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Original Article

Prosthetic emergence angle in different implant sites and their correlation with marginal bone loss: A retrospective study

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KEYWORDS
Dental implant;
Emergence angle;
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Abstract *Background/purpose:* The impact of prosthetic contour on peri-implant health has attracted increasing attention. This study aimed to evaluate the emergence angles in different implant sites and analyze the correlation between emergence angle and marginal bone loss (MBL).

Materials and methods: Single-crown implants with at least 5 years of follow-up were investigated in this retrospective study. Emergence angles and MBL were measured via digital radiography. The differences in emergence angles in different implant sites were analyzed using a one-way analysis of variance. Mann–Whitney U test was used to analyze the differences in MBL between groups (emergence angle$>30^\circ$ and $\leq 30^\circ$), and Spearman's rank analysis was used to analyze the correlation between emergence angle and MBL.

Results: A total of 502 single-crown implants were included. For the mean mesial and distal emergence angles of different implant sites, the anterior position were 21.67 ± 10.80 (°) and 22.48 ± 12.78 (°), and the premolar were 26.29 ± 12.78 (°) and 24.30 ± 10.07 (°), and the molar were 34.53 ± 13.27 (°) and 34.48 ± 13.58 (°) respectively. The emergence angles of molar implant sites were significantly greater than those of anterior and premolar ($P < 0.001$). The Mann–Whitney U test and Spearman's rank analysis revealed that there was no correlation between emergence angle and MBL.

Conclusion: There were significant differences in the emergence angles at different implant sites. However, when considering factors such as different sites or types of implants, there was no correlation between emergence angle and MBL, and more comprehensive research should be conducted in the future.

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Introduction

Osseointegration is the physiological basis for implant success.[1] The marginal bone around the implant crestal region is usually a significant indicator of implant health. By radiographic evaluation, the absence of bone loss beyond crestal bone-level changes resulting from initial bone remodeling is one of the diagnostic criteria for implant health in clinical practice.[2,3] Clinically, MBL around the implant can occur for many reasons. Infection or overloading of the implants has been the leading theory explaining MBL. Other influencing factors, including restoration contours, surgical implants, and systematic patient disorders, have attracted more attention in dental implantology.[4,5] Among these factors, restoration contours are crucial in facilitating favorable aesthetic outcomes and maintaining peri-implant health.[6] Poorly designed restoration contours can lead to unclean passages, causing plaque accumulation and peri-implant inflammation, as well as loss of adjacent contacts, which lead to food impaction, all of which can cause MBL.[7,8] Therefore, studying the restoration contours that can affect MBL is critical.

The glossary of prosthodontic terms describes two specific terms for restoration contours: the emergence angle and emergence profile. The emergence angle is defined as the angle of an implant restoration's transitional contour as determined by the relation of the abutment's surface to the implant body's long axis.[9] It is a familiar concept that has been used in clinical studies to describe the morphology of the gingival part of the restoration. Cross-sectional studies have shown a significant correlation between the emergence angle and MBL. In bone-level implants, a statistically higher incidence of peri-implantitis was observed when the emergence angle was $>30^{\circ}$ and the emergence profile was convex.[10] Similar conclusions were reached in a cross-sectional study by Yuseung Yi.[11] Majzoub et al. found that the emergence angle might affect the early-stage MBL of peri-implantitis.[12] The summary and consensus statements of group 3 in the 6th EAO Consensus Conference 2021 provide evidence that an emergence angle of $>30^{\circ}$, combined with a convex emergence profile of the abutment/prosthesis, is associated with an increased risk for peri-implantitis.[13] Also, it has been shown that a smaller emergence angle can maintain soft tissue stability in the aesthetic area and prevent soft tissue recession.[14] Still, other studies have reached contradictory conclusions. For example, Lops et al. found that the emergence angle did not influence the marginal bone-level change for implants with a stable internal conical connection and platform-switching of the abutment diameter.[15] Moreover, Inoue et al. found that MBL tended to decrease at an emergence angle of around 20°–40°, but the difference was not statistically significant ($P = 0.060$).[16] Therefore, the influence of the emergence angle on peri-implant MBL needs to be studied further.

In order to maintain the long-term health of an implant, the proper emergence angle is necessary. Matching implant platform dimensions to tooth dimensions has become a valuable tenet in case design. The closer the diameter of the implant platform is to the size of the target tooth, the smaller the emergence angle.[17] However, the mesiodistal crown diameters between the permanent molar and anterior and premolar differ significantly; the mesiodistal crown diameters of mandibular molars are even twice that of the mandibular anterior.[18,19] Therefore, the mesiodistal spaces of molars are more significant during implant treatment. Even so, this physiological and anatomical reason may cause different positions of restoration in the emergence angle to differ, but related research in this area has not been substantial to date.

Therefore, the primary purpose of this study was to compare the variation in the emergence angle of different implant sites and analyze the correlation between the emergence angle and peri-implant MBL.

Material and methods

Study subjects

This study was a retrospective study involving patients who underwent implantation and re-evaluation at the Peking University School and Hospital of Stomatology from January 2005 to December 2016. This study was reviewed and approved by the Biomedical Ethics Committee of Peking University Stomatological Hospital (Ethics Review Approval No. PKUSB-202162022), and approved guidelines and regulations were used in all of the protocols. The sample for this study was adopted from the prevalence study of single-crown implant restorations with more than 5 years of follow-up, and the inclusion criteria and exclusion criteria were consistent with those of the prevalence study.

The inclusion criteria were: 1. Age >18 years old; 2. Single-crown implant restoration; 3. At least 5 years of follow-up after the completion of implant restoration; and 4. At least one re-evaluation after completion of the implant restoration.

The exclusion criteria were: 1. Patients with long-term use of non-steroidal anti-inflammatory drugs and bisphosphonates; 2. Uncontrolled or poorly controlled systemic diseases (e.g., HbAlC >7% in diabetic patients); 3. Implant failure due to other reasons (e.g., fracture of the implant); 4. Replacement of the implant after the implant had been dislodged; 5. X-ray examination at baseline and re-evaluation without parallel projection technique; and 6. Patients with immediate restoration after implant surgery.

Radiographic measurement

The radiographs of the patients included in this study at baseline and the follow-up of implants were taken using the Digora Optime digital imaging system (Soredex, Helsinki, Finland) and Rinn holder (Dentsply, Charlotte,NC,USA) by the parallel projection technique. Radiographs at baseline

and revaluation were measured using the program ImageJ/FiJi, 1.46 (National Institutes of Health, Bethesda, MD,USA).

Measurement of the marginal bone level

The marginal bone level was defined as the distance from the implant platform (Ma, Da) to the most coronal intraosseous part at the mesial and distal aspects of the implant (Mb, Db). At baseline, the distance between the implant platform to the initial most coronal intraosseous part at the implant's mesial and distal aspects along the implant's long axis was (M^0, D^0) (Fig. 1). At re-evaluation, the distance between the implant platform and the subsequent most coronal intraosseous parts of the long axis of the implant was (M′, D′) (Fig. 2).

MBL: $\Delta M = M'\text{-}M^0$, $\Delta D = D'\text{-}D^0$

In order to reduce the measurement error, the known implant length was used as a reference for calibration.

Measurement of emergence angle

A straight line was drawn along the mesial and distal edge of the long axis of the implant, and the included angle between the lines tangent to the contour of the prosthesis was the emergence angle, and the mesial and distal emergence angles of the prosthesis were measured (Fig. 3).

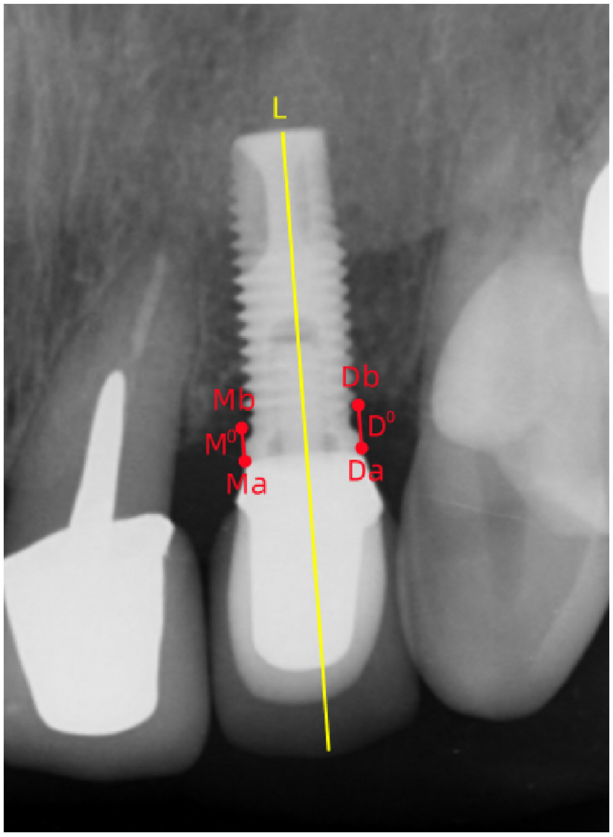

Figure 1 Measurement of the marginal bone level at the baseline. L: implant's long axis at the baseline; Ma: implant platform in the mesial site; Mb: the most coronal intraosseous part in the mesial site; Da: implant platform in the distal site; Db: the most coronal intraosseous part in the distal site; M^0: distance between Ma to Mb along L; D^0: distance between Da to Db along L.

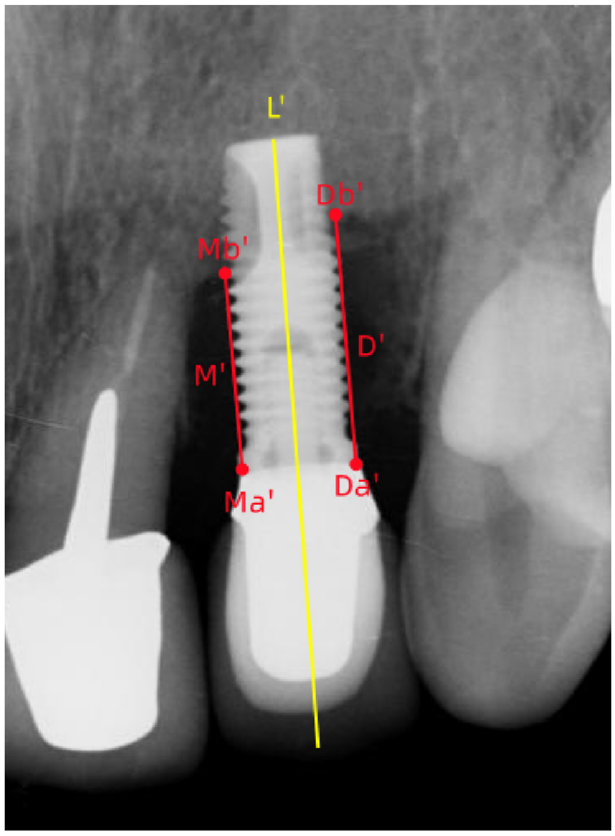

Figure 2 Measurement of the marginal bone level at re-evaluation. L': implant's long axis at re-evaluation; Ma': implant platform in the mesial site; Mb': the most coronal intraosseous part at mesial site; Da': implant platform in the distal site; Db': the most coronal intraosseous part in the distal site; M': distance between Ma' to Mb' along L'; D': distance between Da' to Db' along L'.

Radiographic measurements were performed twice by the same examiner, and the average of the two measurements was taken. The interval between the two measurements was more than 2 weeks. The self-consistency of the surveyor was high, and the Kappa value was more than 0.9 ($P < 0.05$).

Statistical analysis

SPSS 26.0 statistical software (IBM Corp., Armonk, NY, USA) was used for data collation and analysis. The measurement data were expressed as $x \pm s$ ("s" was standing for "standard deviation of the sample mean") if they conformed to the normal distribution, the measurement data were expressed as the median (upper and lower quartiles) if they did not conform to the normal distribution, and the Mann—Whitney U-test was used to compare the two groups. One-way ANOVA was used for comparison between multiple groups, and if homogeneity of variance was found, the LSD test was used for post hoc multiple comparisons; if homogeneity of variance was not found, the Dunnett's T3 test

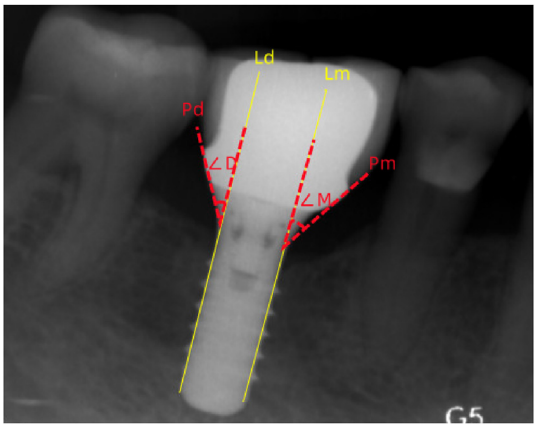

Figure 3 Measurement of the emergence angle. Lm: the implant's long axis line in the mesial site; Ld: the implant's long axis line in the distal site; Pm: the lines tangent to the contour of the prosthesis of the mesial site; Pd: the lines tangent to the contour of the prosthesis of the distal site; ∠M: prosthetic emergence angle of the mesial site; ∠D: prosthetic emergence angle of the distal site.

was used. Spearman rank correlation analysis was used for correlation analysis. $P < 0.05$ was considered to be a statistically significant difference.

Results

According to the inclusion criteria, 502 single-crown implants were included in this study. Among them, 75 implants were located in the anterior region, 114 were in the premolar region, and 313 were in the molar region. The follow-up time for implants was 94.46 ± 25.04 months; The general information of the implants (the distributions of location of the implants, diameter and length of the implants) is shown in Table 1.

Distribution of emergence angle in different implant sites

The mesial and distal emergence angle distributions of different implant sites are shown in Table 2. Among the anterior implants, 80% and 85.4% of emergence angles were <30°. Among the premolar implants, 74.6% and 73.7% of emergence angles were <30°. In the molar region, only 41.2% and 40.2% of emergence angles were <30°.

Comparison of emergence angle in different implant sites

The mean mesial emergence angle for implants located in the anterior was 21.67 ± 10.80 (°), and the mean distal emergence angle was 22.48 ± 12.78 (°). The mean mesial emergence angle for premolar implants was 26.29 ± 12.78 (°), and the mean distal emergence angle was 24.30 ± 10.07 (°). The mean mesial emergence angle for molar implants was 34.53 ± 13.27 (°), and the mean distal emergence angle was 34.48 ± 13.58 (°) (Table 3). One-way ANOVA showed that the differences between the three implant sites were statistically significant in the comparison

Table 1 General characteristics of different dental implant sites.

Variable		Anterior		Premolar		Molar	
		N	%	N	%	N	%
Position	Maxillary	64	85.3	75	65.8	114	36.4
	Mandible	11	14.7	39	34.2	199	63.6
Implant diameter (mm)	D ≤ 4	46	61.3	37	32.5	13	4.2
	4 < D ≤ 4.5	29	38.7	69	60.5	67	21.4
	D ≥ 4.8	0	0	8	7	233	74.4
Implant length (mm)	L < 8	0	0	4	3.5	19	6.1
	L = 8	1	1.3	11	9.6	37	11.8
	L = 10	16	21.3	76	66.7	234	74.8
	L > 10	58	77.4	23	20.2	23	7.3

Abbreviations: D (Implant diameter), L (Implant length).

Table 2 Distribution of emergence angle at different implant sites.

Emergence angle (°)	Anterior				Premolar				Molar			
	Mesial		Distal		Mesial		Distal		Mesial		Distal	
	N	%	N	%	N	%	N	%	N	%	N	%
1–10	11	14.70	5	6.70	6	5.30	6	5.30	5	1.50	4	1.40
11–20	27	36	41	54.70	37	32.50	40	35.10	39	12.50	42	13.50
21–30	22	29.30	18	24	42	36.80	38	33.30	85	27.20	79	25.30
31–40	12	16	6	8	13	11.40	21	18.40	90	28.80	104	33.30
>40	3	4	5	6.60	16	14.0	9	7.90	94	30	84	26.5

Table 3 Comparison of emergence angle in different implant sites.

Position	Anterior ($n = 75$)	Premolar ($n = 114$)	Molar ($n = 313$)	P_1	P_2	P_3
Mesial	21.67 ± 10.80	26.29 ± 12.78	34.53 ± 13.27	0.016	<0.001	<0.001
Distal	22.48 ± 12.78	24.30 ± 10.07	34.48 ± 13.58	0.338	<0.001	<0.001

Note: P_1 represents the comparison results of anterior and premolar, P_2 represents the comparison between anterior and molar, P_3 represents the comparison between premolar and molar.

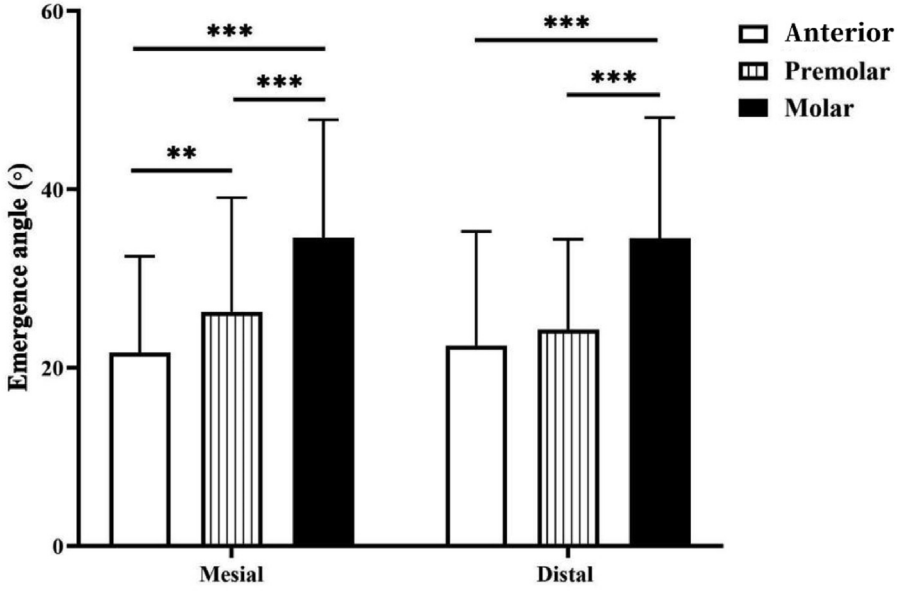

Figure 4 Comparison of emergence angle in different implant sites (mesial/distal). Note: *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

of the emergence angle (mesial) ($F = 39.277$, $P < 0.001$) and emergence angle (distal) ($F = 43.569$, $P < 0.001$). Post hoc multiple comparisons showed that the mesial emergence angle of molar implant sites was more than that of premolar and anterior implant sites ($P < 0.001$). The distal emergence angle of molar implant sites was greater than that of the anterior and premolar implant sites, and the difference was statistically significant ($P < 0.001$) (Fig. 4).

Comparison of marginal bone loss in different implant sites for emergence angle > 30° and ≤ 30°

The Mann–Whitney U test revealed that the differences were not statistically significant when comparing the amount of MBL for emergence angle >30° and ≦30° for anterior, premolar and molar implant sites. ($P > 0.05$) (Table 4).

Correlation of marginal bone loss with emergence angle

The MBL and the emergence angle for implants were analyzed separately in the anterior, premolar, and molar regions. Spearman's rank correlation analysis revealed no correlation between the emergence angle and MBL ($P > 0.05$) (Table 5).

Table 4 Comparison of MBL for emergence angle >30° and ≤30°.

Position	Emergence angle (°)	MBL (mm)	Z-value	P-value
Anterior	>30	0 (0 , 1.22)	−0.863	0.388
	≤30	0.29 (0 , 1.38)		
Premolar	>30	0 (0 , 0.91)	−0.524	0.600
	≤30	0 (0 , 0.60)		
Molar	>30	0 (0 , 0.43)	−0.968	0.333
	≤30	0 (0 , 0.25)		

Abbreviation: MBL (marginal bone loss).

Table 5 Correlation analysis of emergence angle and MBL.

Position	MBL	
	r_s	P
Anterior	0.071	0.390
Premolar	−0.035	0.601
Molar	−0.039	0.333

Abbreviation: MBL (marginal bone loss).

Discussion

This retrospective study included single-crown restoration implants with more than 5 years of follow-up. The study compared the differences in the emergence angle in different implant sites and analyzed the correlation between emergence angle and peri-implant MBL.

This retrospective study measured and analyzed the emergence angle of 502 single-crown implant restorations; 75 were anterior implants, 114 were premolar implants, and 313 were molar implants. The mean values of the emergence angles in the molar regions were higher than those in the anterior and premolar regions ($P < 0.05$). Although no studies have been done on the emergence angle for natural molars, previous studies estimated that the emergence angles of the natural anterior teeth were 10°–15°. The average emergence angles in this study were 21°–22° for implants located in the anterior, which was higher than the emergence angles of the natural teeth.[20,21] The emergence angle of the implants was related to the implant diameter and the target tooth position, (Dixon and London, 2000 2019) 17 The width of the mesiodistal diameters of the natural molars is greater than those of the anterior and premolar regions, resulting in a larger implant space in the molar region. As shown in Table 1, the implant diameters in the anterior implant were all less than 4.5 mm, while 75% of the implants in the molars were >4.8 mm in diameter. Clinically, although the diameter of implants used in the molar area is generally more extensive than that of anterior and premolar, the ratio of the volume of the missing tooth to the diameter of the implant is difficult to conform in different implant sites. However, as several factors influence the emergence angle, (Dixon and London, 2000 2019) 17 prospective studies are still needed to investigate the cause of this discrepancy.

Previous animal studies found increased attachment loss in the 30° over-contour groups compared to the regular crown group, with statistically significant differences. (Kohal et al., 2003) [22] Based on this, previous clinical studies investigated the relationship between the emergence angle of 30° and the MBL. It has been found that an emergence angle over 30° is a risk factor for peri-implantitis in bone-level implants, significantly affecting early-stage MBL in peri-implantitis. (Katafuchi et al., 2018; Majzoub et al., 2021) 10,12 However, in the present study, 80% of the implants located in the anterior had an emergence angle <30°, while in the molar region, 60% of the implants had an emergence angle >30°. In the present study, there was no difference in MBL with the emergence angle >30° and ≤30° in different implant sites, and the present study found no correlation between the emergence angle and MBL. The reason may be that in most previous studies on the emergence angle and MBL, no distinction was made between the implant sites. Also, this study included both bone-level and tissue-level implants, and the implant type was not analyzed as a variable. Studies that did not differentiate between implant types came to similar conclusions. (Lops et al., 2022) [23] Moreover, because this was a retrospective study, the mean re-evaluation period for implants in this study was 22 months, and there was no significant correlation between the emergence angle and MBL a year after the diagnosis of peri-implantitis in the study, which was done in 2021.[12] Moreover, as this study found a significant difference in the range of emergence angles for different implant sites, whether implants in different tooth positions all being 30° is a risk factor for MBL still needs more research.

The incidence of marginal bone resorption (>0.5 mm) at the implant level for more than 3 years in cross-sectional studies was 16% at the implant level and 30% at the patient level. (Cecchinato et al., 2013) [24] As one of the possible causes of MBL, the restoration profile must be considered during the treatment process. For the anterior region, the emergence angle of the natural teeth can be used to guide the three-dimensional position of implant placement. In contrast, the implant diameter should be chosen as close as possible to the target tooth position provided that the bone plate meets the requirements. (Dixon and London, 2000 2019; Scutellà et al., 2015) [17,25] The results indicate that there are differences in the emergence angle of implants in different implant sites, and the differences are statistically significant, providing a basis for further research on the reasonable range of emergence angles in different implant sites.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgments

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