

Correlations of Peri-Implant Parameters with Plaque and Inflammation Indices in Posterior Fixed Implant-Prosthetic Rehabilitation: A Cross-Sectional Study

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ABSTRACT: Purpose. The aim of the study was to analyze the peri-implant clinical and radiological parameters and their correlations with the plaque index (mPI) and the inflammation index (GI) in fixed implant-prosthetic therapy. Materials and method. This research was a retrospective study including 48 patients with posterior partial edentulism (age: mean 63.04±10.723 years) treated by implant-supported metal-ceramic bridges, with a mean 6.19 years follow-up. A total of 166 implants were evaluated by clinical (peri-implant pocket depth-PPD) and radiological (peri-implant marginal bone loss-MBL) examen. Plaque index (mPI) and inflammation index (GI) were recorded for each implant site. Mean values of PPD, MBL (mesial), MBL (distal) were assessed. A comparative analysis was conducted regarding relation between PPD and MBL values (distal and mesial) in relation to the mPI and GI indices using the non-parametric Mann-Whitney and Kruskal-Wallis tests. Correlations between the variables PPD, MBL (mesial), and MBL (distal) for the entire study group were calculated by Pearson linear correlation coefficient. Results. There were very high positive correlations between pocket depth and mesial marginal bone loss ($r=0.951$, $p<0.001$; 95% CI: 0.934-0.964); pocket depth and distal marginal bone loss ($r=0.961$, $p<0.001$; 95% CI: 0.947-0.971), and mesial and distal bone loss values ($r=0.935$, $p<0.001$; 95% CI: 0.913-0.952). Conclusion. The findings indicate that peri-implant bone loss and pocket depth are strongly correlated and significantly influenced by plaque accumulation and inflammation, highlighting the critical role of the patients' oral hygiene in maintaining peri-implant tissue health.

KEYWORDS: Implant, plaque, inflammation, PPD, MBL, correlation.

Introduction

Peri-implantitis is a major factor to late dental implant failure, leading to progressive marginal bone loss and compromising the implant stability [1].

The evaluation of the correlations between peri-implant parameters and plaque (mPI) and inflammation (GI) indices can play an essential role in understanding the interrelationships among these variables and the importance of periodontal/peri-implant supportive therapy [2].

Studying these relationships allows the development of personalized approaches used to prevent or to treat the peri-implant pathology, thus contributing to increased dental implant success rates and their long-term maintenance [3].

The significant and bidirectional relationship between plaque index and bone loss, as well as between plaque index, marginal bone loss and periodontal/peri-implant pocket depth, demonstrates the interdependence of the clinical

and radiological parameters used in daily practice [4].

The role of plaque and inflammation in the onset of the pathological changes of the clinical and radiological parameters imposes a detailed assessment of the peri-implant pathology risk as well as the management of the oral conditions before the surgical phase.

The conversion from perimucositis to peri-implantitis is not yet understood histopathologically and clinically while peri-implantitis can develop early during follow-up with a non-linear and accelerating course [5].

Ethical and legal issues relate to various complications in many field of modern dentistry [6,7].

Thus, risk factors for implant failure must be addressed before starting treatment of patients eligible for fixed implant-prosthetic therapy.

Research groups found strong evidence identifying risk factors for peri-implantitis such as diabetes mellitus [7-9], history or presence of periodontitis [2,8,10,12,13], and smoking [8,10,13].

Along these factors, poor oral hygiene and non-compliance of patients to prophylaxis sessions are crucial in the onset and development of peri-implant pathology [8,11,13].

Functional time and number of implants per patient [14] as well as implant treatment delivered by general practitioners were also associated with higher risk of peri-implantitis [15].

Aim of Study

The aim of the study was to analyze the correlations of peri-implant parameters with the plaque index (mPI) and the inflammation index (GI) in fixed implant-prosthetic therapy.

Materials and Method

In this cross-sectional study 48 patients (mean age: 63.04±10.723 years; gender: 22 males, 26 females) with posterior partial edentulism were treated by implant-supported metal-ceramic bridges, with a mean follow-up of 6.19 years.

The same clinician with implantology and oral surgery specialisation treated all patients.

The study group was selected from Clinical Base of the Faculty of Dental Medicine, "Grigore T. Popa" University of Medicine and Pharmacy, Iași, Romania.

Prosthetic loading was made at 3 months after implant placement (patients with low resorption of alveolar bone) or between 4 and 9 months for patients undergoing bone augmentation procedures.

Inclusion criteria were as follows:

- ≥18 years of age;
- posterior edentulism with Kennedy Class I or II;
- treatment by implant-supported metal-ceramic bridges;
- minimum follow-up of 5 years.

The exclusion criteria were as follows:

- cantilever-type bridges;
- aggressive periodontitis;
- untreated bruxism;
- systemic diseases affecting the status of the peri-implant tissues (uncontrolled diabetes, osteoporosis);
- antibiotic therapy in the last 6 months.

Table 1 shows socio-demographic data, oral hygiene indices, and clinical edentulism features of the study groups (implant level).

Table 1. Distribution of dental implants related to socio-demographics, OHI and location.

		n	%
Gender	males	81	48.8
	females	85	51.2
Age groups	40-60 yrs.	61	36.7
	>60 yrs.	105	63.3
OHI	0-1	121	72.9
	2-3	45	27.1
Location (Mx/Md)	MD	80	48.2
	MX	86	51.8
Location (dental group)	F	3	1.8
	PM	64	38.6
	M	99	59.6

Clinical data regarding the status of peri-implant soft tissues were collected. The diagnosis of peri-implantitis was made according to recent criteria proposed by Heitz-Mayfield et al. (2020, 2024) [16,17]:

-clinical signs of inflammation located to the peri-implant soft tissues (erythema, edema, bleeding on probing, and/or suppuration);

-radiographically visible bone loss of at least 3mm;

-in the absence of a previous radiograph, peri-implantitis was diagnosed based on radiographically visible bone loss of at least 3mm (measured from the implant shoulder), associated with a probing depth of ≥6mm and the presence of bleeding on probing.

Radiological examination was performed using CBCT (Sirona Orthophos XG).

Measurements were carried out by an independent radiologist who was not involved in the study.

Marginal peri-implant bone loss (MBL) (the distance between the implant-abutment interface and the level of marginal peri-implant bone loss) calculated on the mesial and distal peri-implant areas with Sidexis XG/DVT (Dentsply/Sirona) with highest value used as the reference for peri-implant bone loss.

The degree of inflammation of the peri-implant soft tissues was assessed using the GI index [18].

The evaluation of GI was performed on four surfaces (mesial, distal, buccal, lingual/palatal) of 6 teeth. Each surface was examined for inflammation signs such as changes of colour, contour, or presence of edema.

Presence of bleeding and the gingival tissue consistency were assessed by passing gently a periodontal probe along the gingival margin.

Each surface was scored as follows: 0: Normal gingiva-no inflammation, normal color, lack of

bleeding. 1: Mild inflammation-reduced change of gingival tissues, lack of bleeding on probing; 2: Moderate inflammation-presence of bleeding on probing; 3: Severe inflammation-significant redness and edema, and spontaneous bleeding.

We summed the scores on each surface providing a GI value for each tooth, while total GI was calculated by averaging the scores of all the assessed teeth.

Oral hygiene status was evaluated using the mPI indices [19,20].

The modified Plaque Index (mPI) indicating the degree of plaque adhesion on the implant surfaces was measured on a 4-point scale (0-absent plaque; 1-plaque detected when probing of the implant surface; 2-medium degree of plaque accumulation; 3-high accumulation of plaque).

A mean score of all four teeth surfaces (buccal-B, lingual-L, mesial-M, and distal-D) was calculated.

In our study we recorded and assessed only mPI scores of 0 and 1.

Data Collection and Statistical Analysis:

All data were collected by the same practitioner.

Clinical and radiological data were recorded into an Excel database and were statistically analysed by SPSS, version 29 (SPSS Inc., Chicago, USA).

Peri-implant status data were collected at the implant level (PPD, mesial MBL, distal MBL).

The relation between PPD and MBL values (distal and mesial) and mPI and GI indices was analysed by using Mann-Whitney and Kruskal-Wallis tests.

The normal distribution law was determined by applying the Kolmogorov-Smirnov goodness-of-fit test.

For the analysis of associations between categorical variables (where applicable), we used the Pearson Chi-square test.

We also investigated the correlations between the variables PPD, MBL (mesial), and MBL (distal) for the entire group by calculating the Pearson linear correlation coefficient, its significance level, and the associated 95% confidence interval.

The interpretation of the Pearson correlation was as follows [21]: $r \leq 0.25$: very low correlation; $0.25 < r \leq 0.5$: weak correlation; $0.5 < r \leq 0.75$: moderate correlation; $0.75 < r \leq 0.9$: strong correlation; $r > 0.9$: very strong correlation.

Considerations of Ethics

The study received approval of Research Ethics Committee of UMF Grigore T. Popa Iasi (Romania) (ethics code 463/4.07.2024).

Participants received explanations regarding their voluntary participation, the anonymity of the provided data, and their right to withdraw from the study at any time.

Informed consent was consequently obtained from all subjects included in study.

Results

In a previous study we found a 19.9% prevalence rate of peri-implantitis with mean values of the peri-implant parameters as follows: 2.4973mm (PPD), 1.0322mm (MBL-mesial), and 1.0386mm (MBL-distal) [22].

Further, in this study, we explored the correlations of these clinical and radiological peri-implant parameters with inflammation and plaque indices (Tables 2-7).

Table 2. Descriptive statistics-PPD in relation to mPI and mGI.

Study group	N	Mean	SD	Mean std.error	Min	Max	Mediane	Mann-Whitney / Kruskal-Wallis test	
PPD	mPI 0	90	1.8672	0.64207	0.06768	1.25	4.25	1.60	U=1317.000
	1	76	3.2434	1.56152	0.17912	1.25	6.80	2.80	p<0.001**
	GI 0	115	1.8648	0.57720	0.05382	1.25	3.80	1.60	H=89.133
	1	33	3.2000	0.64976	0.11311	1.50	4.35	2.90	p<0.001**
	2	6	3.1500	0.79246	0.32352	2.30	4.25	3.05	
	3	12	6.3000	0.64597	0.18647	5.00	6.80	6.60	
Total	166	2.4973	1.34301	0.10424	1.25	6.80	2.15		

PPD based on the mGI and mPI Indices

Table 2 provides statistic data regarding the relationship of mPI and GI indices with PPD.

Mean PPD values stratified by mPI index (0 vs. 1): The average PPD values of implants with mP I=1 (3.2434±1.56152) are significantly greater than implants without mPI=0 (1.8672±0.64207).

Mann-Whitney U Test indicated statistical significance [U=1317.000, p<0.001] between mean PPD values for mPI=0 and mPI=1.

Differences were significant between PPD levels for GI 0-1 and GI 2-3 (Kruskal-Wallis test: H=89.133, p<0.001).

MBL based on mPI and mGI Indices

Statistical data regarding the distribution of MBL values in relation to mPI and GI indices are provided by Table 5.

Distribution of MBL (Mesial) in Relation to the mPI Index (0 vs. 1):

The mean mesial MBL values indicate that marginal bone loss is greater in implants with mPI=1 (1.8270±1.54334) compared to those with mPI=0 (0.3611±0.52616).

Mann-Whitney U test (U=982.500, p<0.001) indicates significant differences between the mean mesial MBL values associated with mPI=1 and those associated with mPI=0.

Mean MBL (Mesial) Values According to the mGI Index (0, 1, 2, 3):

Mesial MBL values increase progressively as mGI scores increase:

- GI=0: 0.4783±0.62176
- GI=1: 1.5015±0.77927
- GI=2: 1.2500±0.50000
- GI=3: 4.9417±0.27289

The Kruskal-Wallis test (H=74.134, p<0.001) indicates significant differences between the mean mesial MBL values associated with GI=3 and those associated with GI=0, 1, 2.

Distribution of MBL (Distal) in Relation to the mPI Index (0 vs. 1):

The mean distal MBL values are significantly higher in implants with mPI=1 (1.8539±1.86563) compared to those with mPI=0 (0.3500±0.62463).

The Mann-Whitney U test (U=1136.000, p<0.001) confirmed a statistically significant difference between the mean distal MBL values associated with mPI=1 and those associated with mPI=0.

Mean MBL (Distal) Values According to the GI Index (0, 1, 2, 3):

The mean distal MBL values progressively increase with higher GI scores:

- GI=0: 0.3043±0.43652
- GI=1: 1.7667±0.55575
- GI=2: 1.5833±0.84656
- GI=3: 5.8000±0.20338

The Kruskal-Wallis test (H=106.719, p<0.001) indicates a statistically significant difference between mean distal MBL for GI=3 and mean MBL values for GI=0, 1, 2.

Table 3. Descriptive statistics-MBL in relation to mPI and mGI.

Study group	N	Mean	SD	Mean std. error	Min	Max	Median	Mann-Whitney / Kruskal-Wallis test	
MBL (Mezial)	mPI 0	90	0.3611	0.52616	0.05546	0.00	2.00	0.00	U=982.500
	1	76	1.8270	1.54334	0.17703	0.00	5.30	1.50	p<0.001**
	mGI 0	115	0.4783	0.62176	0.05798	0.00	2.50	0.25	H=74.134
	1	33	1.5015	0.77927	0.13565	0.00	3.25	1.50	p<0.001**
	2	6	1.2500	0.50000	0.20412	0.75	2.00	1.25	
	3	12	4.9417	0.27289	0.07878	4.50	5.30	5.00	
Total	166	1.0322	1.32989	0.10322	0.00	5.30	0.625		
MBL (Distal)	mPI 0	90	0.3500	0.62463	0.06584	0.00	2.50	0.00	U=1136.000
	1	76	1.8539	1.86563	0.21400	0.00	6.00	1.125	p<0.001**
	GI 0	115	0.3043	0.43652	0.04071	0.00	2.00	0.00	H=106.719
	1	33	1.7667	0.55575	0.09674	1.00	2.50	1.65	p<0.001**
	2	6	1.5833	0.84656	0.34561	0.75	2.50	1.50	
	3	12	5.8000	0.20338	0.05871	5.50	6.00	5.85	
Total	166	1.0386	1.53538	0.11917	0.00	6.00	0.50		

PPD (Depth Levels) based on mPI and GI Indices

The relationship between PPD (depth levels) and mPI and mGI indices is presented through statistical data in Tables 4 and 5.

Association of PPD with mPI (0 vs. 1): PPD values differ between implants with mPI=0 and mPI=1 (m=0mPI versus m=0mPI).

In the mPI=0 implant group, most of the implants (73.3%) had PPD values 3mm.

In group of implants with PPD=1, only 19.7% of numbers had PPD values 3mm.

The proportion of implants with PPD between 2-3mm increased to 51.5% in the group with mGI=1, while the proportion with PPD>3mm accounted for 48.5%.

In mGI=2 group, 50.0% of implants had PPD between 2-3 mm and 50.0% had PPD>3mm.

All the implants related to mGI=3 group had PPD>3mm.

There was a statistically significant association between mGI indices and peri-implant pocket depth ($\chi^2=106.749$, $p < 0.001$).

Table 4. Statistical results-PPD depths in relation to mPI.

Study group	mPI (0/1/2)				Pearson Chi-squared test	
	0		1			
	N	%	N	%		
PPD	<2mm	66	73.3%	15	19.7%	Chi2=51.186 p<0.001**
	2-3mm	18	20.0%	30	39.5%	
	>3mm	6	6.7%	31	40.8%	
Total	90	100.0%	76	100.0%		

Table 5. Statistical results-PPD levels in relation to GI (study group).

Study group	GI (0/1/2/3)								Pearson Chi-squared test	
	0		1		2		3			
	N	%	N	%	N	%	N	%		
PPD	<2mm	81	70.4%							Chi2=106.749 p<0.001**
	2-3mm	28	24.3%	17	51.5%	3	50.0%			
	>3mm	6	5.2%	16	48.5%	3	50.0%	12	100.0%	
Total	115	100.0%	33	100.0%	6	100.0%	12	100.0%		

Distribution of MBL based on PPD Levels

Table 6: Referenced statistical data on the correlation between PPD (depth levels) and mPI and mGI indices in the study group.

MBL (Mesial) based on PPD Levels:

Mesial bone loss (MBL) progressively increases by the increase of PPD values:

-Implant sites PPD<2mm had a mean MBL value of 0.1481±0.22973mm.

-Implants sites with PPD between 2-3mm, had a mean MBL value of 1.0906±0.38311.

-Implants with PPD>3mm had a mean MBL value of 2.8919±1.57469.

MBL (Distal) based on PPD Levels:

Distal marginal bone loss (MBL) is progressively increased by the increase of PPD values:

-Implants sites with PPD<2mm had a mean MBL value of 0.0957±0.19987.

-Implants sites with PPD 2-3mm had a mean MBL value of 0.9115±0.40676.

-Implants sites with PPD>3mm had a mean MBL value of 3.2676±1.83618.

There are statistically significant differences between levels of PPD >3mm and PPD levels 2-3mm and 3mm, as the mean value of MBL significantly increased up to 3.2676±1.8361.

Table 6. Descriptive statistics-MBL in relation to PPD.

Study group		N	Mean	SD	Mean std. error	Min	Max	Median	Kruskal-Wallis test
MBL (Mesial)	PPD <2mm	81	0.1481	0.22973	0.02553	0.00	0.75	0.0000	H=129.159
	2-3mm	48	1.0906	0.38311	0.05530	0.00	1.55	1.0000	p<0.001**
	>3mm	37	2.8919	1.57469	0.25888	0.00	5.30	2.5000	
	Total	166	1.0322	1.32989	0.10322	0.00	5.30	0.625	
MBL (Distal)	PPD <2mm	81	0.0957	0.19987	0.02221	0.00	0.75	0.0000	H=138.619
	2-3mm	48	0.9115	0.40676	0.05871	0.25	1.75	1.0000	p<0.001**
	>3mm	37	3.2676	1.83618	0.30187	1.00	6.00	2.5000	
	Total	166	1.0386	1.53538	0.11917	0.00	6.00	0.5000	

Correlations between PPD, MBL (mesial) and MBL (distal)

Table 7 shows the correlations of PPD, MBL (mesial), and MBL (distal).

PPD and MBL (Mesial) correlation

A strong positive correlation exists between peri-implant pocket depth and mesial marginal bone loss ($r=0.951$).

This correlation was statistically relevant ($p<0.001$) requiring a consideration of the 95% confidence interval (0.934-0.964).

PPD and MBL (Distal) correlation

PPD correlates even stronger with distal marginal bone loss (MBL) with a coefficient of $r=0.961$.

This relationship is statistically significant ($p<0.001$), and the 95% confidence interval (0.947-0.971) reflects a very strong association.

Correlation between MBL (Mesial) and MBL (Distal)

Mesial bone loss is tightly correlated with distal bone loss ($r=0.935$).

This correlation is statistically significant ($p<0.001$) with a 95% confidence interval (0.913-0.952) which reveals a close association between the 2 variables.

Table 7. Pearson correlation: PPD-MBL, MBL (mesial)-MBL (distal).

Study group	Pearson Correlation	p-value	95% CI		Interpretation
			L. inf.	L. sup.	
PPD-MBL (Mesial)	0.951	<0.001**	0.934	0.964	Corel. positive, very strong
PPD-MBL (Distal)	0.961	<0.001**	0.947	0.971	Corel. positive, very strong
MBL (Mesial)-MBL (Distal)	0.935	<0.001**	0.913	0.952	Corel. positive, very strong

Discussions

The results obtained in our study underline the strong association between bacterial plaque accumulation and the deterioration of peri-implant clinical and radiological parameters.

In our study, the mean PPD was 2.50mm, ranging from 1.25mm (minimum value) to 6.80mm (maximum value).

These values indicate a wide distribution of this parameter.

In the study conducted on a group of patients with fixed implant-supported prosthetic treatment, Seki et al. (2017) reported a modified plaque index (mPI) of approximately 0.2, indicating minimal plaque accumulation, on a group of patients educated and aware of the importance of maintenance sessions and compliance to oral hygiene instructions [4].

Regarding the relationship between PPD and mPI indices in the study group, the Mann-Whitney U test indicated a statistically significant difference ($p<0.001$), suggesting a clear association between increased plaque index and periodontal pocket depth.

Concerning the relationship between PPD and GI indices, the Kruskal-Wallis test revealed a significant difference between groups ($p<0.001$), indicating that more severe gingival inflammation was correlated with an increase in peri-implant pocket depth.

The Mann-Whitney and Kruskal-Wallis tests confirmed the existence of statistically significant differences ($p<0.001$), suggesting the progression of peri-implant marginal bone loss both mesially and distally in relation to the degree of inflammation and bacterial plaque accumulation.

Regarding the relationship between PPD (depth levels) and mPI and GI indices, the Chi-square test ($p<0.001$) indicated a statistically significant association between mPI, GI, and the severity of peri-implant pockets, confirming that patients with higher levels of bacterial plaque and more advanced degrees of inflammation present associated to higher peri-implant pocket depths.

In our study, patients with a higher bacterial plaque index (mPI=1) had a significantly higher probability of presenting with deep peri-implant pockets (>3mm) compared to those with mPI=0.

Pearson Chi-squared statistical tests indicated highly significant associations ($p<0.001$), supporting the link between gingival inflammation, bacterial plaque accumulation, and more advanced stages of peri-implant tissue damage.

This result support a research group reporting a 1.365 times increase of risk of inflammation in soft peri-implant tissues for patients with high plaque scores [23].

Jepsen et al. (2010) highlighted the plaque accumulation as aetiological factor for the development of peri-implantitis, proper patient' plaque control (using manual or electric toothbrushes) was proved to be an effective

preventive measure, while professional oral hygiene instructions and mechanical debridement lead to a decrease of the clinical signs of peri-implant soft tissues inflammation [24].

The correlation between plaque and peri-implant pathology was proved by research groups that highlight that periodontal/peri-implant maintenance program is essential for the long-term outcome of implant treatments [9,25].

Prevalence of peri-implant inflammatory pathology in patients with a history of periodontal disease compliant to supportive periodontal therapy is significantly lower comparing to non-compliant patients [26,27].

Also, high plaque indices associated to active periodontitis increase the risk of peri-implantitis [28].

Our results in the overall sample are comparable to those from previous studies, which reported PPD values ranging from 2.52 to 3.8mm [29,30].

While in our study, we found statistically significant differences [$p < 0.001$] between mean PPD values of patients with mPI 0 versus mPI 1, a weak positive correlation was reported by Seki et al. (2017) between the probing pocket depth and the modified plaque index only for patients with periodontal history [4].

In the study conducted by Seki et al. (2017), 11.5% of implant sites had an average PPD value greater than 4 mm.

However, in the patient group with a history of periodontal disease, the mean PPD value was 3.33 ± 1.07 mm, significantly higher compared to the group of patients without a history of periodontal disease (2.87 ± 0.48 mm) [4].

We found a strong positive correlation of mPI 1 (when compared with mPI 0) and PPD values, a result that support the link between oral hygiene and the presence of peri-implant disease [31].

Also, our results regarding the PPD mean values and their distribution were similar with those reported by a research group reporting mean PPD values of 0.9 ± 1.1 mm mesially and 1.0 ± 1.2 mm distally.

The mean values of PPD were similar between implant areas (MV, V, DV, DL). A strong correlation was found between PPD measured at different points ($r^2 \geq 0.68$; $p \leq 0.001$) [32].

We found a very strong correlation between PPD and mesial MBL ($r=0.951$), statistically significant ($p < 0.001$), indicating an association between increased PPD and advanced peri-implant marginal bone loss.

The relationship was even stronger for distal MBL ($r=0.961$), while the correlation between mesial and distal MBL ($r=0.935$) suggests that bone resorption affects both areas in a similar manner.

In our study, MBL was 1.03mm, with a range from 0.00mm (minimum value) to 5.30mm (maximum value), suggesting significant differences between patients in terms of bone resorption at this level.

Tsaousoglou et al. (2023) found significant higher values mean MBL values, with MBL across all implants of 2.18 ± 1.57 mm, while implants diagnosed with peri-implantitis presented a mean bone loss of 4.42 ± 1.12 mm at over 12 months post-loading [31].

A research group reported significantly lower plaque scores in the right quadrants when compared to the left quadrants ($p=0.04$) were associated with lower MBL mean values, confirming that implants with visible bacterial plaque show significantly greater marginal bone loss both mesially and distally [32].

Also, our results support data provided by Muncu et al. (2019) on direct relation between plaque scores, PPD and MBL [33].

These results support data from the literature regarding the importance of bacterial plaque control and the prevention of soft tissue inflammation to limit peri-implant bone loss.

Patients with increased PPD experience also advanced peri-implant bone loss both mesially and distally, reinforcing the link between peri-implant inflammation and peri-implant bone resorption.

The correlations detected in the overall sample highlight a direct relationship between peri-implant pocket depth and the level of bone loss, emphasizing the need for early treatment, possibly even at the peri-mucositis stage, to prevent the progression of peri-implant pathology [34,35].

Moreover, our findings support the value of patients' compliance to regular maintenance therapy in preserving peri-implant health over long-term.

Some limitation of our study must be considered.

The study is cross-sectional, capturing data at a single point in time and thus limiting the ability to establish a causality relation between the degree of plaque/inflammation and the stage of peri-implant marginal bone loss.

Retrospective nature of this study may introduce recall or selection bias.

Due to focus on the posterior region, the results may not be relevant for implants in the anterior region, where functional and esthetic factors differ.

The selection of study group only from a single academic institution may limit the generalizability of data to other populations.

As clinical measurements (PPD, mPI, GI) were conducted by a single practitioner, this could lead to potential observer bias.

Future studies with microbial or inflammatory biomarker analysis could provide deeper insights into the correlation of peri-implant parameters with inflammation or plaque indices.

Other factors such as age, sex, education level, and socio-economic status can be considered in study design, to increase the impact on patients' awareness and adherence to oral hygiene measures and regular check-ups [34,35].

Conclusions

The findings showed statistically significant strong positive correlations between peri-implant pocket depth and marginal bone loss both mesially and distally as well as between mesial and distal marginal bone loss values, pointing to a highly reproducible relationship of clinical and radiological peri-implant parameters.

The results confirm that poor oral hygiene, reflected by increased plaque accumulation and severe inflammation, is closely associated with deeper peri-implant pockets and greater marginal bone loss, emphasizing the critical role of plaque control in preserving peri-implant tissue health.

Conflict of interest

None to declare.

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