Comparative Results of Single Implants With and Without Laser-Microgrooved Collar Placed and Loaded with Different Protocols: A Long-Term (7 to 10 years) Retrospective Multicenter Study

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Purpose: This nonrandomized, retrospective multicenter study aimed to evaluate success rates, peri-implant marginal bone loss, and clinical parameters around single implants with and without laser-microgrooved collars placed and loaded using different protocols after 7 to 10 years of function. ***Materials and Methods:*** A chart review was used to select patients treated at five private dental clinics with single dental implants with and without laser-microgrooved collars. Cumulative success rates, peri-implant marginal bone loss, probing depth, Plaque Index, bleeding on probing, and gingival recession were recorded at baseline examinations (ie, definitive restoration delivery) and at each year during the follow-up period. ***Results:*** Three hundred single implants (140 without laser-microgrooved collars and 160 with 1.7-mm laser-microgrooved collars) in 300 patients were selected. At the completion of the study period, 26 patients and 26 implants (17 with and 9 without a laser-microgrooved collar) were classified as "dropouts." Implants and restorations were categorized into two subgroups each for a total of four study groups: group 1, immediate implant placement; group 2, delayed implant placement; group 3, immediate nonocclusal loading of prostheses; and group 4, delayed loading of prostheses. Nineteen implants (6.9%) failed clinically (4 [2.7%] with and 15 [11.4%] without a laser-microgrooved collar). The difference in cumulative success rates was statistically significant ($P < .05$). Radiographically, at the end of the follow-up period, the laser-microgrooved group showed a mean peri-implant marginal bone loss of 0.64 mm compared with 1.82 mm for the non–laser-microgrooved group. At the same time point, a mean probing depth of 0.76 mm was observed for the laser-microgrooved group compared with 2.75 mm for the non–laser-microgrooved group. A statistically significant difference in peri-implant marginal bone loss and probing depth between the two types of implant collars was evident ($P < .05$). No statistically significant correlation was noted between the types of implant placement/prosthetic restoration and clinical parameters. ***Conclusion:*** Implants with a laser-microgrooved collar appear to influence the peri-implant soft and hard tissue stability, reducing the probing depth levels and the peri-implant marginal bone loss by more than 50% after 10 years of function, regardless of the type of implant placement and loading protocol. *Int J Oral Maxillofac Implants 2020;35:XXX–XXX. doi: 10.11607/jomi.7605*

Keywords: delayed loading, delayed placement, immediate non-occlusal loading, immediate placement, laser-microgrooved

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Single dental implants supporting prosthetic restorations, placed and loaded in accordance with the original Brånemark protocol, have shown successful results in medium- to- long-term follow-up periods.[1,2] The original Brånemark protocol required implant placement in native or healed bone, and at least 3/6 months of healing before implant loading. Over the years, this protocol has been modified to include immediate implant and restoration placement.[3,4] Literature data indicated that, providing good primary stability, the placement of an immediate implant into a fresh extraction socket leads to comparable outcomes to implants placed in healed postextractive sites.[5] Immediate implant placement may also reduce treatment time by eliminating or reducing the unloaded period. To achieve that goal, different protocols have

been proposed: immediate loading (restorations with occlusal contacts placed immediately after implant placement or within 48 hours), early loading (restorations placed after 48 hours and before the 4/6 months provided for by the Brånemark protocol), and immediate nonocclusal loading (INOL, restorations placed immediately after implant placement, without occlusal contacts).[6] These loading approaches were shown to have predictable results when cases are appropriately selected.[7]

Results obtained using shortened healing and loading times with multiunit implant restorations caused some to consider the same protocols in single-tooth implant restorations.[8] Immediate single-implant placement, with fewer surgeries, could result in less hard and soft tissue remodeling.[9] In addition, immediate placement at the time of single-tooth extractions combined with a provisional restoration could offer further functional, psychologic, and esthetic advantages, preserving, for instance, the original gingival dimensions by the instant mechanical support of provisional restorations.[8] However, it is important to note that despite the favorable results reported, immediate implants failed to totally prevent postextractive alveolar ridge remodeling, especially in the buccal aspect,[10,11] which occurs whether or not concurrent guided bone regenerative procedures are performed.[12–14] Therefore, immediate implant placement, associated or not with immediate/early loading or INOL, is a procedure with risk and requires careful patient selection.[8]

In addition to changes in placement and loading protocols, several new implant surfaces have been investigated to increase the applicability and predictability of implant treatment.[15–17] The laser-microgrooved (LM) surface is obtained by means of controlled Excimer laser ablation. This technique allows creation of a microgeometry characterized by parallel linear grooves with resolution in the micron scale range. A recent literature review with meta-analysis indicated that an LM surface on the implant collar can reduce the amount of marginal bone loss (MBL) and improve the stability of peri-implant soft tissue.[18] However, most of the publications are for short-term follow-up. Long-term outcomes of LM vs non-LM implants are limited in the current literature.[19,20] Therefore, the first aim of the current multicenter retrospective study was to evaluate the effect of LM collars on the cumulative success rate (CSR), radiographic MBL, and clinical parameters after 10 years of function. The second aim was to compare results using different protocols, such as immediate placement or delayed placement of the implant, and INOL or delayed loading of the prosthesis. For this purpose, two implants with the same body design, the same moderately rough grit-blasted surface, with and without LM collars, were evaluated in this study.

MATERIALS AND METHODS

The current nonrandomized retrospective multicenter study was performed at five private dental clinics, where patients were consecutively enrolled. Preliminary results at the 3-year follow-up were previously reported.[21] The mean follow-up period was 8 ± 5.6 years (ranging from 7 to 10 years).

Since data collection was performed without the possibility of identifying the patient, the study was exempt from an institutional ethics board or committee approval. However, each included patient was asked to sign an informed consent, and the study was conducted in compliance with the Declaration of Helsinki.

Inclusion Criteria. The inclusion criteria were as follows:

- Patients older than 18 years
- Absence of remarkable medical histories and conditions known to contraindicate implant surgery
- Absence of alcohol or drug abuse
- Presence of at least a single edentulism requiring prosthetic treatment
- Absence of overhanging margins and/or caries and periodontal and/or endodontic lesions in teeth adjacent to the edentulous sites

Exclusion Criteria. The exclusion criteria were:

- Poor oral hygiene at the enrollment (full-mouth plaque score [FMPS] and full-mouth bleeding score [FMBS] ≥ 25%)
- Patients who abandoned the supportive therapy

Patients who smoked more than 10 cigarettes/day were categorized as smokers. In the presence of attachment loss > 3 mm and/or radiographic bone loss > 30% of root length in > 30% of sites, patients were classified as periodontally compromised.

Teeth scheduled for extraction were first treated with nonsurgical periodontal therapy aimed to eliminate or reduce inflammation. They were subsequently extracted before or during the implant surgery.

Implants

BioHorizons TLX and TRX implants (BioHorizons) were used. Implants have the same design and surface. Unlike the TRX, the TLX (Fig 1) has an additional 1.7-mm LM collar surface (Fig 1). The selection of implant type (TRX or TLX) was based on the patient's or dentist's choice; different clinics used different implants during the period of recruitment.

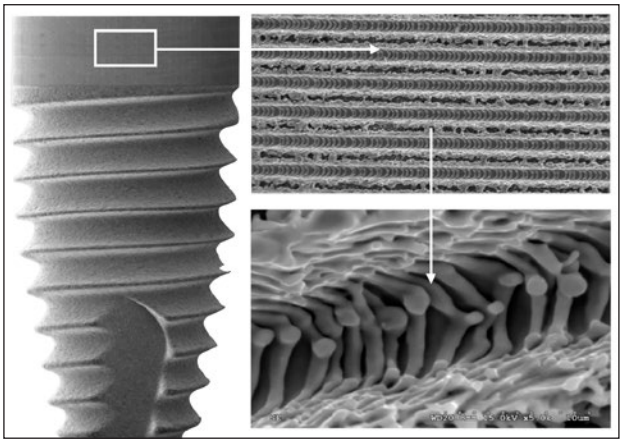


Fig 1 *(left)* Implant with an LM collar surface.



Fig 2 *(right)* Individualized acrylic resin device fixed to the residual dentition and a radiograph holder used for each patient.

Surgical and Prosthetic Procedures

A detailed description of the surgical and prosthetic procedures was reported in a previous publication.[21] Delayed implants were placed in the presence of the following intraoperative findings: *(1)* extraction sites requiring augmentations; *(2)* presence of active periapical pathology; *(3)* nonideal soft tissue contour; *(4)* unfavorable implant three-dimensional (3D) position that is potentially difficult to restore; or *(5)* absence of primary stability. In these cases, after the tooth extraction, a ridge preservation technique with allograft (Miner-Oss) and resorbable membrane (Mem-Lok), was carried out, and the implant was placed 4/6 months later.

The INOL protocol was used only if the implant insertion presented a final torque of at least 35 Ncm. In these cases, provisional crowns without occlusal contacts were immediately placed, and definitive crowns with a functional occlusion were delivered after 4 to 6 months. In cases of immediate and delayed implant placement, without immediate nonocclusal loading of restorations, definitive crowns were delivered 4 to 6 months after implant placement.

Follow-up

At the delivery of the definitive prosthetic restoration (baseline), patients were placed on a maintenance care program with 6-month recall visits. At each appointment, patients were reinstructed, remotivated, and subjected to scaling, root planing, and polishing of teeth and implants according to their needs.

Once a year, Plaque Index (PI), probing depth (PD), bleeding on probing (BOP), and gingival recession (REC) were surveyed at four or six sites per implant (mesial, distal, buccal, and lingual).

Radiographic Examination

For initial and subsequent radiographs, an individualized acrylic resin device was fixed to the residual dentition, and a radiograph holder was constructed and used for each patient (Fig 2). During the first 2 years, radiographs were digitalized by means of a dedicated scanner and converted into JPEG files. After the first 2 years, the radiographs were recorded digitally. The distance in millimeters between the implant shoulder and the bone-to-implant contact, mesially and distally, was measured by means of a software program (VixWin Platinum Imaging Software; Gendex). MBL was estimated as the difference in bone height between the mesial and distal levels at baseline and every subsequent annual examination.

A stable prosthesis, no patient complaint, and absence of a continuous radiolucency around the implant were considered success criteria.

Implant loss, implant fracture, or screw fracture that compromised the prosthetic stability, MBL > 3 mm, PPD > 5 mm, or PPD = 5 mm with BOP were considered failure criteria.

Data Analysis

Significant deviations in outcomes from normal distribution were detected using the Kolmogorov-Smirnov test. Influence of age, sex, smoking, arch, region, implant type, implant placement, and prosthetic loading on PD, BOP, REC, and MBL at the baseline and 10-year time point were evaluated with the Spearman rank correlation/Mann-Whitney *U* test.

Changes in PD, BOP, REC, and MBL were similarly evaluated. Variations in PD, BOP, REC, and MBL over time were evaluated with repeated measures analysis of variance (ANOVA) with Bonferroni adjustment. The SPSS program for Windows was used for the statistical analysis.

Table 1 Distribution of Treatments Among the Study Groups

Implant treatment/implant type	n	Age (y); mean ± SD (range)	Sex (n [%]); Women/Men	Smoker (n[%]); No/Yes
Immediate placement				
LM	76	49 ± 11.0 (29 to 73)	38 (50)/38 (50)	40 (40.8)/36 (59.2)
Non-LM	70	47.2 ± 9.2 (26 to 67)	40 (57.1)/30(42.9)	38 (54,2)/(45.8)
Total	146	48.1 ± 10.1 (26 to 73)	78 (52.8)/68 (47.2)	78 (53.4)/68 (46.5)
Delayed placement				
LM	68	46.5 ± 10 (25 to 72)	35 (51.4)/33 (48.6)	37 (54.5)/31 (45.5)
Non-LM	60	48.2 ± 8.8 (28 to 68)	29 (48.3)/31 (51.7)	42 (70.0)/18 (30.0)
Total	128	47.3 ± 9.5 (25 to 72)	64 (50)/64 (49)	79 (61.7)/49 (38.3)
INOL				
LM	91	49.3 ± 9.5 (29 to 67)	43 (46.7)/49 (53.3)	57 (55.8)/45 (44.2)
Non-LM	75	50.5 ± 12.1 (25 to 75)	31(41.3)/46 (58.6)	45 (54.2)/38 (45.8)
Total	166	49.9 ± 11.0 (25 to 75)	74 (44.3)/93 (55.6)	102 (55.0)/83 (45.0)
DL				
LM	53	49.7 ± 8.3 (34 to 64)	26 (49)/27 (51)	26 (49)/27 (51)
Non-LM	55	46.2 ± 7.4 (38 to 64)	28 (50.1)/27 (49.9)	28 (50.2)/27 (49.9)
Total	108	47.9 ± 7.2 (34 to 64)	54 (48.8)/54(51.2)	54 (50)/54 (50)
Immediate placement and INOL				
LM	43	50.2 ± 10.8 (29 to 74)	21 (45.7)/25 (54.3)	24 (52.1)/22 (47.9)
Non-LM	41	45.1 ± 8.4 (28 to 67)	19 (38.0)/31 (62.0)	23 (54.0)/27 (46.0)
Total	91	47.6 ± 10.4 (28 to 74)	40 (41.7)/56 (58.3)	47 (53.5)/49 (46.5)
Immediate placement and DL				
LM	30	50.7 ± 9.2 (33 to 66)	12 (40)/18 (60)	14 (46.6)/16 (53.3)
Non-LM	30	49.4 ± 9.4 (33 to 63)	11 (36.6)/19 (63.4)	17 (56.6)/13 (43.4)
Total	60	50.5 ± 8.3 (33 to 66)	23 (38.3)/37 (61.6)	31 (51.6)/29 (48.3)
Delayed placement and INOL				
LM	40	49.9 ± 10.2 (28 to 60)	20 (50)/20 (50)	26 (65)/14 (35)
Non-LM	32	45.3 ± 9.1 (29 to 64)	17 (53.1)/15 (46.9)	17 (53.1)/15 (46.9)
Total	72	47.7 ± 10.9 (28 to 64)	37 (51.3)/39 (48.7)	43 (59.8)/29 (40.2)
Delayed placement and DL				
LM	27	53.2 ± 8.2 (39 to 57)	14 (51.8)/13 (48.2)	12 (44.4)/15 (55.6)
Non-LM	24	46.2 ± 10,4 (36 to 60)	13 (54.1)/11 (45.9)	16 (66.6)/8 (41.4)
Total	51	54.7 ± 7.9 (36 to 60)	27 (52.9)/24 (47.1)	28 (54.9)/23 (45.1)

LM = Laser-microtextured collar surface; non-LM = non–laser-microtextured collar surface; INOL = immediate nonocclusal loading; DL = delayed loading.

To ensure reproducibility, radiographic measurements of the same 40 implants (20 LM and 20 non-LM) were repeated after 7 days, assessing an intraexamination reliability of 90% (data not shown). The same 20 implants (10 LM and 10 non-LM) were then measured once a year for the examiner's recalibration.

RESULTS

For the present study, 300 single implants (160 with laser-microgrooved collars [LM] and 140 without laser-microgrooved collars [non-LM]) placed in 300 patients were selected. At the end of the follow-up period, 26 patients with 26 implants (17 LM and 9 non-LM) were classified as dropouts, leaving the study group at 274 patients (146 men and 128 women; mean age: 48.1 years; range: 45 to 75 years) and 274 implants (143 LM and 131 non-LM). Of the 274 subjects, 124 subjects (45.2%) were smokers and 62 (22.6%) were periodontally compromised. Table 1 summarizes the demographics and the distribution of treatments among the different study groups.

Implants and restorations were categorized into two subgroups each for a total of four study groups: group 1 = 146 implants (76 LM and 70 non-LM) with immediate implant placement; group 2 = 128 implants (68 LM, 60 non-LM) with delayed implant placement; group 3 = 166 implants (91 LM, 75 non-LM) with immediate nonocclusal loading of prostheses (INOL); and group 4 = 108 implants (53 LM, 55 non-LM) with delayed loading of prostheses.

Among the patients, 70 implants (34 LM and 36 non-LM) were placed in the anterior maxilla and 54 (30 LM and 24 non-LM) in the posterior maxilla, while 70 implants (36 LM and 34 non-LM) were placed in the anterior mandible and 80 (43 LM and 37 non-LM) in the posterior mandible. One hundred fifty implants (81 LM and 69 non-LM) were placed in smokers, while 124 (71 LM and 53 non-LM) were placed in nonsmokers. Two hundred twelve implants (112 LM and 110 non-LM) were placed in periodontally healthy patients and 62 (35 LM and 27 non-LM) in periodontally compromised patients.

Table 2 reports the implant success and failure rates among the 274 patients. During the follow-up period,

19 implants (4 LM and 15 non-LM) were explanted. Nine of the failed implants (2 LM and 7 non-LM) were positioned in the maxilla, and 10 (2 LM and 8 non-LM) in the mandible. Six of the failed implants (0 LM and 6 non-LM) were in anterior regions (3 non-LM in the mandible and 3 non-LM in the maxilla), while 13 (4 LM and 9 non-LM) were in posterior regions (2 LM and 4 non-LM in the mandible, and 2 LM and 5 non-LM in the maxilla). Sixteen (3 LM and 13 non-LM) failed implants were in smokers and 3 (1 LM and 2 non-LM) were in nonsmokers. Fifteen (2 LM and 13 non-LM) failed implants were in periodontally compromised patients, and 4 implants (2 LM and 2 non-LM) were in periodontally healthy patients. Failure rates were significantly lower for LM vs non-LM (2.7% vs 11.4%), in nonsmokers vs smokers (2% vs 12.9%), and in periodontally healthy vs periodontally compromised patients (1.8% vs 24.2%). Implants placed in the posterior region of the mouth showed statistically higher failure rates compared with implants placed in the anterior region (Table 2). Based on the placement protocol, 11 failed implants were immediate (2 LM and 9 non-LM) and 8 (2 LM and 6 non-LM) were delayed. Based on the loading protocol, 11 failed implants (2 LM and 9 non-LM) were in the INOL group, while 8 (1 LM and 7 non-LM) were in the delayed group. In both groups (LM and non-LM), the time of placement and loading showed no significant influence on the success rate (χ^2 test; $P > .05$) (Table 2).

During the follow-up period, all patients demonstrated good oral hygiene and compliance. The mean BOP value was 6% in the LM group and 7.1% in the non-LM group. The mean PI value was 8% in the LM group and 7.4% in the non-LM group.

The recorded PD values showed increasing divergence between the LM and non-LM groups as time progressed. LM implants appeared to have more stable PD (0.76 mm) over the 10-year follow-up (Fig 3). Gingival recession was also lower at all time points for LM implants, reaching approximately 1 mm at T10 compared with 2.46 mm for non-LM implants (Fig 4). At T10, MBL for LM and non-LM was 0.64 mm and 1.82 mm, respectively (Fig 5). Differences in MBL between the two groups were statistically significant, but not associated with the timing of implant placement and loading (Figs 6 to 9).

Table 2 Implant Success and Failure Rates Among 274 Patients

Parameters	n	Success (%)	Failure (%)	Explantation
Implant type				
LM collar surface	143	97.3	2.7	4
Non-LM surface	131	88.6 *	11.4 *	15*
Sex				
Men	146	93.9	6.1	9 (2 LM/7 non-LM)
Women	128	92.2	7.8	10 (2 LM/8 non-LM)
Smoker				
No	150	98	2	3 (1 LM/2 non-LM)
Yes	124	87.1 *	12.9*	16* (3 LM/13 non-LM*)
Periodontitis				
No	212	98.2	1.8	4 (2 LM/2 non-LM)
Yes	62	75.9*	24.1*	15* (2 LM/13 non-LM*)
Region				
Maxilla anterior	70	95.7	4.2	3 (0 LM/3 non LM*)
Maxilla posterior	54	88.1*	11.1*	6* (2 LM/4 non-LM*)
Mandible anterior	70	94.3	4.2	3 (0 LM/3 non-LM*)
Mandible posterior	80	91.1*	8.7*	7* (2 LM/5 non-LM*)
Time of placement				
Immediate	146	92.5	7.5	11 (2 LM/9 non-LM)
Delayed	128	93.5	6.5	8 (2 LM/8 non-LM)
Loading				
INOL	166	93.5	6.5	11 (2 LM/9 non-LM)
DL	108	92.5	7.4	8 (2 LM/6 non-LM)
Placement + loading				
Immediate + INOL	91	93.5	6.5	6 (1 LM/5 non-LM)
Immediate + DL	60	91.7	8.3	5 (1 LM/5 non LM)
Delayed + INOL	72	93.1	6.9	5 (1 LM/4 non-LM)
Delayed + DL	51	94	6	3 (1 LM/2 non LM)
Total	274	93.1	6.9	19 (4 LM/15 non-LM*)

*Statistical significance (χ2 test; $P < .05$). LM = Laser-microtextured collar surface; non-LM = non–laser-microtextured collar surface; INOL = immediate nonocclusal loading; DL = delayed loading.

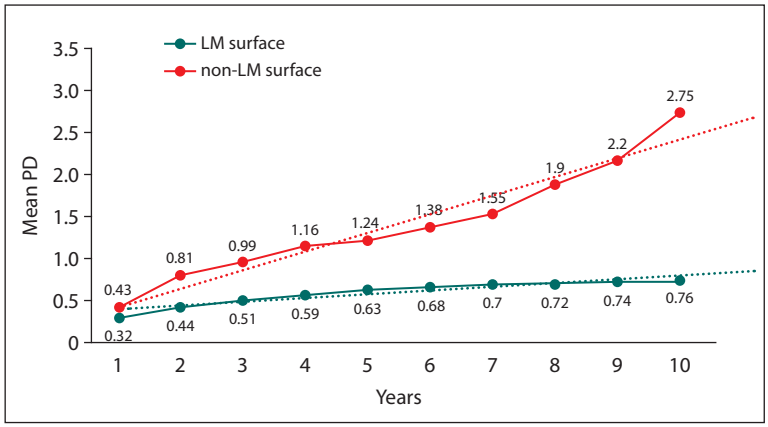


Fig 3 Mean values of probing depth (PD) recorded during the follow-up (difference was statistically significant; $P < .05$). LM = Laser-microtextured collar surface; non-LM = non–laser-microtextured collar surface.

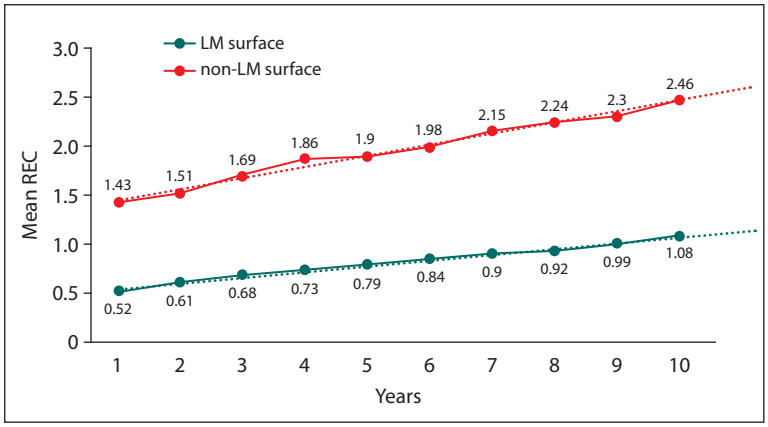


Fig 4 Mean values of gingival recession (REC) recorded during the follow-up (difference was statistically significant; $P < .05$). LM = Laser-microtextured collar surface; non-LM = non–laser-microtextured collar surface.

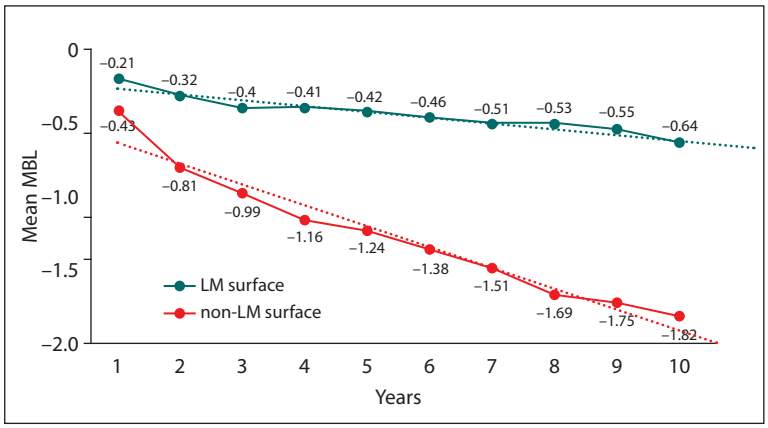


Fig 5 Mean values of marginal bone loss (MBL) recorded during the follow-up (difference was statistically significant; $P < .05$). LM = Laser-microtextured collar surface; non-LM = non–laser-microtextured collar surface.

DISCUSSION

The results of this study, on the effect of modified implant collars, are in agreement with previously published data indicating that LM implants show better CSR and hard and soft peri-implant tissue conditions compared with non-LM implants. Iorio-Siciliano et al[20] reported CSR values of 94% vs 90%, a mean MBL value of 0.81 (SD: 0.24) mm vs 2.02 (SD: 0.32) mm, a mean PD value of 2.32 (SD: 0.44) mm vs 4.25 (SD: 0.87) mm), and a mean REC value of 0.16 (SD: 0.3) mm vs 0.22 (SD: 0.3) mm for LM and non-LM implants, respectively, after 5 years of loading. In a previous publication by Guarnieri et al,[19] LM implants showed a statistically significant difference for PD, MBL, and REC after 10 years compared with non-LM. However, these outcomes were related to implants placed and loaded according to the original Brånemark protocol. The results of the present study indicate that the LM surface on implant collars keeps its long-term positive influence on CSR regardless of implant placement and prosthetic loading protocols. Those findings could be associated with the capacity of LM to influence peri-implant soft tissue responses during the years of function.

Histology of implants with machined/smooth collars has shown circumferential organization of peri-implant connective tissue with fibers mostly parallel to the collar surface.[22–25] On the other hand, LM implants exhibited a physical and functional connective tissue attachment with fibers oriented perpendicular to the implant collar.[26–27] Promoting the stability of peri-implant tissues, the LM surface protects the peri-implant bone from the oral environment and counteracts the peri-implant inflammatory processes.[27] The physical attachment of connective tissues to LM surfaces has been histologically documented both around implants placed in native bone[25,26] and in fresh extraction sites.[28] Studies have proven the clinical value on both soft and hard peri-implant tissues in the short-term follow-ups.[21,29–31] The present study not only confirms previous short-term reports, it highlights the long-term effect of LM on CSR, MBL, PD, and REC regardless of the implant placement and prosthetic loading protocol. The cause of failure for all 19 removed implants in the present study was peri-implantitis. The statistically significant difference in the incidence of peri-implantitis between LM and non-LM implants could indicate that LM implants exhibited more resistance to the onset and progression of peri-implant disease. Several studies documented that the peri-implant lesion around machined/textured implants occupied almost the entire connective tissue compartment and extended apical to the pocket epithelium.[32–34] Moreover, the peri-implant lesion was characterized by the absence of a connective tissue capsule that separated the inflammatory cell infiltrate from bone, and by the presence of a great number of neutrophil granulocytes and macrophages that extended to the bone crest.[33] Different histopathologic features have been documented in an experimental animal study on induced peri-implant lesions around LM implants.[35] At the breakdown stage, despite the presence of an inflammatory infiltrate, LM implants exhibited a connective tissue attachment at the LM area, with dense connective fibers perpendicularly oriented. On the other hand, non-LM implants showed an

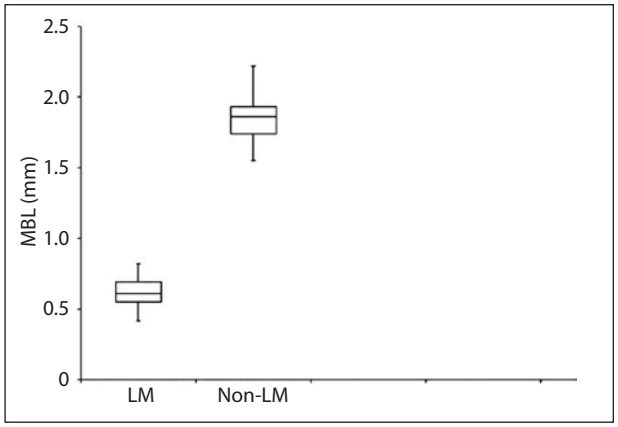


Fig 6 Comparative results of MBL between LM and non-LM implants according to immediate placement/INOL protocol at the end of the follow-up (difference was statistically significant; $P < .05$).

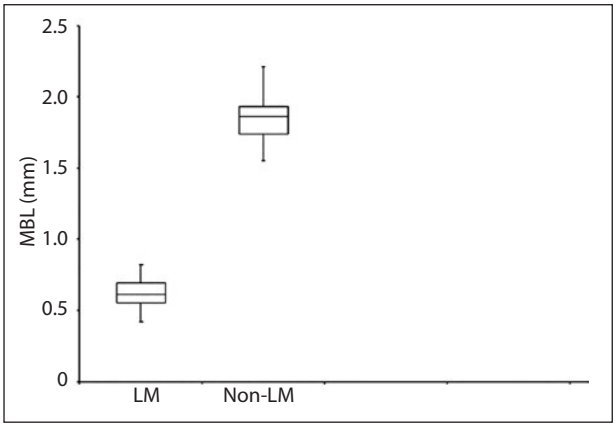


Fig 7 Comparative results of MBL between LM and non-LM implants according to immediate placement/delayed loading protocol at the end of the follow-up (difference was statistically significant; $P < .05$).

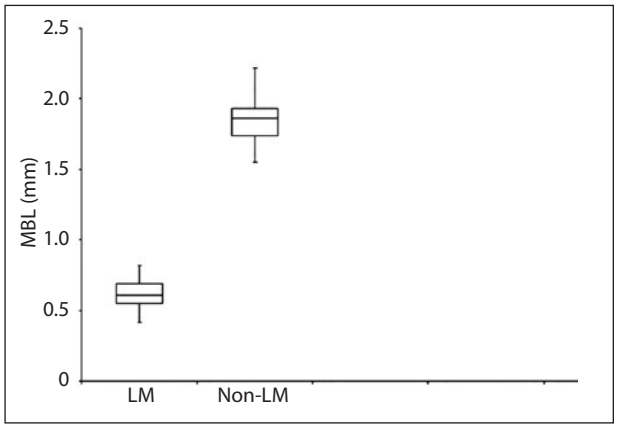


Fig 8 Comparative results of MBL between LM and non-LM implants according to delayed placement/INOL protocol at the end of the follow-up (difference was statistically significant; $P < .05$).

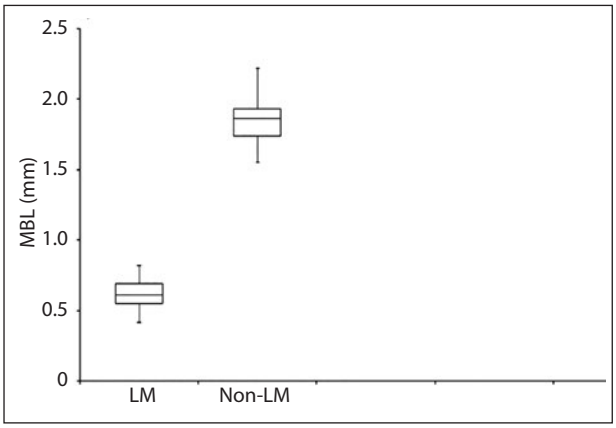


Fig 9 Comparative results of MBL between LM and non-LM implants according to delayed placement/delayed loading protocol at the end of the follow-up (difference was statistically significant; $P < .05$).

absence of connective attachment, higher histologic probing depths, more pronounced bone loss (2.4 mm for non-LM vs 1.8 mm for LM), and higher and deeper presence of inflammatory infiltrate. Moreover, once the ligatures were removed, LM implants exhibited less disease progression than non-LM implants. Accordingly, authors have indicated that LM implants are more resistant at the disease induction phase. The greater resistance of LM implants, compared with non-LM implants, to peri-implant tissue inflammation has been documented by another recent comparative clinical study with 5 years of follow-up.[36] In a sample of 74 patients who received at least 1 LM implant and 1 non-LM implant, authors reported an implant-based incidence of peri-implantitis of 3.6% for LM vs 11.9% for non-LM, and a patient-based incidence of 4% for LM vs 13% for non-LM.

The results at the 3-year follow-up of the investigated implants of the present study have been previously published.[21] In the short-term period, no statistical difference in CSR between the two groups of implants was noted (97.5% for LM vs 96.5% for non-LM). This might seem to be in contrast with these results reported at 10 years. However, in the comparative evaluation of outcomes, it is important to note that peri-implantitis, a bacterial-induced disease, may take a longer time to develop. Therefore, only long-term data can provide a ponderable comparative evaluation between implants with and without LM collars in terms of peri-implant hard and soft tissue stability, and resistance to peri-implant tissue inflammation. As is the case with natural teeth, it is conceivable to assume that also with dental implants, the natural defense mechanisms to biofilm accumulation depend on the biologic functions of the

various components that make up the structure of the peri-implant tissue.[37,38] Since a connective tissue attachment at the implant collar is supposedly creating a physical barrier to the oral environment, its absence could reduce the natural protective mechanisms, allowing for an easier apical progression of inflammation. The LM collar surface, while not analogous to the cemental surface of natural teeth, seems to act as a predetermined site, attracting the formation of a physical connective tissue, which in turn counteracts the onset and progression of inflammatory processes.[35]

Based on the collected data of the present study, no statistically significant correlations were found between age, sex, time of placement, and/or loading and CSR, PD, REC, and MBL. This is in concordance with literature data on long-term outcomes of implants replacing single missing teeth with standard[1,2] and immediate placement/loading.[8] Studies have indicated that, in select cases with optimal implant 3D position, adequate bone volume, and soft tissue dimensions, immediate implant placement and loading have similar success rates, MBL, and soft tissue stability to conventionally placed and loaded implants.[7,8,39] Taking into account the total number of implants, a significant statistical correlation has been found between the position (anterior vs posterior) and the CSR and MBL. A possible explanation of this result could be linked to the low density and reduced bone quality in the posterior areas.[40] Another explanation could be associated with the fact that all anterior extraction sites, receiving immediate implants, had to demonstrate hard and soft tissue preservation.

Another significant statistical correlation has also been found between smoking, periodontitis, and CSR and MBL. This confirms the results of several studies reporting that the insertion of implants in smokers and in periodontally compromised patients affected the failure rates and the MBL.[41,42]

The nonrandomized design is one of the major limits of the present study. Furthermore, the selection of implant type (TRX or TLX) was based on the patient's or dentist's choice. To minimize variations, a considerable effort was taken, selecting sites as similar as possible in that regard.

CONCLUSIONS

The results of this study showed that LM implants appear to influence the peri-implant soft and hard tissues, stabilizing the probing depth levels and reducing MBL by more than 50% after 10 years of loading. Timing of implant placement and prosthetic loading showed no significant difference in CSR, MBL, PD, BOP, and REC.

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