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Marginal bone stability around bone level versus tissue level implants in non-compliant patients with healthy or reduced periodontium: A 10-year retrospective study

Joyce NICOLAS

Nada BOU ABBOUD NAAMAN

Johnny NOHRA

Mark BOU CHAAYA

MARGINAL BONE STABILITY AROUND BONE LEVEL VERSUS TISSUE LEVEL IMPLANTS IN NON-COMPLIANT PATIENTS WITH HEALTHY OR REDUCED PERIODONTIUM: A 10-YEAR RETROSPECTIVE STUDY

Joyce Nicolas* | Nada Bou Abboud Naaman | Johnny Nohra*** | Mark Bou Chaaya *****

Abstract

The aim of this retrospective study was to investigate the effects of bone level implants (BL) in non-compliant patients on marginal bone alterations compared with the tissue level implants group (TL) at a mean follow-up period of at least 10 years.

This study reports on 44 non-compliant patients selected from 3 private practices located in Beirut. Patients selected underwent implant surgery between 2005 and 2009 and had BL (Branemark and 3I Biomet) or TL (Straumann) implants. Periapical radiographs were taken directly after loading and at least at 10 years later. Crestal bone loss (CBL) for a total of 140 implants, including 97 BL and 43 TL implants was measured on radiographic images using the image tool software. Image calibration was done according to implant length. Hygiene level, smoking status and implant surface were also registered.

After a mean period of 10 years, implants in the TL group had a mean CBL of 1.18± 0.89 (0.85 on the mesial side and 1.5 on the distal side). The BL group showed a mean CBL of 0.97 ± 0.64 (0.65 on the mesial side and 1.29 on the distal side). No significant difference ($p > 0.05$) was found between the 2 groups. Hygiene level was significantly associated with mesial and average bone loss. TiUnite surface showed a lower distal bone loss compared to SLA and acid etched surfaces. Furthermore, the average bone loss was significantly elevated in multiple-implant compared to single-tooth fixed implant restorations. No significant difference in bone loss was found between the maxilla and the mandible or between non-smokers and smokers.

Analysis of the obtained results did not reveal a lower bone loss between bone level and tissue level implants in patients who didn't commit to a strict maintenance program. However, bone loss was strongly correlated to hygiene level, confirming the importance of SPT and compliance.

Keywords: Dental implants - bone loss - periodontal treatment – dental hygiene.

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STABILITÉ OSSEUSE MARGINALE AUTOUR DES IMPLANTS « BONE LEVEL *» PAR RAPPORT AUX IMPLANTS «* TISSUE LEVEL *» CHEZ LES PATIENTS NON COMPLIANTS AYANT UN PARODONTE SAIN OU RÉDUIT : UNE ÉTUDE RÉTROSPECTIVE SUR 10 ANS*

Résumé

Le but de ce travail était d'évaluer rétrospectivement, et après au moins 10 ans de fonction, les changements du niveau osseux crestal autour des implants «niveau osseux» par opposition aux implants «niveau muqueux» chez des patients qui n'ont pas suivi un programme de maintenance parodontale.

Les dossiers médicaux des patients de trois cabinets privés à Beyrouth ont été analysés. Les patients qui ont subi une chirurgie implantaire depuis 10 ans (entre 2005 et 2008), recevant des implants Straumann «niveau muqueux»(TL) ou Branemark/3i Biomet «niveau osseux» (BL) et n'ayant pas suivi un programme de maintenance ont été évalué. 44 patients ont été inclus dans l'étude, et les radiographies prises directement après mise en charge et après 10 ans ont été comparées. La standardisation des radios a été réalisée selon la longueur de l'implant. D'autres paramètres ont été enregistrés comme le niveau d'hygiène, le tabagisme et la surface implantaire.

Au total, 140 implants comprenant 97 implants BL and 43 implants TL ont été inclus dans cette étude. Après 10 ans de mise en charge, le groupe TL a présenté une perte osseuse moyenne de 1.18± 0.89 (0.85 en mésial et 1.5 en distal) alors que le groupe BL a montré une perte osseuse moyenne de 0.97 ± 0.64 (0.65 en mésial et 1.29 en distal). Les études statistiques n'ont pas montré de différences significatives ($p > 0.05$) entre les groupes. Une corrélation positive a été révélée entre la perte osseuse et le niveau d'hygiène. La surface implantaire TiUnite a montré une perte osseuse moindre en distal comparée aux autres surfaces. Par contre, nos résultats n'ont pas pu montrer une différence significative dans la perte osseuse entre le maxillaire et la mandibule ou une corrélation avec le tabagisme.

L'analyse des résultats n'a pas montré une résorption osseuse marginale moindre entre les implants BL et TL chez les patients n'ayant pas suivi un protocole de maintenance parodontale. Toutefois, la perte osseuse est corrélée à l'hygiène buccale d'où l'importance de la maintenance.

Mots-clés: implant dentaire - perte osseuse marginale - maintenance parodontale.

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* D.D.S., Masters student,
Dpt of Periodontology, Faculty of Dentistry,
Saint-Joseph University of Beirut, Beirut, Lebanon
joyce.j.nicolas@gmail.com

** PhD, DDS,
Professor and private practice, Dpt of Periodontology,
Honorary Dean of the Faculty of Dentistry,
Saint-Joseph University, Beirut, Lebanon

*** DDS, Masters in Periodontology
Teacher, Dpt of Periodontology, Faculty of Dentistry,
Saint-Joseph University of Beirut, Beirut, Lebanon

DDS, Masters in Periodontology,
Faculty of Dentistry,
Saint-Joseph University of Beirut, Beirut, Lebanon

Introduction

Over the past decades, implant therapy has been used as an alternative to conventional prosthetic rehabilitation in partially or totally edentulous patients. It is proved that implant therapy has a long term high success and survival rates and is considered as the treatment of choice for replacing missing teeth [1-3] 1–3.

One important parameter for evaluating treatment outcome and long-term success is peri-implant crestal bone loss (CBL)[1]1. It is accepted that, during the first year of loading, CBL around implants is inevitable and is considered as an adaptive response to surgical trauma and loading [1, 2]1,2. After the first year of loading, the marginal bone level is more stable, and most implants show minimal annual CBL. According to established criteria for the assessment of implant survival and success, CBL in the first year should be lower than 1.5 mm, and ongoing annual bone loss should be lower than 0.2 mm [4,5]4,5. However, some implants will show more bone loss than others and a few will even show continuous loss over time, this would be related to an infectious process, i.e., periimplantitis[1,2,6]1,2,6. Lang et al. in 2011, suggested that the incidence of biologic complications, and more specifically of peri-implantitis, may be up to 50% [7]7. Recently, it was suggested that CBL around implants is influenced by many factors [1]1, like systemic diseases (smoking and diabetes) [8]8, soft tissue thickness [9]9,inter-implant distanc e [10]10, implant surface [11]11, crown–implant ratio [12]12, implant system used [13]13, implant neck design [6,14,15]6,14,15, implant location [16]16, antagonistic occlusion [17]17, characteristics of the prosthesis [4]4, mode of retention [18]18.

It is important to note that subjects receiving implants ought to have healthy oral conditions before any surgery and need to be included in a well-structured maintenance program [3,7]3,7. Periodontally compromised patients (PCP) are patients experiencing continuing tooth loss due to uncontrolled periodontal disease and following no supportive periodontal therapy (SPT) [1]1. Hardt et al., in their 5-year retrospective study in 2002, reported a failure rate of 8% for PCP compared with 3% for periodontally healthy patients (PHP) [19]19. More studies showed that implants can successfully be used in PCP who have received periodontal therapy and regularly obtain SPT, but the rate of both biological complications and implant failure is greater in PCP group [21,22] 21,22. There is no consensus on the best frequency of SPT. According to Miyamoto et al., all patients who demonstrated any pocket depth (PD) ≥4 mm were assigned to 3-month intervals of maintenance, otherwise, the patients were assigned to 6-month intervals of SPT [23,24]23,24. Armitage et al. suggested 2–3 months intervals in individuals at high risk of disease recurrence, whereas, longer intervals are sufficient to PHP. In addition, longitudinal clinical results showed that SPT at 3- to 4-month intervals works for most individuals [25]25.

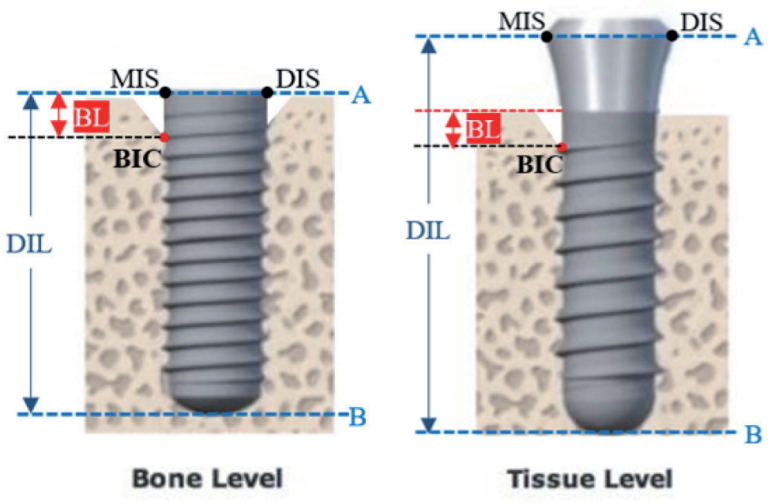

Fig. 1: Schematic representation of the radiographic analysis used to standardize the radiograph and determine the bone level applied on BL and TL implants. MIS: Mesial implant shoulder, DIS: Distal implant shoulder, A: Line connecting MIS and DIS, B: Line tangential to the implant apex and parallel to A, DIL: Distorted implant length - bisecting line of the angle of A and B, BIC: Most coronal visible bone-to-implant contact, BL: Bone loss.

Moreover, there is little evidence on the difference in behavior of bone level (BL) versus tissue level (TL) implants in non-compliant patients, although both implant types have been proven successful. Conventionally, BL implants are placed at the bone crest and the implant-abutment microgap is located at the bone crest [5]5. Whereas, TL implants are typically placed transmucosally, and the implant-abutment micro-gap is coronal to the bone crest [26]26. The distance from the gingival margin to the bone crest around implants, i.e., the implanto-gingival unit, has been found to be a physiologically formed stable structure. The CBL has been attributed to various factors and one of which is the presence of bacterial infiltration at the microgap [27]27. When the crown-implant junction is beneath the bone crest, the re-establishment of the protective environment, the biological width, causes a non-physiological response that initiates bone loss. With TL implants, and because of the existence of a smooth–rough surface interface on the implant itself, bone loss occurring up to that interface can be considered

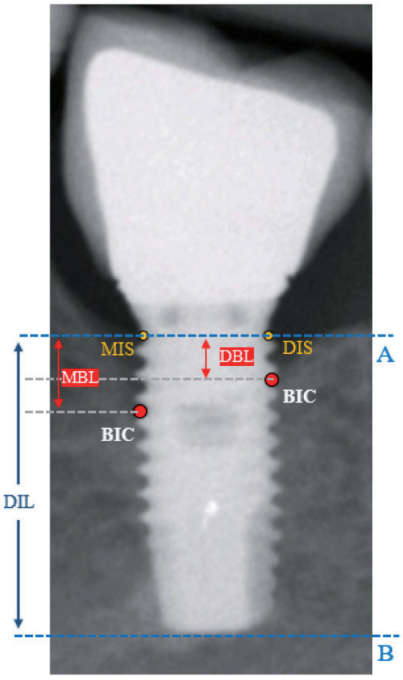

Fig. 2: Radiographic analysis applied on bone level implants.

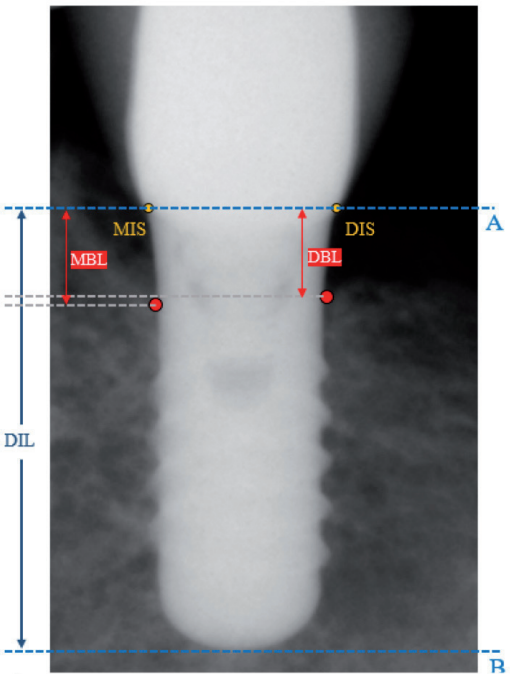

Fig. 3: Radiographic analysis applied on tissue level implants.

physiological remodeling, while bone loss occurring apical to that point can hence be regarded as pathological [11]11. It has been suggested that the transmucosal location of the microgap in TL implants seems to be advantageous because it is positioned at a distance from the bone crest [5]5.

Nonetheless, there is little evidence on the long-term prognosis of implants in non-compliant patients. Wilson defined compliance as "personal conduct with respect to the recommendations received from the health professional" [28]28. Compliance is calculated based on the total number of recall visits attended and the individually prescribed follow-up intervals. Different classifications have been suggested, Checchi et al. in 1994 divided patients in three groups: insufficient compliance (attended<50% of prescribed recall visits); partial compliance (attended <100% and >50% of recall visits); and complete compliance (attended all recall visits) [29,30]29,30. According to Zeza et al. a patient is compliant if he skips less than 30% of his appointments [30]30.

Wang et al. evaluated retrospectively bone alterations in non-compliant patients, and the effects of uncontrolled periodontitis (without SPT) on CBL around TL implants compared to PHP over 6 years. The results showed no differences in bone loss around TL implants between PHP and PCP [1]1.

The primary aim of the present retrospective study was to compare CBL for BL and TL implants in non-compliant patients after a follow-up period of at least 10 years. The secondary end goal was to compare the influence of hygiene level, smoking status and implant surface on CBL in the same conditions.

Materials and methods

Population screening

The study protocol was approved by the Ethics Committee and the research Council at the Saint Joseph University of Beirut and allocated the number USJ-2018-61.

Patients who underwent implant surgery 10 years ago (between 2005 and 2008) were screened from 3 private practices located in Beirut and selected for the study when they met the following inclusion criteria: i) having received the initial phase then implants in the posterior region and were lost to follow-up; ii) implants were placed more than 10 years ago; iii) Straumann Tissue Level implants (Straumann Dental Implants System, Switzerland) and Branemark / 3i Biomet Bone Level external hexagon implants, iv) non-compliant patients, who attended 7 or less visits in the 10 years follow-up [30]30; and v) smoking ≤ 10 cigarettes/day.

Exclusion criteria were as follow: i) systemic health problems (uncontrolled diabetes, medication that may affect bone metabolism); ii) completely edentulous patients; iii) untreated periodontitis; iv) unavailability or inappropriate radiographs; v) augmented sites; and vi) extraction and immediate implant placement.

Radiographic parameters

Radiographic measurements were performed on periapical radiographs processed using the image tool software DBSWIN system® (Durr Dental, Baden-Wurttemberg, Germany)

for CBL as illustrated in Figure 1. Standardization was done according to implant length. The mesial and distal implant shoulders (MIS-DIS) were defined and a line (A) connecting both was drawn. Another line (B) tangential to the implant apex and parallel to (A) was also drawn. The bisecting line of the angle of (A) and (B) was therefore produced and measured to evaluate the distorted implant length (DIL). Knowing the actual length of the implant, the software delivers a calibration factor and automatically computed all measured distances in real values, eliminating the distortion factor.

Then, bone level (BL) measurements were recorded from the implant platform/shoulder mesially (MIS) and distally (DIS) to the most coronal visible bone-to-implant contact (BIC) on the mesial and distal sides of each implant. The mesial bone level post-loading (MBL0), distal bone level post-loading (DBL0), mesial bone level after 10 years (MBL10), and distal bone level after 10 years (DBL10) were recorded. Finally, the 10 years bone loss measurements were calculated by subtracting the values obtained from periapical radiographs at loading and at 10 years, both at the mesial (MBL) and the distal side (DBL), and the mean of the distal and mesial measures was considered average bone loss (ABL) around the implant (Figures 2 and 3 illustrate an example of the measurements performed on the periapical radiographs).

Radiographs of 33% of implants (40 implants) were selected for the second analysis of the CBL to assess the inter examiner variability.

Clinical parameters

Other variables were noted: i) Mandibular or maxillary location of implants; ii) Hygiene level (Poor, fair or good); iii) Smoking status (light smokers < 10 cig/day or heavy smokers > 10 cig/day); iv) Single or multiple implant restorations; v) Years in function; and, vi) Implant surface.

	N	Mean ± Std. Deviation	ICC with 95% confidence interval
DIL- J.N. (mm)	50	49.24 ±27.23	0.999 (0.999 - 1.000)
DIL- M.C. (mm)	50	49.29 ± 27.22	
BL D after 10 yrs - J.N. (mm)	50	1.35 ± 0.68	0.979 (0.963 – 0.988)
BL D after 10 yrs - M.C. (mm)	50	1.35 ± 0.67	

Table 1: Reproducibility of measurements between examiners.

Statistical analysis

The IBM SPSS statistics (version 25.0) was used to perform the statistical analyses. The alpha error was set at 0.05. Reproducibility of measurements was evaluated using the Intraclass correlation coefficient (ICC). The normality distribution of continuous variables was assessed using Kolmogorov-Smirnov tests. Repeated-measures analysis of variance was used to compare mesial and distal bone loss between different implant systems.

Analysis of variance followed by Tukey post-hoc tests and Kruskal-Wallis tests were used to compare continuous variables between three groups. Student t-tests and Mann-Whitney tests were used to compare continuous variables between two groups.

Results

Reproducibility between measurements

Reproducibility between measurements was tested using the intraclass correlation coefficient ICC); the ICC was very high indicating an excellent reproducibility.

Description of the study population

In total, 44 patients were included in the study (table 2), 140 implants, including 97 Bone Level (3i Biomet/ Branemark) implants and 43 Tissue Level (Straumann) implants were analyzed. Twenty-one (47.7%) patients had a good oral hygiene and 13(29.5%) had a low oral hygiene. Only 10 (22.7%) patients were smokers (8 light and 2 heavy smokers). Implants length and diameter are showed in table 3.

Comparison between mesial and distal bone loss

Mesial bone loss (MBL) was 0.68 ± 0.74, 0.61 ± 0.83, and 0.85 ± 1.25 for 3i BL, Branemark BL and Straumann TL, respectively. Distal bone loss (DBL) was 1.45 ± 0.74, 1.10 ± 0.84, and 1.50 ± 0.80 for 3i, Branemark and Straumann TL, respectively. Average bone loss (ABL) was 1.07 ± 0.61, 0.856 ± 0.67, and 1.18 ± 0.89 for 3i BL, Branemark BL and Straumann TL, respectively (Table 4).

Bone loss was significantly greater on the distal side of the implant for 3i Biomet system ($p<0.001$), Branemark ($p=0.001$) and Straumann TL ($p<0.001$). MBL was not significantly different between the 3 implants systems ($p=0.48$), however, on the distal side, bone loss was statistically lower with Branemark implants ($p=0.04$) while the difference was not significant between 3i Biomet and Straumann TL implants ($p=1.000$).

Factors associated with CBL around implants after 10 years period

Our data revealed that MBL ($p=0.71$) and DBL ($p=0.18$) was not significantly different between the maxilla and the mandible. Moreover, implant system was not significantly associated with MBL ($p=0.24$) and DBL ($p=0.16$). Also, MBL ($p=0.93$) and

	Frequency	Percentage
Arch		
Maxillary	61	43.6
Mandible	79	56.4
Implant surface and system		
Acid etched 3i Biomet	52	37.1
TiUnite Branemark	45	32.1
SLA Straumann	43	30.7
Implant type		
Bone Level	97	69.3
Tissue Level	43	30.7
Restoration		
Unitary	47	33.6
Multiple	93	66.4

Table 2: Distribution of the 140 implants.

DBL (p=0.53) were not significantly different between non-smokers and smokers.

On the other hand, hygiene level was significantly associated with MBL (p=0.01) and ABL (p=0.02). Furthermore, the ABL was significantly higher in bridge restoration compared to single-unit restoration (p=0.04).

Discussion

The primary aim of the current study was to compare, in non-compliant patients, CBL between BL and TL implants, after 10 years of follow up.

Patients usually seek professional service for active treatment because of the symptoms of the disease, nevertheless, many studies have shown that patients' compliance with SPT is generally insufficient with a percentage of 19.6 to 34% of patients being non-compliant [13,28,29,31]13,28,29,31. The disappointing behavior of patients during SPT suggests that the health professional should be more aggressive in motivating patients [28]28.

As for the comparison of BL and TL implants after 10 years of function, our study couldn't prove a difference in the CBL between TL and BL implants in non-compliant patients, and implant type was not significantly associated with mesial, distal and mean bone loss. Data showed a higher bone loss around TL implants, but the difference was not statistically significant and a larger sample must be considered for more investigation. In 2017, Rokn et al. aimed to evaluate the prevalence of biologic complications of TL and BL implants without regular SPT. The results showed a significant difference in mean CBL between TL and BL implants. After 5 years of loading, TL implants had lower values of periimplantitis prevalence and CBL [37]37. In 2018, Wallner et al. investigated bone loss around TL and BL implant sites in the esthetic zone. They concluded that peri-implant bone height did not depend on implant design [27]27. Their results are in accordance with the current study. In a systematic review, Vouros et al. in 2012, showed no statistically significant differences in bone loss between BL and TL implants over a period of 1 to 3 years [5]5.

Bone loss was significantly greater on the distal side of the implant for 3i Biomet system, Branemark and Straumann TL. Different techniques have been used in the literature for the radiographic measurements. Some studies used the ABL between mesial and distal side [4,12,17,38,39]4,12,17,38,39, others used each side of the implant (mesial and distal) as a unit [35]35 and others considered the site with the greatest bone loss as the representative of each implant [37]37. In their study in 2009, Linkevicius et al. used the mesial side and the distal side, then they calculated the bone loss on both sides and on average [9]9. Radiographic measurements revealed

Implant System	Implant diameter (mm)	Implant length (mm)	Frequency	Percent
3i Biomet	**3.25**	13.0	1	100.0
	3.75	8.5	2	10.0
		10.0	9	45.0
		11.5	7	35.0
		13.0	1	5.0
		15.0	1	5.0
		Total	**20**	**100.0**
	4.00	8.5	1	3.4
		10.0	17	58.6
		11.5	6	20.7
		13.0	4	13.8
		15.0	1	3.4
		Total	**29**	**100.0**
	5.00	10.0	1	50.0
		11.5	1	50.0
		Total	**2**	**100.0**
Branemark	**3.75**	8.5	1	6.3
		10.0	5	31.3
		11.5	6	37.5
		13.0	3	18.8
		15.0	1	6.3
		Total	**16**	**100.0**
	4.00	8.5	1	4.8
		10.0	14	66.7
		11.5	5	23.8
		13.0	1	4.8
		Total	**21**	**100.0**
	5.00	8.5	1	12.5
		10.0	4	50.0
		11.5	3	37.5
		Total	**8**	**100.0**
Straumann	**3.30**	10.0	1	100.0
	4.10	8.0	1	4.0
		10.0	10	40.0
		12.0	14	56.0
		Total	**25**	**100.0**
	4.80	8.0	2	11.8
		10.0	11	64.7
		12.0	4	23.5
		Total	**17**	**100.0**

Table 3: Implants diameter and length description.

	3i Biomet (Acid etched) (N=52)	Branemark (TiUnite) (N=45)	Straumann TL (SLA) (N=43)	p-value
Mesial Bone Loss	0.68 ± 0.74	0.61 ± 0.83	0.85 ± 1.25	0.48
Distal Bone loss	1.45 ± 0.74b	1.10 ± 0.84a	1.50 ± 0.80b	0.04
p-value	**<0.001**	**0.001**	**<0.001**	
Average bone loss	1.07 ±0.61	0.856 ±0.67	1.18 ±0.89	0.11

Table 4: Calculated bone loss for the 3 different implant systems at 10 years.
a, b: Different letters indicate the presence of a significant difference according to Tukey post-hoc tests.

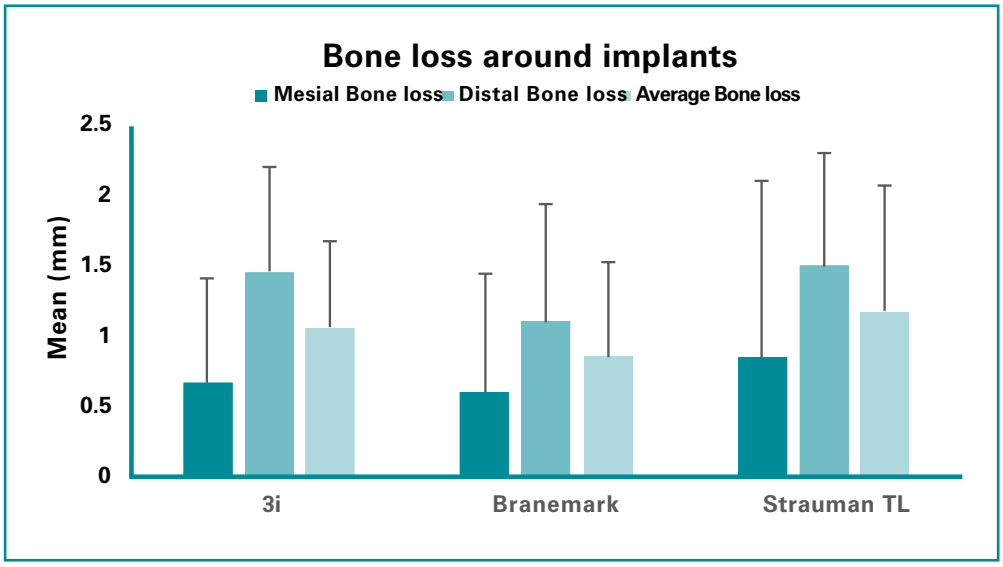

Table 5: ABL around the 3 different implant systems.

variations in the extent of bone loss between mesial and distal sites, as it was showed in our study. These differences can be explained by the fact that a flat alveolar ridge is not always available at the implantation site, as some implants can be placed on the ascending alveolar ridge. This resulted in different implant-abutment junction positions mesio-distally in relation to the bone crest [9]9.

Moreover, the purpose of surface modification of implant surfaces is to positively affect the host-to-implant tissue response. The modification methods can be divided into subtractive (i.e. blasting, etching or oxidation) and additive processes (i.e. titanium plasma spraying) [40]40. TPS surface was a common surface over a decade ago. Later, a sandblasted and acid-etched (SLA) surface was confirmed to yield an excellent survival rate. The TPS surface has an increased surface roughness compared to SLA. This feature should be particularly important in PCP, because micro-roughness is an important factor influencing the amount of plaque accumulation [35]35. In our study, the MBL and ABL didn't show any significant difference between the different implant surfaces. Our study shows the lowest MBL on the TiUnite, followed by the acid etched surface then by the SLA surface. The DBL was significantly lower on TiUnite compared to other implant surfaces. Dam et al in 2014 also proved that the SLA surface showed less bone loss than the TPS ($P < 0.05$) [11]11. In Berglundh's experiment in 2007, the radiographic examinations indicated that similar amounts of bone loss occurred at SLA and polished surface sites during the active breakdown period, while the progression of bone loss was larger at SLA than at polished sites following ligature removal. It is suggested that the progression of peri-implantitis, if left untreated, is more pronounced at implants with a moderately rough surface than at implants with a polished surface [41]41. This is in accordance with Doornewaard's review that suggests that CBL around minimally rough implant systems was significantly lower in comparison to the moderately rough and rough implant systems [42]42. In addition, De Bruyn et al demonstrated that SLA surface implants yielded less CBL than turned surfaces or TiUnite surface implants [40]40.

	Mesial Bone Loss (MBL)	Distal Bone Loss (DBL)	Average Bone loss (ABL)
Arch			
Maxillary	0.75± 0.92	1.25± 0.81	0.99 ± 0.73
Mandible	0.69 ± 0.98	1.44 ± 0.80	1.06 ± 0.74
p	0.71	0.18	0.62
Implant type			
Bone level	0.65 ± 0.78	1.29 ± 0.81	0.97 ± 0.64
Tissue level	0.85 ± 1.25	1.50 ± 0.80	1.18 ± 0.89
P	0.24	0.16	0.12
Hygiene level			
Good	0.65 ± 0.81	1.33 ± 0.75	0.99 ± 0.64a
Moderate	0.33 ± 1.29	1.23 ± 0.82	0.77 ± 0.88a
Fair	1.03 ± 0.92	1.56 ± 0.83	1.30 ± 0.73b
p	0.01	0.09	0.02
Restoration			
Unitary	0.61 ± 1.25	1.20 ± 0.87	0.91 ± 0.93
Multiple	0.76 ± 0.75	1.43 ± 0.77	1.10 ± 0.60
p	0.37	0.11	0.04
Smoking status			
No	0.72 ± 0.86	1.3 8± 0.80	1.05 ± 0.69
Light / Heavy	0.70 ± 1.31	1.27 ± 0.87	0.98 ± 0.89
p	0.93	0.53	0.68

Table. 6: ABL around the 3 different implant systems.

In our study, hygiene level was significantly associated with mesial and average bone loss. The hygiene evaluation was subjective and cannot be conclusive but still underlines the importance of complying with a strict SPT program to maintain bone level around implants.

Smoking was identified as a strong risk factor associated with peri-implant diseases, affecting the long prognosis of oral implants, a significantly greater failure rate in smokers was reported when compared to nonsmokers in a 6-year follow-up study [43]43. In our study, bone loss was not significantly different between non-smokers and smokers, the low percentage of smokers (22.7%) may have corroborated to better results and less bone loss. Dam et al showed that, after at least 5 years, CBL increased, approximately, for more than 25% in smokers. Implants in smokers showed a statistically higher values of CBL, over 1.5 mm than implants in non-smokers [11]11. Urdaneta et al also found a positive correlation between smoking and bone loss stating that a TPS-coated mandibular implant will more likely lose bone if the patient is a smoker [17]17. Karoussis et al. showed that smoking PCP yields a documented higher risk for implant loss than the non-smoking PCP or the PHP [43]43. In a prospective study, patients undergoing a successful smoking cessation protocol showed significantly higher implant-success rates compared to patients who continued smoking after implant placement. Therefore, the dentist should motivate the smokers for smoking cessation during the SPT sessions [43]43.

Furthermore, it has been proposed that splinting implant restorations could provide a better distribution of the occlusal forces among the inserted implants [12]12. Therefore, the effect of stress-related factors such as the type of opposing structure may be more significant around single implants than on splinted implants [17]17. Splinting has been recommended in the prosthetic rehabilitation of

implants placed in the posterior jaw in order to reduce CBL. However, the use of single units offers some advantages like better emergence profiles, improved passive fit of the metal framework and better oral hygiene access [17]17. In our study, 66.4% of the implant restorations were splinted. The results showed that the MBL, DBL and ABL were more elevated in the multiple-implant restoration group. In fact, the ABL was significantly more elevated in bridge restoration compared to single-implant restoration. The disproportion of sample could have tampered the results.

Finally, this study revealed that MBL, DBL and ABL were not significantly different between the maxilla and the mandible. There was a tendency for more bone loss in the mandible however, the difference was not statistacally significant. This is in agreement with Urdaneta et al in 2014 where higher CBL around mandibular implants was shown compared with maxillary implants [17]17.

There are some limitations for this study. First, as it is a retrospective study, there was a lack of proper radiographic standardization. The radiographs were not free of distortion, as the surrounding tissues inevitably create a certain distance between the films and the implant body. A prospective study with standardized radiographs would offer more precise results. Second, the measurement method in the study involved the risk of personal bias, as it was based on the examiners' impartiality when determining bone height values. With two repeated measurements at each site of the radiographic images, the appearance of errors has been kept to a minimum. In addition, the positive long-term outcomes may also have benefited from the fact that all implants were placed by experienced implant surgeons. The benefit is that subjects recruited from private clinics, rather than university clinics, provide information on the "effectiveness" rather than the "efficacy" of implant therapy.

Conclusions and perspectives

Today, poor oral hygiene is known as an important risk factor in the development and progression of peri-implant disease. It is of major importance to put every implant patient in a strict SPT program to maintain implant health. Besides, there is little evidence on the difference in behavior of BL versus TL implants in non-compliant patients. In this study, after a mean period of 10 years, no significant difference ($p > 0.05$) in CBL was found between TL and BL implants in non-compliant patients. Hygiene level was significantly associated with marginal bone loss.

Future research with larger samples is necessary to get more precise outcomes for a better comparison between bone level and tissue level implants in non-compliant patients. Furthermore, the difference in bone loss between the mesial and distal side of the implant should be questioned.

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