallelizer (parallel technique) | Implant location (I, C, PM, M) | Implant diameter Prosthetic rehabilitation (cemented or screwed) | Implant design | No statistically significant differences were found between implants with a 1.5 mm smooth neck (“smooth group”), a rough neck with grooves (“rough group”) or a scalloped rough neck with grooves (“scallop group”). |
| Sayardoust et al. 2017       | Clinical trial| 32 patients | 92 implants | MBL in mm (does not specify program used) with a magnification x7 | Intraoral Rx with parallelizer (parallel technique) | Smoking habit | Bone quality and quantity Type of implant | Implant location (maxilar, mandible) | Smoking has an early effect on osseointegration, which is dependent on the implant surface properties and the local host response. |
| Pessoa et al. 2017           | Clinical trial| 12 patients | 24 implants | MBL in mm measured with Image J, National Institutes of Health, Bethesda, MD, USA | Intraoral Rx with parallelizer (parallel technique) | Implant connection (external hexagonal or internal Morse) | Gingival biotype Probing depth | Implant connection (external hexagonal or internal Morse) | Radiographic peri-implant bone loss depends on the implant connection type. Morse-taper connections showed less peri-implant bone loss compared to external hexagon connections, but no statistically significant differences were found. |
| Lee et al. 2010              | Prospective   | 54 patients | 135 implants | MBL in mm measured with UTHSCSA Image Too | Intraoral Rx with parallelizer (parallel technique) | Implant location (maxilar or mandible) | Implant system | Significant differences were noted in the MBL recorded for the three groups: rough-surface implants, a hybrid of smooth and rough-surface implants and rough surface with microthread implants (P < 0.0001). At 3 years, the rough surface with microthread implants had a mean crestal bone loss of 0.59 ± 0.30 mm; the rough-surface implants, 0.95 ± 0.27 mm and the hybrid surface implants, 1.05 ± 0.34 mm. |
| Koutouzis et al. 2011        | Retrospective | 100 patients | 287 implants | MBL in mm measured with DEXIS, Des Plaines, IL. | Intraoral Rx with parallelizer (parallel technique) | Bone regeneration or not | Implant location (maxilar or mandible) | Bone regeneration or not | There were no statistically significant differences between the subcrestally placed dental implants grafted with a xenograft and the subcrestally placed dental implants without any grafting material. They were reviewed regarding marginal peri-implant hard-tissue loss. |
Table 1 continue-16: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study | Design | Patients | Implant Type | Marginal Bone Level | Implant Length | Bone Quality | Prosthetic Rehabilitation | Topical Bisphosphonate | Oral Health Indicators |
|-------|--------|----------|--------------|---------------------|----------------|-------------|--------------------------|-----------------------|-----------------------|
| Nickenig et al. 2009 | Radiographic evaluation of marginal bone levels adjacent to parallel-screw cylinder machined-neck implants and rough-surfaced microthreaded implants using digitized panoramic radiographs. Clin Oral Implants Res. 2009 Jun;20(6):550-4 | Prospective | 34 patients | MBL in mm measured with Friacom Dental Office Software 2.4, Fria-tec AG, Mannheim, Germany | OPG | Implant design | The machined-neck group had a mean crestal bone loss of 0.5 mm (range: 0 to 2.3) after the healing period, 0.8 mm after 6 months (range: 0 to 2.4) and 1.1 mm (range: 0 to 3) at the end of the follow-up. The rough-surfaced microthreaded implant group had a mean bone loss of 0.1 mm (range: −0.4 to 2) after the healing period, 0.4 mm (range: 0 to 2.1) after 6 months and 0.5 mm (range: 0 to 2.1) at the end of the follow-up. The two implant types showed significant differences in marginal bone levels (healing period: P = 0.01; end of follow-up: P < 0.01). |
| Vigolo et al. 2010 | Clinical evaluation of marginal bone level change of multiple adjacent implants restored with splinted and non-splinted restorations: a 5-year prospective study. Int J Oral Maxillofac Implants. 2010 Nov-Dec;25(6):1189-94. | Prospective | 44 patients | MBL in mm (does not specify program used) with a magnification x6 | Intraoral Rx with parallelizer (parallel technique) | Implant length | Bone quality | Prosthetic rehabilitation (splinted or not) | The mean marginal bone level changes at the 5-year recall were −0.7 ± 0.2 mm for splinted restorations and −0.8 ± 0.2 mm for non-splinted restorations. The peri-implant MBL around non-splinted implants in the present study was statistically equivalent to that observed in splinted implants. |
| Barone et al. 2012 | A randomized clinical trial to evaluate and compare implants placed in augmented versus non-augmented extraction sockets: 3-year results. J Periodontol. 2012 Jul;83(7):836-46. | Clinical trial | 40 patients | MBL in mm measured with UTHSCSA Image Tool, v.3.0, University of Texas Health Science Center, San Antonio, TX | Intraoral Rx with parallelizer (parallel technique) | Implant length | Implant diameter | Postextraction implants with regeneration or not | No statistical differences were found between the grafted extraction sockets compared to implants placed into non-grafted sites in terms of implant survival and MBL. |
| Sakka et al. 2013 | Investigation of the effect of ibuprofen on the healing of osseointegrated oral implants. J Investig Clin Dent. 2013 May;4(2):113-9 | Clinical trial | 28 patients | MBL in mm manually measured with magnification x8 | Intraoral Rx with parallelizer (parallel technique) | Ibuprofen intake or not after surgery | | There were no significant differences between the ibuprofen and no-ibuprofen groups when comparing bone changes. |
| Zuffetti et al. 2015 | The topical administration of bisphosphonates in implant surgery: a randomized split-mouth prospective study with a follow-up up to 5 years. Clin Implant Dent Relat Res. 2015 Jan;17 Suppl 1:e168-76. | Prospective | 39 patients | MBL in mm measured with ImageJ version 1.46, National Institutes of Health, Bethesda, MD, USA; | Intraoral Rx with parallelizer (parallel technique) | Topical bisphosphonate during surgery or not | Implant length | Type of edentulism (total or partial) | The mean MBL was 0.85±0.71 mm in the TG (a 3% clodronate solution mixed with the surfactant Tween-20 at a 1:3 ratio topically administered at the implant surface and at the implant site) and 1.12±0.85 mm in the CG (a conventional insertion) after 1 year of loading and was stable thereafter. The difference was not significant. |
### Table 1 continue-17: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study Reference     | Interventions                                                                 | Study Design | Sample Size | Measurement Methodology | Implant Location | Bone Loss Filter | Prosthetic Rehabilitation | Other Notes |
|---------------------|-------------------------------------------------------------------------------|--------------|-------------|----------------------------|------------------|------------------|--------------------------|-------------|
| Alissa et al. 2009  | Influence of ibuprofen on bone healing around dental implants: a randomised double-blind placebo-controlled clinical study. Eur J Oral Implantol. 2009 Autumn;2(3):185-99. | Clinical trial | 61 patients 132 implants | MBL in mm manual measured magnification; MAG 6, Pyser-SGI, Kent, UK | Intraoral Rx with parallelizer (parallel technique) | Ibuprofen intake or not after surgery | Implant location (maxillary vs. mandible) | For the mean marginal bone level changes at 3 months (P = 0.27) and at 6 months (P = 0.97), there were no statistically significant differences between a short course of systemic ibuprofen for post-operative pain management subsequent to implant placement and a placebo. |
| Lago et al. 2018    | Crestal Bone Level Around Tissue-Level Implants Restored with Platform Matching and Bone-Level Implants Restored with Platform-switching: A 5-Year Randomized Controlled Trial. Int J Oral Maxillofac Implants. 2018 Mar/Apr;33(2):448-456. | Clinical trial | 100 patients 202 implants | MBL in mm measured with ImageJ (Wayne Rasband, National Institutes of Health) | Intraoral Rx with parallelizer (parallel technique) | Type of implants (tissue level vs. bone level) | Implant length | The mean difference between the tissue-level implants restored with platform matching and the bone-level implants restored with platform-switching was 0.31 mm at the baseline to 1 year, 0.53 mm at 1 to 5 years and 0.85 mm at the baseline to 5 years. There was a statistically significant difference in the MBL (P < .001). |
| Derks et al. 2016   | Peri-implantitis - onset and pattern of progression. J Clin Periodontol. 2016 Apr;43(4):383-8 | Retrospective | 427 patients 596 implants | MBL in mm (does not specify program used) | Does not specify the radiographic method used | Progression pattern of peri-implantitis in implants with moderate to severe peri-implantitis from 1 to 9 years | | A total of 70% and 81% of subjects presented with ≥ 1 implant with a bone loss of > 0.5 mm at 2 and 3 years, respectively. Peri-implantitis progresses in a non-linear, accelerating pattern and, for the majority of cases, the onset occurs within 3 years of functioning (p < 0.0001). |
| Esposito et al. 2016| Dental implants with internal versus external connections: 5-year post-loading results from a pragmatic multicenter randomised controlled trial. Eur J Oral Implantol. 2016;9 Suppl 1(2):129-41. | Clinical trial | 120 patients 203 implants | MBL in mm (does not specify program used) | Intraoral Rx (parallel technique) | Implant connection | MBL | Five years after loading, there were no statistically significant differences in marginal bone level estimates between the internal and external connections (difference = 0.14 mm, 95% CI: −0.28 to 0.56, P (ancova) = 0.505), and both groups had statistically significant bone loss from implant placement: 1.13 mm for the external connection implants and 1.21 mm for the internal connection implants. |
| Gamper et al. 2017  | Randomized controlled clinical trial comparing one-piece and two-piece dental implants supporting fixed and removable dental prostheses: 4- to 6-year observations. Clin Oral Implants Res. 2017 Dec;28(12):1553-1559. doi: 10.1111/cor.13025. Epub 2017 May 29. | Clinical trial | 60 patients 151 implants | MBL in mm measured with ImageJ, National Institutes of Health, Bethesda, Maryland USA | Intraoral Rx (parallel technique) | Implant design (implant and abutment one piece or not) Bone regeneration or not Prosthetic rehabilitation | | The median marginal bone level for the one-piece implant system group changed from 0.51 mm at the baseline to 0.47 mm. The two-piece implant system changed from 1.02 mm to 1.35 mm (P < 0.001) from the 4- to 6-year follow-up. |
Table 1 continue-18: Studies included after the research “marginal bone loss and peri-implantitis” and marginal bone loss and dental implant.

| Study Reference | Study Design | Sample Size | Methodology | Data Collection | Outcomes |
|-----------------|--------------|-------------|-------------|----------------|----------|
| Sahrmann et al. 2016 | Clinical trial | 172 implants | MBL in mm measured with ImageJ (ImageJ64; National Institutes of Health, Bethesda, MD, USA) | Intraoral Rx (parallel technique) | Implant length | We found no significant change in the crestal bone level from the baseline to 3 years for 6-mm or 10-mm implants. The changes were $-0.19 \pm 0.62$ mm and $-0.33 \pm 0.71$ mm, respectively. The intergroup difference was not significant. |
| Küstan et al. 2015 | Clinical trial | 28 patients 56 implants | MBL in mm (does not specify program used) | Intraoral Rx (parallel technique) | Implant location (crestal or subcrestal) | After 3 years, the mean radiographic vertical bone loss for the control bone-level group was significantly lower than in the below bone-level group ($0.56 \pm 0.35$ mm and $1.21 \pm 1.05$ mm, respectively) ($p < .01$). |
| Guljé et al. 2014 | Clinical trial | 41 patients 41 implants | MBL in mm measured with DicomWorks, Biomedical Engineering, University Medical Center Groningen, the Netherlands | Intraoral Rx (parallel technique) | Implant length Bone regeneration (maxillary sinus lift or not) | No statistical differences were found between 6-mm implants and 11-mm implants combined with sinus floor elevation surgery to support a single crown in the resorbed posterior maxilla after a 1-year follow-up. |
| Ravald et al. 2013 | Clinical trial | 66 patients 184 implants | MBL in mm (does not specify program used) | Intraoral Rx (parallel technique) | Implant location (maxilla or mandible) Implant design Moment of implant loading (immediate or deferred) | No statistically significant difference in implant loss or bone level change was found between Astra Tech TiOblast surfaces and Bränemark-turned implants. |
| Gottfredsen et al. 2012 | Clinical trial | 20 patients 20 implants | MBL in mm was changed to Digora digital film (The Dental Imaging Company Ltd, Portslade, East Sussex, UK) | Intraoral Rx (parallel technique) | MBL | The average marginal bone-level change was less than 1 mm, and there was no difference between early and delayed implant placement. |
Marginal bone loss analysis

Temmerman et al. 2017 (27) focused their study on postmenopausal women with osteoporosis/osteopenia, showing an MBL around implants of 0.01 ± 0.51 mm (Control Group [CG]: 0.05 ± 0.52 mm); the mean MBL from a subject was of 0.04 ± 0.27 mm (Osteoporosis/Osteopenia Group: -0.17 ± 0.30 mm, CG: 0.04 ± 0.23 mm). They concluded that rehabilitation using implants in patients with osteoporosis can be carried out with the same success rate as in healthy patients.

The stability analysis of dental implants can also be conditioned due to certain drugs that treat the patient’s underlying pathology and that alter bone remodeling immunity (28). Bisphosphonates are one such drug family that has been studied due to their ability to inhibit normal bone resorption, which entails a reduction in remodeling, for a higher bone density, better mineralization and a lower risk of bone fracture (29). Tallarico et al. 2016 (26) found that patients who were previously under bisphosphate treatment had a 98.98% overall implant survival success rate and 100% prosthesis success rate. The mean MBL was 1.35 ± 0.21 mm (95% CI 1.24-1.38) at 3 years. Zuffetti et al. 2015 (30) obtained 100% survival rates in the implants for the experimental group; the implants for this group were topically rinsed with bisphosphate before surgery implantation. The CG, on the other hand, had a 91.3% success rate; in this group, the implants were placed without applying the topical bisphosphonate rinse, and a significant difference was observed at 5 years (p < 0.01). The average MBL observed was 0.85 ± 0.71 mm in the experimental group and 1.12 ± 0.85 mm in the CG after one year of prosthetic loading; it then remained stable with no statistically significant differences. Thus, some authors suggested that implants coated with bisphosphonates allow the prolonged conservation of marginal bone. These authors observed that the implants coated with bisphosphonates show even less marginal bone resorption than the CG not coated with bisphosphonates, and a mean difference after 5 years of loading 0.34 mm (95% confidence interval 0.00-0.75 mm, p = 0.04) was observed (23).

The medication prescribed after surgery must also be taken into account due to its possible effect on MBL, since several studies observed a greater MBL in patients who were administered ibuprofen after surgery, although their results were not statistically significant (20).

-MLB Factors Related to Implant Design

Dental implant surface is one of the factors more frequently analyzed, a greater crestal bone loss was observed in those implants with a mechanized surface (p = 0.01, end of follow-up: p < 0.01) (31). Among implants with a rough surface, those with coronal microtreatments have the lowest MBL compared with rough surface and hybrid implants (p < 0.05) (32, 33). Other authors agreed with these results, although they did not observe any statistically significant differences between the rough surface implants and the implants with mechanized coronal parts (34). However, the type of surface treatment used by different brands of implants with rough surfaces has been found to have lower MBL (p = 0.002) (35). However, they suggested that implants with a microtreatment in the crestal area of the implant may not have a positive effect on implants located in the anterior maxilla and with relatively recent extractions (36).

In addition to considering the surface of an implant, implant design has been studied, comparing cylindrical implants and conical implants; these studies have concluded that the implants with less highly polished surfaces and cylindrical shapes suffered less MBL per year in a statistically significant way (p < 0.05) (37). The extension of the spirals along the implant is another feature that has been studied and that shows a statistically significant difference in crestal bone loss, specifically between implants designed with spirals that run until the coronal part of the implant, which suffered a loss of 0.16 mm (SD 0.19 mm) after one year of functional loading compared to 0.30 mm (SD 0.22 mm) in the implants without spirals reaching the coronal part (38). Implant platform and connection type to the prosthetic abutment have also been shown to influence MBL. The implant abutment connection being located in the crestal area in straight implants and implants with platform-switching reflects greater marginal bone resorption, and the implants with platform change in infracrestal locations showed a significantly lower bone loss (8). This suggests that platform-switching can facilitate bone conservation at the crestal level (4). The implants with platform-switching and conical connection presented MBL that was significantly lower than implants with a standard platform (5). Some authors highlighted a slightly lower MBL in crestal implants compared with infracrestal implants (p < 0.01) (6). However, other authors did not obtain differences in the MBL of infracrestal implants with platform-switching in the maxilla and mandible (7). When analyzing the implant’s location with an internal conical connection screwed into an infracrestal and a crestal position and with respect to implants with a conical connection and a Morse-type internal seal in similar positions, no significant differences were observed, although the group with the crestal location and Morse-type connection presented the lowest MBL (8).

The type of connection between dental implant and prosthetic rehabilitation has also been studied; some studies show that after one year of follow-up, there is significant MBL in implants with internal connection and in implants with external connection without a statistically significant difference existing between the type of connections (39). However, the results obtained in other studies highlight a greater MBL in external connection implants (40).
Conclusions
The analyzed articles maintain a common criterion regarding the concept and measurement of the MBL, emphasizing the importance of the radiodiagnosis for its quantification. Few articles focus on the relationship between systematic pathology and MBL. In relation to the characteristics of the implants, the conclusions are more unequal and less homogeneous, highlighting an MBL in all the implants, regardless of the type of prosthetic rehabilitation and moment of loading. MBL is lower when an implant’s surface is rough and in implants with platform-switching and infracrestal position. However, greater loss is described in those with external connections. No statistically significant alterations were observed in surgical techniques with a flap neither in one-piece implants nor in the type of crown fixation (screwed versus cemented). Therefore, several factors of different natures can influence MBL, requiring more studies be done to increase our knowledge about how to prevent MBL.

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Conflict of interest
The authors have declared that no conflict of interest exist.