The Impact of Implant Abutment Angle and Height on Peri-implant Tissue Health: Retrospective Analyses from a Randomized Controlled Clinical Trial

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Purpose: To examine the influence of abutment emergence angle and abutment height on marginal peri-implant bone stability in patients not considered susceptible to peri-implantitis. Furthermore, it was analyzed whether titanium-base (Ti-base) abutments lead to wider abutment emergence angles compared to one-piece abutments. ***Materials and Methods:*** A total of 48 abutments (ie, 24 Ti-base and 24 one-piece abutments in 24 patients) were evaluated at abutment installation, after 1 year, and thereafter on a yearly basis for up to 5 years. Clinical and radiographic outcome variables were assessed. ***Results:*** With regard to peri-implant marginal bone stability, only moderately negative, albeit significant, correlations were found on the mesial sides of the one-piece abutments after 4 and 5 years for an abutment emergence angle > 30 degrees. No statistically significant negative correlations were found for distances of ≤ 1.5 mm between the restoration margin and the crestal peri-implant bone level for either Ti-base or for one-piece abutments. Furthermore, abutments bonded to Ti-bases were not associated with larger emergence angles than one-piece abutments. ***Conclusions:*** For patients at low risk of developing peri-implantitis, it can be concluded that neither a larger abutment emergence angle (> 30 degrees) nor a distance of ≤ 1.5 mm between the restoration margin and the crestal peri-implant bone level are associated with marginal peri-implant bone loss. Furthermore, abutments bonded to Ti-bases are not associated with wider emergence angles than one-piece abutments. *Int J Prosthodont 2024;37:16–26. doi: 10.11607/ijp.8138*

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The long-term success and survival of implant-supported fixed dental prostheses (FDPs) ultimately depends on peri-implant soft-tissue health along with marginal peri-implant bone stability.[1] Both soft-tissue health and marginal bone stability are known to be influenced by patient-related factors (eg, systemic conditions/diseases and soft-tissue phenotype) and therapeutic factors (eg, surgical procedures and prosthodontic rehabilitation).[2]

Regarding prosthodontic factors, the type of implant-abutment connection (eg, platform-matched or platform-switched), abutment material, abutment design (eg, emergence angle and concaveness or convexness), and height are of interest.[1,3–10] In particular, abutment height—with an even stronger influence than soft-tissue phenotype—is discussed as an influencing factor for marginal peri-implant bone stability.[1,6,7] In line with abutment height, the influence of abutment design has recently received increasing attention. Thus, Katafuchi et al[5] showed a negative effect of wide emergence angles and convex emergence profiles on the prevalence of peri-implantitis. This effect has been confirmed in a recent cross-sectional study by Yi et al.[9] Conversely, no negative effect of wide emergence angles on peri-implant bone stability could be found in a cross-sectional study by Hentenaar et al.[8]

In this respect, the trend toward CAD/CAM implant abutments or crowns bonded to titanium bases (Ti-bases) is of interest. It can be speculated that the 90 degree angle between the abutment shaft and platform of Ti-bases in combination with a platform height of at least 0.8 mm may in general favor wider emergence angles and thereby potentially influence marginal peri-implant bone stability.

Therefore, the current investigation's objectives were to examine the long-term (5 years) effect of abutment emergence angles and abutment height on marginal peri-implant bone stability in patients not considered susceptible to peri-implantitis, and to investigate whether abutments bonded to Ti-bases are associated with wider emergence angles compared to one-piece abutments.

It was hypothesized that wider abutment emergence angles and distances of < 1.5 mm between restoration margins and crestal peri-implant bone levels would be associated with a negative effect on marginal peri-implant bone stability (ie, marginal peri-implant bone loss). Further, it was hypothesized that abutments bonded onto Ti-bases would be associated with wider emergence angles compared to one-piece abutments.

MATERIALS AND METHODS

Data of a terminated split-mouth, double-blind, randomized, controlled, clinical trial (RCT) to investigate the influence of adhesive abutments (ie, implant abutments bonded to Ti-bases) on peri-implant health—performed in compliance with the CONSORT checklist, executed in a private office (F.R. and M.S.), approved by the Medical Ethics Committee of the University of Freiburg (013/1630), and registered in the German Clinical Trials Register (DRKS00006163, 2014-05-21)—were retrospectively assessed.

Study Population and Sample Size Calculation of the Original Clinical Trial

Because scientific data for differences in MBL between Ti-base and one-piece abutments were lacking, sample size calculation could not be performed. However, it was presumed that a total of 24 patients, each with one test and one control implant, might be suitable for a meaningful post-hoc power calculation. Thus, a total of 24 patients from the private office of implantology and periodontology (8 men and 16 women; between 28 and 76 years of age) who were at least 18 years old (ie, capable of giving consent), had an ASA score of 1, were nonsmokers, had a full mouth plaque index (FMPI) under 20% and a full mouth bleeding index (FMBI) under 20%, had no history of periodontitis, were scheduled for the treatment with at least two nonadjacent dental implants, and had signed an informed consent form were enrolled in the original clinical trial. In addition, pregnant or breastfeeding patients as well as patients in whom simultaneously peri-implant augmentations had to be performed were excluded. Participants were recruited from March 2014 until May 2015. All dental implants placed (Conelog, Camlog Vertriebs) had an internal connection with a 7.5-degree conus and were platform-switched.

It should not remain unmentioned that in fact, as part of the data analysis of the original study, a post hoc power analysis was able to find a power of 58% (calculation with G*Power, HHU) for a DMBL intragroup comparison.

Study Design of the Original Clinical Trial

The flow chart of the clinical trial is shown in Fig 1. In brief, at Visit 1 (V1) patients were screened (F.R. or M.S.) according to the inclusion/exclusion criteria. Thereafter, qualified patients signed the informed consent form. Implant surgery was performed at Visit 2 (V2). After a submerged healing period of 3 months, healing abutments were connected to the implants (Visit 3, V3). After 3 more weeks, impressions were taken (Visit 4, V4). Implants were randomly allocated to either the test or the control group. The test abutments were individualized CAD/CAM-titanium abutments bonded to Ti-bases (test group, Ti-base), whereas control abutments were individualized one-piece CAD/CAM-titanium abutments (control group, one-piece abutment). At Visit 5 (baseline, V5), the test and control abutments were connected to the implants and restored with all-ceramic crowns. After 1 year (Visit 6, V6) and thereafter on a yearly basis for up to 5 years (Visits 7 to 10, V7 to V10), predetermined clinical and radiographic outcome variables were assessed. All patients were enrolled in an individualized supportive peri-implant therapy program in the private office.

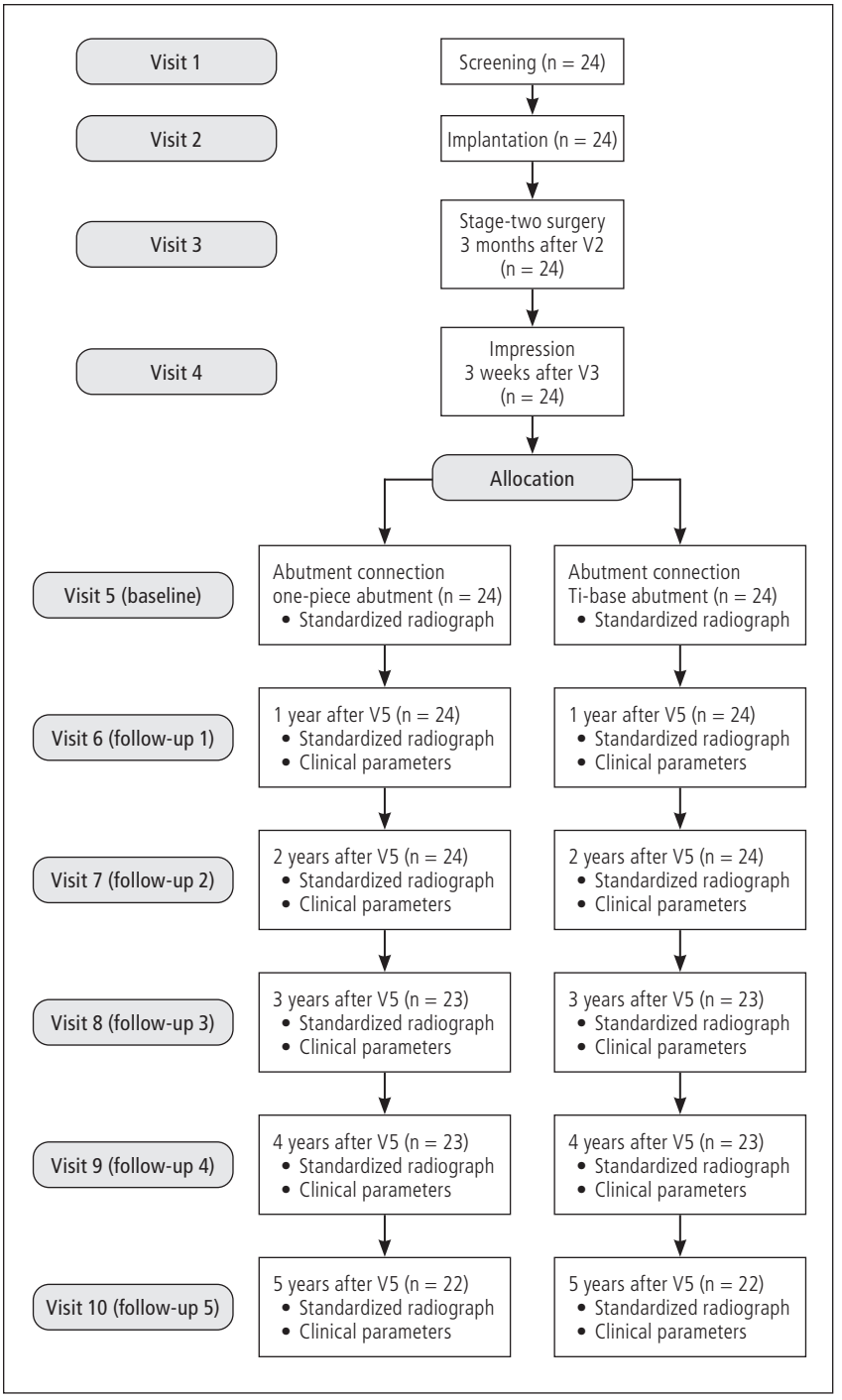

Fig 1 Timeline of the study.

Randomization and Blinding of the Original Clinical Trial

Random implant allocation to the test or control group was done by an independent study nurse by coin tossing. Thereafter, the study nurse kept the implant assignment in a sealed envelope. The implant assignment was only revealed to the dental technician. The patient, prosthodontist, and investigator (F.R.) remained blinded.

Outcome Variables of the Original Clinical Trial

Marginal peri-implant bone level (MBL) was chosen as the primary outcome variable. Local plaque index at abutments (LPab), local bleeding index at abutments (LBab), probing pocket depth at abutments (PPDab), and recession at abutments (RECab) were chosen as secondary outcome variables

Radiographic Assessment of the Primary Outcome Variable of the Original Clinical Trial

In the original trial, one investigator (J.B.) performed all radiographic measurements and calculations for the primary outcome variable (marginal peri-implant bone level, MBL). These marginal, peri-implant bone level data were used for the current retrospective assessment. In brief, the parallel technique was used to take periapical radiographs for interproximal bone level evaluation. To ensure standardization, XCP dental film holders (XCP Evolution 2000, Dentsply Sirona) were individualized with a dental silicone (Metal-Bite, R-Dental).[11] An imaging software (DBSWIN, Dürr Dental) with an implemented measurement tool was used for linear interproximal bone level measurements. Reference points for the linear measurements were the first (ie, most coronal) bone-to-implant contact point (first BIC) and the coronal margin of the implant shoulder. Linear measurements were taken from the first BIC parallel to the long axis of the implant to the corresponding point of the implant shoulder (ie, perpendicular to the coronal margin of the implant shoulder). To compensate for distortions, the software was calibrated for each radiograph using the known length of the implant. Bone level changes at mesial and distal implant sites were calculated. Beforehand, intraexaminer calibration was performed for the examiner (J.B.) on radiographs not belonging to the original clinical

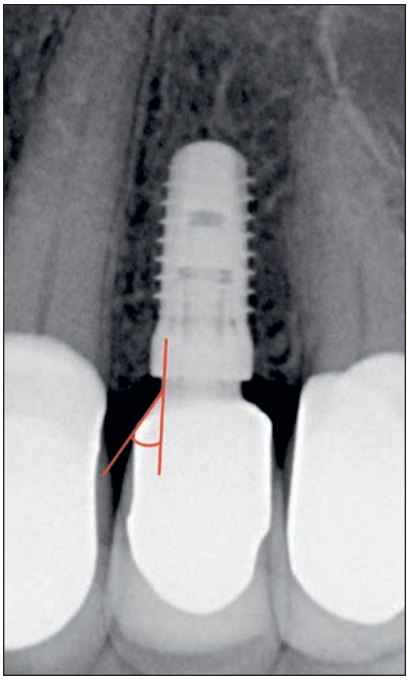

Fig 2 Measurement of abutment emergence angle according to Katafuchi et al[5] (EA-K).

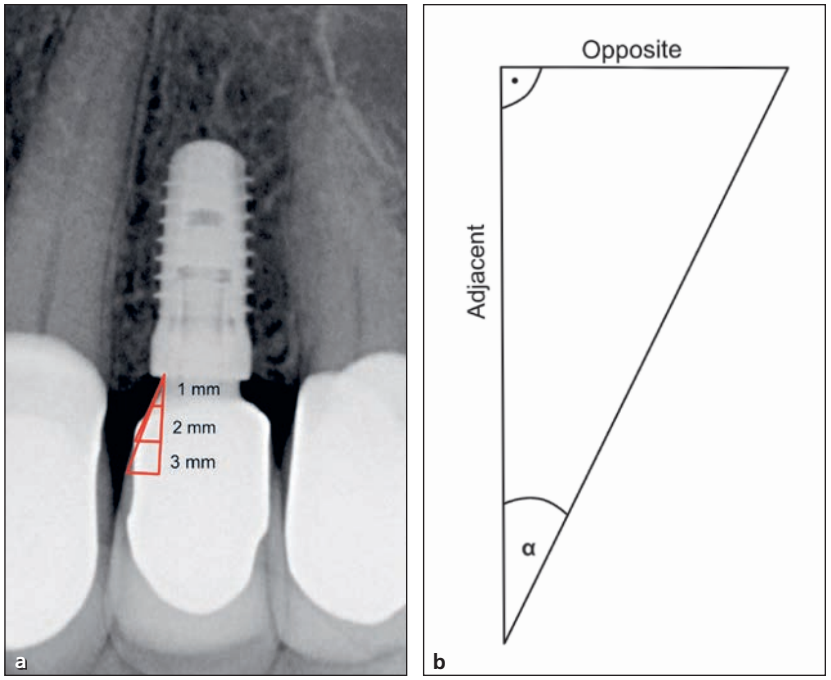

Fig 3 *(a)* Measurement of abutment emergence angle according to Hentenaar et al[8] (EA-H); *(b)* tan α = opposite side/adjacent side was used to compute the abutment emergence angle at the three heights measured.

trial. Therefore, the study nurse prepared 50 periapical radiographs showing single crown restorations on implants of the same type as in the original trial with a known length to calibrate the measurement. Radiographs were pseudonymized with a three-digit, consecutive number (101 to 150) and stored. For calibration, 20 of these radiographs were randomly selected by the study nurse and assessed by the examiner (J.B.). The corresponding measurement data was saved as initial measurement data. After 3 weeks, the examiner (J.B.) repeated the measurements without knowledge of the initial data. These measurements were saved as second measurement data. Subsequently, the first (initial) and second measurement data were evaluated and compared and the quality of the pairwise agreement was documented (M.S.).

Assessment of Outcome Variables (Radiographic Assessment) of the Current Retrospective Analysis

For the current retrospective evaluation, additional measurements on the radiographs taken at V5 (baseline) were performed independently—after intra- and inter-examiner calibration (according to the calibration for the examiner [J.B.] in the original trial, data not shown)—by two examiners (N.L. and L.M.). In brief, the implant crown's emergence angle was first measured mesially and distally between a line parallel to the long axis of the implant at the abutment shaft (vertical line) and the tangents to the mesial and distal crown's contour resulting in the greatest angle to the vertical line, as described by Katafuchi et al[5] (EA-K; Fig 2). Next, it was measured mesially and distally between a line parallel to the long axis of the implant at the abutment shaft and the corresponding tangents to points of the crown's mesial and distal contour at distances of 1 mm, 2 mm, and 3 mm parallel to the implant shoulder, as described by Hentenaar et al[8] (EA-H; Fig 3). Further, the linear distance from the marginal bone crest to the restoration margin (ie, perpendicular from a horizontal line at the marginal bone level to a parallel line through the restoration margin) was measured.[1] As described previously, to compensate for distortions, the software was calibrated for every single radiographic image using the known length of the implant.

These measurements were done to correlate the emergence angle and abutment height with peri-implant data (eg, marginal, peri-implant bone level changes) and to investigate whether abutments bonded onto Ti-bases were associate with wider emergence angles compared to one-piece abutments.

Assessment of the Secondary Outcome Variables of the Original Clinical Trial

In the original study, one experienced periodontist (F.R.) executed all clinical measurements and calculations. All measurements were made with a pressure-sensitive,

Table 1 Patient and Implant Characteristics

Characteristics	No.	%
Sex		
Female	17	71
Male	7	29
Implant region		
Anterior	7	15
Premolar	17	35
Molar	24	50
Implant position		
Interdental	7	15
Noninterdental	41	85
Implant type: bone level	48	100
Implant brand: Camlog/Conelog	48	100
Implant-abutment connection: a platform-switched internal connection with a 7.5-degree cone	48	100
Implant length		
9 mm	41	85
11 mm	7	15
Implant diameter		
3.8 mm	16	33
4.3 mm	17	36
5.0 mm	15	31

calibrated (0.2 N), color-coded (3/5/7/9) probe (Click-Probe, Kerr) at six sites per tooth or implant: mesiobuccal, buccal, distobuccal, distopalatal, palatal, and mesiopalatal.

The following clinical measurements and calculations were performed:

- Full-mouth plaque index (FMPI): Plaque (present = 1, absent = 0) and calculated as percentage of all sites; measured at V1.
- Local plaque index at abutments (LPIab): Plaque (present = 1, absent = 0) and measured at six sites per abutment; measured at V5 to V10.
- Full-mouth bleeding index (FMBI): BoP (present = 1, absent = 0) and calculated as percentage of all sites measured at V1.
- Local bleeding index at abutments (LBIab) measured at six sites per abutment BoP (present = 1, absent = 0) measured at V5 to V10.
- Probing Pocket depth at abutments (PPDab) measured at six sites per abutment at V5 to V10.
- Recession at abutments (RECab) measured at six sites per abutment at V5 to V10.

Abutments and Single Crowns

All abutments were designed and, after milling, further processed by one dental technician. Both the one-piece abutments (control) as well as the titanium cores of the two-piece abutments (to be bonded to Ti-bases; test) were milled by Dedicam (Camlog Biotechnologies). For two-piece abutments, both pieces—the titanium base (Ti-Base) and core—were sandblasted with 50-µm aluminum oxide at max 2.0 bar and cleaned from dust and grease by evaporation and using alcohol. Under ×10 magnification, Panavia F 2.0 (Kuraray Noritake Europe) was used for bonding the titanium base to the titanium core according to the manufacturer's specifications. Finally, it was not possible to distinguish control and test abutments by their external appearance.

For both abutment types, single crowns were milled out of zirconia and individualized with a veneering ceramic by the same dental technician. After checking the occlusion and approximal contact points, the single crowns were cemented with a carboxylate cement (Durelon, 3M). To avoid excess cement, the crowns were first connected to a cement stump before they were definitively cemented to the abutment.

Statistical Analysis

Measurements of the two independent examiners (N.L. and L.M.) were averaged before statistical evaluation was performed. Quantitative parameters were descriptively presented as mean, SD, minimum and maximum, and quartiles. Because those parameters were not normally distributed (Kolmogorov-Smirno test, $P < .05$), analysis was performed using nonparametric methods. Two independent samples (groups) were compared in those parameters using the nonparametric Mann-Whitney *U* test. To statistically evaluate the dependence between two quantitative nonnormally distributed parameters, Spearman correlation analysis was chosen. Statistical tests were performed two-sided at a significance level of 5%. Due to the descriptive nature of the present analysis, no alpha adjustment for multiple testing was applied, and the results were interpreted accordingly. Statistical analyses were done with SPSS Statistics 26 (IBM). Statistical analysis was executed by Medistat.

RESULTS

A total of 48 dental implants were placed in 24 patients. All patient and implant characteristics are summarized in Table 1. At stage-two surgery, after a healing period of 3 months, all implants were osseointegrated. None of the implants were lost during the entire study period. One patient dropped out after the 2-year follow-up because she moved to Northern

Table 2 Mesial Emergence Angle (EA-K and EA-H) of Ti-base and One-Piece Abutments and Their Correlation with MBL at Different Time Points

	EA-K/EA-H		MBL mesial V8	MBL mesial V9	MBL mesial V10
Ti-base	Mesial (> 30 degrees)	Correlation coefficient [R]	0.102	0.014	0.166
		P value	.645	.948	.461
		N	23	23	22
	Mesial 1-mm height	Correlation coefficient [R]	0.108	0.128	0.178
		P value	.624	.561	.428
		N	23	23	22
	Mesial 2-mm height	Correlation coefficient [R]	–0.008	–0.165	–0.033
		P value	.971	.452	.886
		N	23	23	22
	Mesial 3-mm height	Correlation coefficient [R]	0.023	–0.111	–0.033
		P value	.916	.616	.886
		N	23	23	22
One-piece	Mesial (> 30 degrees)	Correlation coefficient [R]	0.405	0.468	0.508
		P value	.055	.024*	.016*
		N	23	23	22
	Mesial 1-mm height	Correlation coefficient [R]	0.094	0.212	0.215
		P value	.671	.331	.337
		N	23	23	22
	Mesial 2-mm height	Correlation coefficient [R]	0.359	0.443	0.463
		P value	.093	.034*	.030*
		N	23	23	22
	Mesial 3-mm height	Correlation coefficient [R]	0.363	0.411	0.456
		P value	.089	.051	.033*
		N	23	23	22

Spearman-Rho, *$P < .05$ significance level.

Germany. One further patient did not appear to the 5 year-follow up appointment due to the Covid-19 pandemic. The mean follow-up time was 4.83 years. Two implants from two different patients were diagnosed with peri-implantitis at V9 (one-piece abutment) and V10 (Ti-base abutment), respectively. *Peri-implantitis* was defined as having PPD > 5 mm, BoP+, and showing a progressive bone loss beyond crestal bone level changes resulting from initial bone remodeling (MBL at V6).[12]

Correlation between Emergence Angle and Marginal Peri-implant Bone Level

For mesial sites of EA-K with a threshold value of over 30 degrees, moderate (R = 0.4 to 0.5)—although statistically significant ($P < .05$)—correlations were found at V9 and V10. For EA-H measurements at V9 and V10 for 2 mm and at V10 for 3 mm, moderate (R = 0.4 to 0.5), although statistically significant ($P < .05$)—correlations were found. For mesial sites of Ti-base abutments as well as distal sites of one-piece and Ti-base abutments, neither EA-K nor EA-H showed statistically significant ($P < .05$) correlations (Tables 2 to 5).

Abutment Height and Marginal Peri-implant Bone Level Stability

Regarding the linear distance from the marginal peri-implant bone crest to the restoration margin, no statistically significant ($P < .05$) correlations between ≤ 1.5 mm to or > 1.5 mm distance between restoration margin and crestal peri-implant bone level were found for one-piece or Ti-base abutments.

Correlation between Emergence Angle and Clinical Outcome Data

No statistically significant differences were found at V8 to V10 for the prevalence of LPlab at single crown

Table 3 Distal Emergence Angles (EA-K and EA-H) of Ti-base and One-Piece Abutments and Their Correlation with MBL at Different Time Points

	EA-K/EA-H		MBL distal V8	MBL distal V9	MBL distal V10
Ti-Base	Distal (> 30 degrees)	Correlation coefficient [R]	0.359	0.213	0.227
		P value	.092	.329	.309
		N	23	23	22
	Distal 1-mm height	Correlation coefficient [R]	0.194	0.216	0.170
		P value	.374	.322	.449
		N	23	23	22
	Distal 2-mm height	Correlation coefficient [R]	0.252	0.103	0.142
		P value	.246	.640	.529
		N	23	23	22
	Distal 3-mm height	Correlation coefficient [R]	0.292	0.138	0.178
		P value	.177	.531	.428
		N	23	23	22
One-piece	Distal (> 30 degrees)	Correlation coefficient [R]	0.176	0.140	0.109
		P value	.421	.524	.629
		N	23	23	22
	Distal 1-mm height	Correlation coefficient [R]	0.201	0.131	0.113
		P value	.358	.550	.618
		N	23	23	22
	Distal 2-mm height	Correlation coefficient [R]	0.040	0.006	–0.079
		P value	.856	.979	.728
		N	23	23	22
	Distal 3-mm height	Correlation coefficient [R]	0.118	0.019	–0.118
		P value	.593	.933	.602
		N	23	23	22

Spearman-Rho, *$P < .05$ significance level.

Table 4 ΔMBL of Mesial Sites of Ti-base and One-Piece Abutments with Emergence Angles > and < 30 Degrees

Abutment type	Emergence angle > 30 degrees		No.	ΔMBL [mm]; mean ± SD
Ti-base	Yes	ΔMBL V5–V8	24	0.46 ± 0.93
		ΔMBL V5–V9	24	0.39 ± 1.06
		ΔMBL V5–V10	22	0.73 ± 1.41
	No	ΔMBL V5–V8	22	0.31 ± 0.62
		ΔMBL V5–V9	22	0.33 ± 0.66
		ΔMBL V5–V10	22	0.26 ± 0.69
One-piece	Yes	ΔMBL V5–V8	28	0.6 ± 0.69
		ΔMBL V5–V9	28	0.99 ± 1.13
		ΔMBL V5–V10	28	1.02 ± 1.3
	No	ΔMBL V5–V8	18	0.11 ± 0.76
		ΔMBL V5–V9	18	0.06 ± 0.74
		ΔMBL V5–V10	16	–0.25 ± 0.68

Table 5 ΔMBL of Distal Sites of Ti-base and One-piece Abutments with Emergence Angles > and < 30 Degrees

Abutment type	Emergence angle > 30 degrees		No.	ΔMBL [mm]; mean ± SD
Ti-base	Yes	ΔMBL V5–V8	22	0.87 ± 1.02
		ΔMBL V5–V9	22	0.82 ± 1.09
		ΔMBL V5–V10	20	1.22 ± 1.31
	No	ΔMBL V5–V8	24	0.32 ± 0.6
		ΔMBL V5–V9	24	0.33 ± 0.66
		ΔMBL V5–V10	24	0.26 ± 0.75
One-piece	Yes	ΔMBL V5–V8	26	0.3 ± 0.99
		ΔMBL V5–V9	26	0.05 ± 1.21
		ΔMBL V5–V10	24	0.36 ± 1.66
	No	ΔMBL V5–V8	20	0.53 ± 0.93
		ΔMBL V5–V9	20	0.57 ± 0.84
		ΔMBL V5–V10	20	0.33 ± 0.69

Table 6 ΔPPD of Mesial Sites of Ti-base and One-Piece Abutments with Emergence Angle > and < 30 Degrees

Abutment type	Emergence angle > 30 degrees		No.	ΔMBL [mm]; mean ± SD	*P*
Ti-base	Yes	ΔPPD between V5–V8	24	–0.17 ± 1.45	.781
		ΔPPD between V5–V9	24	–0.64 ± 1.65	.308
		ΔPPD between V5–V10	22	–0.77 ± 1.89	.21
	No	ΔPPD between V5–V8	22	–0.14 ± 1.4	.781
		ΔPPD between V5–V9	22	0.2 ± 1.44	.308
		ΔPPD between V5–V10	22	–0.02 ± 0.99	.21
One-piece	Yes	ΔPPD between V5–V8	28	–0.25 ± 1.03	.8
		ΔPPD between V5–V9	28	–0.18 ± 1.14	.295
		ΔPPD between V5–V10	28	–0.55 ± 1.25	.19
	No	ΔPPD between V5–V8	18	–0.17 ± 1.86	.8
		ΔPPD between V5–V9	18	0.42 ± 1.17	.295
		ΔPPD between V5–V10	16	0.41 ± 1.23	.19

U test, **P* <.05 significance level.

Table 7 ΔPPD of Distal Sites of Ti-base and One-Piece Abutments with Emergence Angles > and < 30 Degrees

Abutment type	Emergence angle > 30 degrees		No.	ΔMBL [mm]; mean ± SD	*P*
Ti-base	Yes	ΔPPD V5–V8	22	0.05 ± 0.95	.852
		ΔPPD V5–V9	22	–0.41 ± 1.54	.599
		ΔPPD V5–V10	20	–0.9 ± 1.5	.112
	No	ΔPPD V5–V8	24	–0.06 ± 1.47	.852
		ΔPPD V5–V9	24	0.25 ± 1.38	.599
		ΔPPD V5–V10	24	0.13 ± 1.18	.112
One-piece	Yes	ΔPPD V5–V8	26	–0.15 ± 1.14	.876
		ΔPPD V5–V9	26	–0.29 ± 1.01	.038*
		ΔPPD V5–V10	24	–0.52 ± 1.06	.118
	No	ΔPPD V5–V8	20	–0.13 ± 1.07	.876
		ΔPPD V5–V9	20	0.63 ± 1.09	.038*
		ΔPPD V5–V10	20	0.18 ± 1.4	.118

U test, **P* <.05 significance level.

restorations on abutments with emergence angles of > 30 degrees compared to < 30 degrees.

Furthermore, regardless of the emergence angle (ie, > 30 degrees compared to ≤ 30 degrees), DPPDab was found to be statistically significantly increased ($P < .05$) between V5 to V9 only at the distal sites of the one-piece abutments (Tables 6 and 7).

However, for BoP+, the Fisher-Yates test showed a statistically significant correlation between an emergence angle of > 30 degrees and BoP+ for one-piece abutments on V8 ($P < .05$) and V9 ($P < .05$), respectively. The percentages of BoP+ for EA > 30 degrees are shown in Tables 8 and 9.

Furthermore, RECab occurred only rarely, which is why corresponding statistical analyses for DRECab were not carried out.

Emergence Angles of Ti-Base and One-Piece Abutments

For Ti-base abutments, the mean EA-K value was 32.9 degrees (SD: 12 degrees) for mesial sites and 33.9 degrees (SD: 13.4 degrees) for distal sites. For one-piece

Table 8 BoP+ Sites of Ti-base and One-Piece Abutments with Mesial Emergence Angles > and < 30 Degrees at the 3-Year Follow-up

				Emergence angle > 30 degrees		
				No	Yes	Total
Ti-Base	BoP mesial V8	No	Quantity	8	5	13
			%Emergence angle >30%	72.7%	41.7%	56.5%
		Yes	Quantity	3	7	10
			%Emergence angle >30%	27.3%	58.3%	43.5%
	Total		Quantity	11	12	23
			%Emergence angle >30%	100%	100%	100%
One-piece	BoP mesial V8	No	Quantity	10	2	12
			%Emergence angle >30%	71.4%	22.2%	52.2%
		Yes	Quantity	4	7	11
			%Emergence angle >30%	28.6%	77.8%	47.8%
	Total		Quantity	14	9	23
			%Emergence angle >30%	100%	100%	100%
Total	BoP mesial V8	No	Quantity	10	15	25
			%Emergence angle >30%	50%	57%	54.3%
		Yes	Quantity	10	11	21
			%Emergence angle >30%	50%	42.3%	45.7%
	Total		Quantity	20	26	46
			%Emergence angle >30%	100%	100%	100%

Table 9 BoP+ Sites of Ti-base and One-Piece Abutments with Mesial Emergence Angles> and < 30 Degrees at the 5-Year Follow-up

				Emergence angle > 30 degrees		
				No	Yes	Total
Ti-Base	BoP mesial V10	No	Quantity	4	6	10
			%Emergence angle >30%	36.4%	54.5%	45.5%
		Yes	Quantity	7	5	12
			%Emergence angle >30%	63.6%	45.5%	54.5%
	Total		Quantity	11	11	22
			%Emergence angle >30%	100%	100%	100%
One-piece	BoP mesial V10	No	Quantity	7	5	100%
			%Emergence angle >30%	87.5%	35.7%	54.5%
		Yes	Quantity	1	9	10
			%Emergence angle >30%	12.5%	64.3%	45.5%
	Total		Quantity	8	14	22
			%Emergence angle >30%	100%	100%	100%
Total	BoP mesial V10	No	Quantity	11	11	22
			%Emergence angle >30%	57.9%	44%	54.3%
		Yes	Quantity	8	14	22
			%Emergence angle >30%	42.1%	56%	50%
	Total		Quantity	25	19	44
			%Emergence angle >30%	100%	100%	100%

Table 10 Radiographically Measured Emergence Angle of Ti-base and One-Piece Abutments

Abutment type	Site	Emergence angle [degrees]; mean ± SD	*P* value
Ti-base	Mesial	32.90 ± 11.99	.439
One-piece		36.17 ± 13.45	
Ti-base	Distal	33.88 ± 13.41	.902
One-piece		33.77 ± 11.33	

Mann-Whitney *U* test.

abutments, the mean EA-K value was 36.2 degrees (SD: 13.5 degrees) for mesial sites and 33.8 degrees (SD: 11.3 degrees) for distal sites.

No statistically significant differences were found between Ti-base and one-piece abutments either mesially or distally ($P > .05$; Table 10).

DISCUSSION

The current retrospective evaluation of a terminated double-blind, split-mouth RCT aimed to assess the long-term (5 years) influence of abutment emergence angle and the influence of abutment height on peri-implant outcome variables (eg, marginal changes in peri-implant bone level) in patients who are not considered susceptible to peri-implantitis. A further aim was to investigate whether abutments bonded to Ti-bases are associated with greater emergence angles compared to one-piece abutments of the same material.

Accordingly, it was hypothesized that a larger emergence angle (> 30 degrees) and a distance ≤ 1.5 mm between the restoration margin and the crestal peri-implant bone level would be associated with a negative effect on marginal peri-implant bone stability (ie, marginal peri-implant bone loss). Furthermore, it was hypothesized that abutments bonded to Ti-bases would be associated with larger emergence angles compared to one-piece abutments.

As only moderate negative correlations were found for the emergence angle (EA-K, threshold > 30 degrees) and ΔMBL on the mesial sides of the one-piece abutments on V9 and V10, we tend to reject the hypothesis that a larger emergence angle (> 30 degrees) is associated with a negative effect on marginal peri-implant bone stability. However, an emergence angle > 30 degrees was significantly correlated with BoP at one-piece abutments at V8 and V9. BOP in combination with marginal bone loss could favor peri-implantitis in the future.

Also, the hypotheses that a distance of < 1.5 mm between restoration margin and crestal peri-implant bone level would be associated with marginal peri-implant bone loss as well as that abutments bonded onto Ti-bases would be associated with wider emergence angles compared to one-piece abutments must be rejected.

However, the present results must be interpreted in the context of a study population selected to have a minimal risk of peri-implant inflammation, especially a minimal risk of peri-implantitis (good general health, nonsmokers, FMPI < 20%, FMBI < 20%, good to excellent compliance, no history of periodontitis, and—probably therefore—not prone to peri-implantitis) and certainly cannot be extrapolated to patients in a more general population (ie, not selected according to these criteria). Nevertheless, after an observation period of 5 years, the clinical and radiographic results are consistent with the prevailing view of the pathophysiology of peri-implant disease.[13–15] In brief, there is convincing evidence that plaque accumulation in combination with the patient's individual susceptibility are the main etiologic factors for peri-implantitis and concomitant progressive peri-implant bone loss. We therefore assume that in selected patients with adequate plaque control, wider abutment emergence angles (> 30 degrees) have a limited effect on peri-implant bone loss, which might favor the development of peri-implantitis.

This is in line with Hentenaar et al.[8] After a follow-up period of 5 years, no correlation was found between cervical crown contour and peri-implant soft tissue health or peri-implant marginal bone loss in bone-level implants placed in patients who were not prone to peri-implantitis. In contrast, Katafuchi et al[5] correlated emergence angles (≤ 30 degrees vs > 30 degrees) as well as abutment emergence profiles (concave versus convex) with the prevalence of peri-implantitis at bone-level and tissue-level implants. After a mean follow-up time of approximately 11 years, bone level implants with emergence angles > 30 degrees had a statistically significant higher prevalence of peri-implantitis ($P < .05$) compared to abutments with emergence profiles ≤ 30 degrees. This correlation was even more evident in bone level implants with emergence angles > 30 degrees in combination with convex abutment emergence profiles ($P < .01$). Differences between the current clinical trial and Hentenaar et al[8] could be explained by the different settings and, perhaps most importantly, by a study population that was not selected to minimize the risk of developing tissue destructive peri-implant inflammatory diseases (diabetic patients, smokers, and patients with a history of periodontitis were included by Katafuchi et al[5]). This explanation is also supported by Yi et al,[9] who excluded patients with systemic diseases, patients without regular maintenance care, and patients who smoked. They reported significantly more marginal bone loss at implants in a group of patients with a history of periodontitis.

As stated previously, statistically significant negative correlations were not found for Ti-base or one-piece abutments with respect to ΔMBL between a distance ≤ 1.5 mm vs > 1.5 mm between the restoration margin and the crestal peri-implant bone level. However, it is worth mentioning that only a few restoration margins (18% in total) were found with a distance of ≤ 1.5 mm to the crestal peri-implant bone margin. The generalizability should therefore be treated with caution. However, despite this small number, this seems once again in line with the prevailing view of the pathophysiology of peri-implant diseases (inadequate plaque control combined with individual susceptibility to peri-implantitis-related peri-implant bone deconstruction).[13–15] Nonetheless, this finding contradicts that of Derks et al[1] and can probably

be explained by a completely different study design: no randomized clinical trial as the basis for the retrospective analysis, no selection of patients especially with regard to a minimal risk to develop peri-implantitis, different practitioners (not all specialist dentists), and different implant systems.

Although the patients' risk of developing a peri-implantitis was minimized by the selection criteria, two implants from two different participants developed peri-implantitis. Interestingly, both implants showed all three restorative risk indicators (ie, an emergence angle of > 30 degrees, a convex emergence profile, and a distance ≤ 1.5 mm between the restoration margin and crestal bone).

A drawback of this retrospective analysis is that the original RCT was not designed to investigate the long-term influence of abutment emergence angles, and abutment heights on marginal peri-implant bone stability.

This drawback, as already mentioned, limits the generalizability even for comparable settings and patients with a low risk of developing peri-implantitis. Therefore, appropriate RCTs (with adequate sample size) specifically addressing the effects of emergence angle, emergence profile (ie, convex or concave), and abutment height on marginal peri-implant bone stability are required.

CONCLUSIONS

Within the limits of this retrospective analysis, it is concluded for patients at low risk of developing peri-implantitis that a larger abutment emergence angle (> 30 degrees) alone should not be considered a risk factor for inflammation-related marginal peri-implant bone loss. This also applies to a distance of ≤ 1.5 mm between the restoration margin and the crestal peri-implant bone level. Furthermore, abutments bonded to Ti-bases are not as such associated with wider emergence angles than one-piece abutments.

Suggestion for Further Research

As even in patients at low risk of peri-implantitis, a combination of a larger emergence angle (> 30 degrees), a convex emergence profile, and a distance ≤ 1.5 mm between the restoration margin and the crestal peri-implant bone margin may predispose peri-implant sites to marginal peri-implant bone loss, further appropriate RCTs on this topic are reasonable.

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