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EPIDEMIOLOGY (COHORT STUDY OR CASE-CONTROL STUDY)

Restoration contour is a risk indicator for peri-implantitis: A cross-sectional radiographic analysis

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Abstract

Aim: The purpose of this study was to determine whether restoration emergence angle was associated with peri-implantitis.

Materials and Methods: A data set consisting of 96 patients with 225 implants (mean follow-up: 10.9 years) was utilized. Implants were divided into bone-level and tissue-level groups, and radiographs were analysed to determine the restoration emergence angles, as well as restoration profiles (convex or concave). Peri-implantitis was diagnosed based on probing depth and radiographic bone loss. Associations between peri-implantitis and emergence angles/profiles were assessed using generalized estimating equations.

Results: Eighty-three patients with 168 implants met inclusion criteria. The prevalence of peri-implantitis was significantly greater in the bone-level group when the emergence angle was >30 degrees compared to an angle ≤30 degrees (31.3% versus 15.1%, $p = .04$). In the tissue-level group, no such correlation was found. For bone-level implants, when a convex profile was combined with an angle of >30 degrees, the prevalence of peri-implantitis was 37.8% with a statistically significant interaction between emergence angle and profile ($p = .003$).

Conclusions: Emergence angle of >30 degrees is a significant risk indicator for peri-implantitis and convex profile creates an additional risk for bone-level implants, but not for tissue-level implants.

KEYWORDS
dental implant, dental prosthesis, implant-supported, peri-implantitis, prevalence, risk factors

1 | INTRODUCTION

Peri-implantitis has been a growing issue in dentistry. Although the long-term overall implant survival rate is reported to be 97% (Busenlechner et al., 2014), survival rates do not take into account the presence of peri-implantitis among existing implants. Systematic review and meta-analysis after at least 5 years of function show that 18.8% of patients have peri-implantitis (Atieh, Alsabeeha, Faggion, & Duncan, 2013). According to a recent report from a Swedish population with 9-year follow-up, 45% of all patients presented with peri-implantitis. Moderate/severe peri-implantitis was diagnosed in 14.5%. (Derks et al., 2016). Daubert, Weinstein, Bordin, Leroux, and Flemmig (2015) investigated the prevalence of peri-implantitis in a US population with mean follow-up time of 10.9 years and reported a 16% implant level prevalence of peri-implantitis. It is critical to have a better understanding of the risk factors for peri-implantitis in order to prevent it.

Risk indicators for peri-implant disease have been identified in previous studies. Poor oral hygiene, history of periodontitis and cigarette smoking are important factors associated with peri-implant disease

(Ferreira, Silva, Cortelli, Costa, & Costa, 2006; Karoussis et al., 2003; Roos-Jansåker, Renvert, Lindahl, & Renvert, 2006). Diabetes has also been linked with peri-implantitis risk (Daubert et al., 2015). Derks et al. (2016) demonstrated higher odds ratios for moderate to severe peri-implantitis in patients with periodontitis and with ≥4 implants, as well as implants of certain brands and prosthetic therapy delivered by general practitioners. Higher odds ratios were also identified for implants placed in the mandible and with crown restoration margins positioned ≤1.5 mm from the crestal bone at baseline. Excess cement was identified as a possible risk indicator for peri-implant disease and an association has been found with a tendency to higher disease prevalence with cemented compared to screw-retained implant restorations (Staubli, Walter, Schmidt, Weiger, & Zitzmann, 2016).

The restoration contour of fixed dental prostheses on natural teeth has been reported to have an impact on the periodontium. Numerous studies since the early 1970s have been conducted to understand the effects of restoration contours on gingival inflammation. Over-contoured restorations have been linked with gingival erythema due to plaque retention, whereas well-contoured restorations allowed for the maintenance of gingival health (Becker & Kaldahl, 1981; Yuodelis, Weaver, & Sapkos, 1973). Another study reported that restoration contours more pronounced than natural tooth convexities have potential to create problematic plaque retention (Parkinson, 1976). On the other hand, the majority of studies that report on the restoration contour of implant-supported prostheses have been related to the gingival aesthetics. To our knowledge, restoration contour as a risk factor for peri-implantitis has not been assessed in a clinical trial.

The glossary of prosthodontic terms (2005) describes two specific terms for restoration contours: emergence angle and emergence profile. Emergence angle is defined as the angle of an implant restoration's transitional contour as determined by the relation of the surface of the abutment to the long axis of the implant body. Emergence profile is defined as the contour of a tooth or restoration, such as a crown on a natural tooth or dental implant abutment, as it relates to the adjacent tissues.

We hypothesized that over-contoured restorations, defined as having a wide emergence angle and/or convex profile, would increase the risk for peri-implantitis. The aim of this study was to analyse a cross-sectional data set comparing healthy implants to those diagnosed with peri-implantitis to determine whether emergence angle and profile were associated with the prevalence of peri-implantitis.

Clinical Relevance

Scientific rationale for the study: No prior study has evaluated whether emergence angle has any influence on peri-implantitis risk, and how much restoration flare can be tolerated before the risk of peri-implantitis increases.

Principal findings: This study found a correlation between restoration emergence angle and peri-implantitis and identified a wider emergence angle is a risk for peri-implantitis.

Practical implications: With knowledge of the emergence angle, clinicians can adjust their implant selection and placement depth, as well as their restoration design when using bone-level implants to reduce the risk of peri-implantitis.

2 | MATERIALS AND METHODS

2.1 | Subjects and diagnosis of peri-implantitis

The research protocol was approved by the Institutional Review Board at the University of Washington (No. 41380). All subjects provided written informed consent. STROBE guidelines were followed.

Subject recruitment, details on diagnosis and clinical examination, and prevalence and risk that resulted from analysis of this subject population were previously reported (Daubert et al., 2015). Briefly, patients were assessed who had implants placed in a university setting between 1998 and 2003 and had radiographs taken after the initial remodelling. New radiographs were taken of the implants at the follow-up examination. Ninety-six patients presented for a follow-up examination (48 males and 48 females, aged 34 to 86 years; mean ± *SD* age: 67.6 ± 10.6 years) with a total of 225 implants included.

Peri-implantitis was defined as the presence of BOP and/or suppuration, with 2 mm of detectable bone loss after initial remodelling, and PD ≥4 mm. The presence of 2 mm of bone loss alone without mucositis symptoms did not count as a case of peri-implantitis. Because of non-standardized radiographs at prosthetic insertion and follow-up examination, the case definition of a threshold of 2 mm from the expected marginal bone level after remodelling after implant placement was included (Sanz & Chapple, 2012). Implant failure was defined as a removed, lost, mobile or fractured implant (Buser et al., 2012).

This data set was utilized to explore the question of restoration contour and was utilized for the radiographic analysis. Implants with any of following conditions were excluded from the radiographic analysis: (i) implants with a fixed-detachable restoration or removable overdenture; (ii) failed implants; (iii) implants that were not restored with definitive implant-supported restorations; and (iv) implants that supported an ill-fitting restoration. All implants included radiographic analysis were divided into bone-level and tissue-level groups depending on the location of the implant platforms. Details on implants including size, locations, brands and bone grafting are included in the prior publication (Daubert et al., 2015).

2.2 | Radiographic analysis

Radiographs used for analysis were taken when the patients came in for the study examination and peri-implant diagnosis. Digital radiographs were made of the implants at the time of the follow-up examination using film holders to ensure paralleling technique and diminish distortion of the image. The image processing program (Image J, National Institutes of Health) was used to assess the emergence angle and profile of restorations. While performing the radiographic analysis, the examiner was blinded to the implant status (healthy, peri-implant mucositis or peri-implantitis) in order to prevent potential bias. Selected radiograph images were cropped to hide the marginal bone loss if it exists to aid with blinding. Examples of emergence angle and profile assessments are shown (Figure 1). The method of the emergence angle measurement described by Yotnuengnit, Yotnuengnit, Laohapand, and Athipanyakom (2008) was utilized to measure the emergence angle of implant restorations on the radiographs. The emergence angle was calculated as the angle between the implant long axis and a line tangent to the restoration. First, a line parallel to implant long axis was drawn at the outer collar of the implant. Then, another line tangential to the restoration from the platform was drawn. The angle of the intersection was measured as the emergence angle. The measurements were repeated twice, and the mean was calculated for each mesial and distal interproximal surface. Each emergence profile was categorized as either concave, straight or convex. Both mesial and distal surfaces were rated three times, and the majority selection was chosen as the emergence profile. For the implants in the bone-level group, the transmucosal abutment was considered as a part of restoration. Therefore, the emergence angle and profile were assessed from the platform at the marginal bone level. The implants in the tissue-level group have a polished shoulder that allows for soft tissue adaptation around it, and the platform is located at the tissue level. The contour of the transmucosal part is preset. The emergence angle and profile were assessed only above the platform at the tissue level. A volunteer examiner was recruited and calibrated to repeat assessment on 20 randomly selected surfaces. For the emergence angle measurement, intra-rater reliability and inter-rater reliability were calculated. For the emergence profile rating, intra-rater agreement and inter-rater agreement were calculated. Additionally, for the bone-level group, implant depth was categorized as supracrestal, crestal and subcrestal on each mesial and distal aspect using radiographs at the implant placement.

2.3 | Statistical analysis and validation of radiographic analysis

Associations between peri-implantitis and emergence angle and profile were assessed using generalized estimating equations to account for multiple implants within patients. Analyses of emergence angle as a dichotomous variable (less than or equal to 30 degrees versus greater than 30 degrees) used ANOVA models to assess main effects of emergence angle and profile as well as their interaction for each type of implant (bone level and tissue level). We used logistic regression models with emergence angle as a continuous variable to plot estimated peri-implantitis prevalence versus emergence angle. We also used logistic regression models to build a predictive model for peri-implantitis. The following predictor variables were considered for inclusion in the model: patient age, patient periodontal disease status, patient diabetic status, implant diameter, implant type, emergence angle and emergence profile. A final model was selected for presentation by minimizing the Akaike information criterion (AIC).

For the emergence angle measurement, intra-rater reliability between the examiner's two measurements was very high ($r = 0.95$). Inter-rater reliability between the examiner and the volunteer was also high ($r = 0.82$). For the emergence profile rating, intra-rater agreement was high (81.6%) and inter-rater agreement was moderately high (70%). While this is only a moderately high agreement percentage, the six cases for which there was disagreement involved a discrepancy of only one rating level (e.g. convex versus straight). There were no discrepancies greater than one level (e.g. convex versus concave).

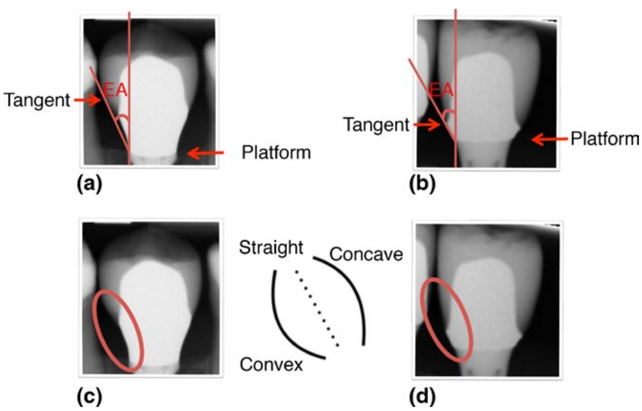

FIGURE 1 Example of the emergence angle measurement on an implant in the bone-level group (a) and in the tissue-level group (b). Example of the emergence profile assessment on an implant in the bone-level group (c) and in the tissue-level group (d). EA, Emergence angle

3 | RESULTS

3.1 | Prevalence of peri-implantitis within Included patients and implants

Eighty-three patients with 168 implants were included in the radiographic analysis. There were 101 implants, placed in 59 unique patients, in the bone-level group. In the tissue-level group, there were 67 implants placed in 27 unique patients. Implant level prevalence of peri-implantitis was 22.8% in the bone-level group and 7.5% in the tissue-level group (Table 1). Thirteen patients and 57 implants were excluded from the radiographic analysis. The details regarding excluded implants follow: (i) thirty-five implants with a fixed-detachable restoration or removable overdenture were excluded due to the difficulty of performing emergence angle and profile assessments. (ii) Eighteen failed implants were excluded. (iii) One patient with three implants had a long-term implant-supported provisional restoration for orthodontic treatment. Those implants were excluded because the contour of the restoration may not have been consistent over time. (iv) One implant had an obvious ill-fitting restoration with a significant

TABLE 1 Prevalence at implant and patient level of peri-implantitis by implant type

	Bone level	Tissue level	Overall
Implant level	(*N* = 101)	(*N* = 67)	(*N* = 168)
Peri-implantitis, *n* (%)	23 (22.8%)	5 (7.5%)	28 (16.7%)
Patient level	(*N* = 59)	(*N* = 27)	(*N* = 83)
Peri-implantitis, *n* (%)	17 (28.9%)	4 (14.8%)	21 (25.3%)

open-margin. This patient had been given a recommendation to have the restoration replaced at the follow-up examination.

3.2 | Distribution of emergence angle and profile

In the bone-level group, the mean ± *SD* emergence angle was 27.8 degrees ± 11.6 on the mesial surface and 25.1 degrees ± 10.3 on the distal surface. In the tissue-level group, the mean ± *SD* emergence angle was 28.6 degrees ± 14.4 on the mesial surface and 28.3 degrees ± 13.3 on the distal surface. There was no statistically significant difference in the distribution of emergence angle either within a group or between groups (Table 2). In the bone-level group, the convex profile was found on 35.6% of the mesial surfaces and 39.6% of the distal surfaces. In tissue-level group, the convex profile was found on 35.8% of the mesial surfaces and 38.8% of the distal surfaces. There was no statistically significant difference in the distribution of the convex profile either within a group or between groups (Table 2). Emergence angles tended to be larger for convex profiles (mean 37.5, *SD* 11.7) compared with straight or concave profiles (mean 26.7, *SD* 8.9). This pattern was similar for bone and tissue-level implants.

3.3 | Patient and implant characteristics

Implants were placed into two groups: those with at least one interproximal surface with >30 degrees, and those with both interproximal surfaces measuring ≤30 degrees. Implants were also grouped into two additional groups: those having at least one interproximal surface with a convex profile, and those with both interproximal surfaces either concave or straight. For both bone- and tissue-level groups, patient characteristics consisting of gender, age, smoking, diabetes and presence of periodontal disease, and implant characteristics consisting of cemented restoration and posterior implant were distributed evenly between the two groups of emergence angles as well as between the two groups of emergence profiles. We found no indication of differences in angle or profile by brand for bone-level implants (Table 3).

TABLE 2 Distribution of emergence angle and profile by surface and implant type

Surface	Bone level	Tissue level
Emergence angle		
Mesial, mean (*SD*)	27.8 (11.6)	28.6 (14.4)
Distal, mean (*SD*)	25.1 (10.3)	28.3 (13.3)
Emergence profile		
Mesial	(*N* = 101)	(*N* = 67)
Convex, *n* (%)	36 (35.6%)	24 (35.8%)
Concave or Straight, *n* (%)	65 (64.4%)	43 (64.2%)
Distal	(*N* = 101)	(*N* = 67)
Convex, *n* (%)	40 (39.6%)	26 (38.8%)
Concave or Straight, *n* (%)	61 (60.4%)	41 (61.2%)

3.4 | Prevalence of peri-implantitis by emergence angle

Average mesial and distal emergence angles were the same. The mean of the emergence angle ranged from 25 to 29 degrees. Therefore, we decided to use 30 degrees as a threshold for over-contour. This angle was used as a benchmark in a prior animal study where 30 degrees was described as a normal contour (Kohal, Gerds, & Strub, 2003; Kohal, Pelz, & Strub, 2004).

In the bone-level group, the risk of peri-implantitis was significantly greater when the emergence angle was >30 degrees compared to an angle of ≤30 degrees (31.3% compared to 15.1%, $p = .04$). In contrast, in the tissue-level group, the emergence angle was not associated with peri-implantitis (Table 4). We also found an association between peri-implantitis and emergence angle as a continuous variable in the bone-level group but not in the tissue-level group (Fig. S1).

3.5 | Prevalence of peri-implantitis by emergence profile

In the bone-level group, the prevalence of peri-implantitis was 28.8% with a convex profile when compared to 16.3% with a straight or concave profile. The difference was not statistically significant.

In the tissue-level group, the emergence profile was not associated with peri-implantitis (Table 4).

3.6 | Prevalence of peri-implantitis by a combined effect of emergence angle and profile

The combined effect of the emergence angle and emergence profile on the presence of peri-implantitis was analysed. An interaction plot for the bone-level group showed that the highest rate of peri-implantitis (37.8%) occurred when a convex profile was combined with a restoration emergence angle of >30 degrees. Regression analysis found a statistically significant interaction between the restoration emergence angle and emergence profile ($p = .003$; Figure 2a). For the tissue-level group, there was no evidence for a combined effect of restoration emergence angle and emergence profile on the rate of peri-implantitis (Figure 2b).

3.7 | Prediction of peri-implantitis

The predictive model selected using AIC included patient age, periodontal disease status, implant type and emergence angle as predictors (Table S1). The area under the receiver operating curve is 0.78 (Fig. S2).

3.8 | Effect of implant depth in the bone-level group

We found emergence angle was affected by implant depth. The mean emergence angle was 28.9, 29.0 and 22.3 degrees for implant depths for supracrestal, crestal and subcrestal, respectively. However, we found no association between implant depth and peri-implantitis for

TABLE 3 Distribution of patient characteristics by emergence angle and profile

	Mesial and/or distal EA >30 degrees	Both EA 30 degrees or less	Mesial and/or distal convex	Both concave or straight
Bone-level implants				
N	48	53	52	49
Male, *n* (%)	28 (58.3%)	29 (54.7%)	26 (50.0%)	31 (67.6%)
Age, mean (*SD*)	66.4 (9.8)	65.2 (11.9)	67.3 (10.1)	64.1 (11.5)
Smoking, *n* (%)	4 (8.3%)	6 (11.3%)	7 (13.5%)	3 (6.1%)
Diabetes, *n* (%)	3 (6.3%)	8 (15.1%)	5 (9.6%)	6 (12.2%)
Periodontal Disease*, *n* (%)	9 (18.8%)	17 (32.1%)	12 (23.1%)	14 (28.6%)
Periodontal Disease* at Baseline, *n* (%)	15 (31.3%)	18 (34.0%)	15 (28.9%)	18 (36.7%)
Cemented restoration, *n* (%)	41 (85.4%)	42 (79.2%)	45 (86.5%)	38 (77.6%)
Posterior implants, *n* (%)	46 (96%)	40 (75%)	44 (85%)	42 (86%)
Brand				
Nobel Biocare	11 (23%)	9 (17%)	11 (21%)	9 (18%)
Branemark system	1 (2%)	4 (8%)	2 (4%)	3 (6%)
Biomet 3i	29 (60%)	30 (57%)	33 (63%)	26 (53%)
Centerpulse	3 (6%)	6 (11%)	4 (8%)	5 (10%)
Astra	2 (4%)	0 (0%)	1 (2%)	1 (2%)
Sulzer dental	2 (4%)	3 (6%)	1 (2%)	4 (8%)
Steri-oss	0 (0%)	1 (2%)	0 (0%)	1 (2%)
Tissue-level implants				
N	39	28	34	33
Male, *n* (%)	27 (69.2%)	12 (42.9%)	23 (63.3%)	16 (48.5%)
Age, mean (*SD*)	69.1 (9.9)	67.7 (12.5)	69.4 (10.8)	67.5 (11.2)
Smoking, *n* (%)	1 (2.6%)	0 (0%)	1 (2.9%)	0 (0%)
Diabetes, *n* (%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Periodontal Disease*, *n* (%)	6 (15.4%)	12 (42.9%)	6 (17.6%)	12 (36.4%)
Periodontal Disease* at Baseline, *n* (%)	16 (42.1%)	16 (59.3%)	19 (55.9%)	13 (41.9%)
Cemented restoration, *n* (%)	35 (89.7%)	25 (89.3%)	32 (94.1%)	28 (84.8%)
Posterior implants, *n* (%)	38 (97%)	27 (96%)	33 (97%)	32 (97%)
Brand				
Straumann	39 (100%)	28 (100%)	34 (100%)	33 (100%)

EA, emergence angle.
*Moderate or severe periodontal disease.

bone-level implants (Table S2). Furthermore, in sensitivity analyses, adjustment for depth did not substantially change the results for effects of emergence angle and profile on prevalence of peri-implantitis (Table S3).

3.9 | Effect of number of implants per patients in the bone-level group

Adjustment for number of implants did not substantially change the results for effects of emergence angle and profile on prevalence of peri-implantitis. (Table S3).

4 | DISCUSSION

4.1 | Brief summary

In this present study, restoration emergence angle and emergence profile (convex, straight, concave) were assessed to determine whether they are associated with peri-implantitis. For bone-level implants, a restoration emergence angle >30 degrees on at least one proximal surface was associated with a higher rate of peri-implantitis. The highest rate of peri-implantitis was found when a convex profile was combined with a restoration emergence angle of >30 degrees. These results suggest that an over-contoured restoration on a dental

TABLE 4 Prevalence of peri-implantitis by emergence angle and profile

Implant type	Mesial and/or distal EA >30	Both EA 30 degrees or less	Difference (95% CI), *p*-value
Bone-level, *n* (%)	15/48 (31.3%)	8/53 (15.1%)	16.2% (0.5%, 31.8%), 0.04
Tissue-level, *n* (%)	3/39 (7.7%)	2/28 (7.1%)	0.5% (−14.5%, 15.6%), 0.94
	Mesial and/or distal convex	**Both straight or concave**	
Bone-level, *n* (%)	15/52 (28.8%)	8/49 (16.3%)	12.5% (−3.4%, 28.5%), 0.12
Tissue-level, *n* (%)	2/34 (5.9%)	3/33 (9.1%)	−3.2% (−13.0%, 6.6%), 0.52

EA, emergence angle.

implant (wide emergence angle and convex profile) may have a negative impact on the peri-implant health, and increase the risk of developing peri-implantitis, supporting our primary hypothesis. A wider restoration emergence angle represents a significant risk indicator for peri-implantitis in bone-level implants, and a convex profile is an additional risk when combined with it. Our results suggest that a shallower emergence angle with a straight or concave profile at the interproximal sites should be considered to minimize peri-implantitis risk for bone-level implants. For the tissue-level implants, neither emergence angle nor emergence profile is associated with an increased prevalence of peri-implantitis, and therefore, no emergence angle or profile recommendation can be ascertained. To our best knowledge, this is the first cross-sectional study to assess restoration contours related to the prevalence of peri-implantitis.

4.2 | Strengths and limitations of the study

Are restoration contours related to peri-implantitis? This is a valuable question to ask. Not enough literature is available to support the superiority of implant-supported restoration design, such as shape and emergence profile in relation to implant health, although certain design might be related to peri-implantitis due to limited accessibility/capability of proper oral hygiene (Serino & Ström, 2009). Canullo et al. (2016) classified peri-implantitis into three categories, surgically triggered, prosthetically triggered and plaque-induced peri-implantitis, based on the specific predictive profile. Excess cement was reported as a prosthetic risk factor (Canullo, Schlee, Wagner, & Covani, 2015; Linkevicius, Puisys, Vindasiute, Linkeviciene, & Apse, 2013; Wilson, 2009). Derks et al. (2016) reported that prosthetic therapy delivered by general practitioners exhibited higher odds ratios for peri-implantitis as well as implants with crown restoration margins positioned 1.5 mm from the crestal bone. Our study provides novel information regarding prosthesis design characteristics for bone-level implants. The position of an implant, its direction and its diameter affect the emergence angle and emergence profile. Therefore, the resulting restoration contours are determined not only by the restorative dentists and laboratory technicians, but are also influenced by the implant position. The results of this study may aid in decision-making when selecting the size of implant and deciding implant position at surgery as well as restoring implant.

In contrast to the bone-level group, the prevalence of peri-implantitis in the tissue-level group was not affected by either the emergence angle or profile. The platform of the implant in this group is typically at the tissue level so that a wider emergence angle and a convex profile may not affect the peri-implant tissue. The data, however, need to be interpreted with caution. Only 27 patients with 67

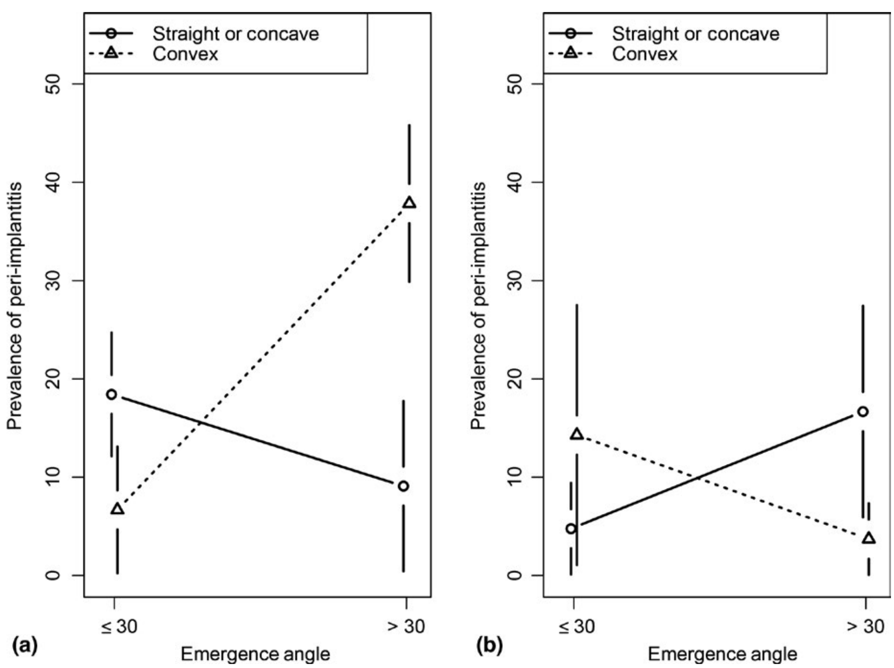

FIGURE 2 Interaction plot of a combined effect of emergence angle and profile on the prevalence of peri-implantitis for the bone-level group (a) and the tissue-level group (b). The bone-level group showed that the highest prevalence (37.8%) occurred when a convex profile was combined with an angle of greater than 30 degrees. Statistically significant interaction was found between the emergence angle and profile in the bone-level group (p = .003)

implants were included in the tissue-level group, and the prevalence of peri-implantitis in this group was 7.5%.

In this study, the outcome parameter was the status of the implant, not the marginal bone loss on each interproximal site. Therefore, the direct association between the restoration contour and the marginal bone loss were unknown. A question may also arise regarding the facial and lingual aspects of the restoration contour. Computed tomography is applicable to assess those aspects at follow-up examination. It was avoided due to ethical reasons related to additional radiation. Alternatively, the implant restorations can be removed to assess those aspects but it also raises ethical questions, especially for a cemented restoration. Those contours should be examined on the model that the restoration is fabricated on before it is inserted in a prospective study. Although how the facial and lingual contours affect implant health is unknown in the present study, the correlation we found on interproximal contours to peri-implantitis is novel and valuable data for clinicians.

4.3 | Interpretation of the study supported by existing evidence and possible mechanism

Peri-implantitis is thought to be infectious in nature and caused by bacteria from dental biofilms followed by a local host inflammatory response (Figuero, Graziani, Sanz, Herrera, & Sanz, 2014; Lang & Berglundh, 2011). Ferreira et al. (2006) reported that very poor oral hygiene is associated with peri-implantitis with an odds ratio of 14.3. Jepsen et al. (2015) recommended implant suprastructures should be designed in a way facilitating sufficient access for diagnosis by probing as well as for oral hygiene measures. In the report from Chaves, Lovell, and Tahmasebi (2014), the restoration contour was adjusted when peri-implantitis was treated surgically, to provide access for proper plaque control after healing. We suspect that compromised oral hygiene access and plaque accumulation around implants are the potential mechanism for the increased prevalence of peri-implantitis at implants with a wider emergence angle and a convex profile.

Restoration contours and overhangs on teeth have been investigated since the early 1970s (Padbury, Eber, & Wang, 2003). Jeffcoat and Howell (1980) reported bone loss was greater for teeth with overhangs. Pack, Coxhead, and McDonald (1990) demonstrated that periodontal disease was more severe when overhangs were present. Lang, Kiel, and Anderhalden (1983) documented changes in the subgingival microflora with overhanging margins. There is not enough information available on the role of over-contoured implant restorations related to peri-implantitis. However, the evidence regarding over-contour and overhanging restorations on teeth might help to reveal the mechanism for increased prevalence of peri-implantitis in the bone-level group in this study.

4.4 | Controversies and future research

The size of the abutment connection of the platform switching implant is smaller than the diameter of the implant. This concept appears to be beneficial in order to maintain the marginal bone level (Canullo, Fedele, Iannello, & Jepsen, 2010). In general, the emergence angle on platform switching implants may become larger than the emergence angle on non-platform-switched implants, implying the platform switching implants may increase the risk for peri-implantitis according to the present study. A larger scale long-term study assessing the prevalence of peri-implantitis in platform switching implants and its relation to restoration contours is warranted.

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CONFLICT OF INTEREST

The authors have stated explicitly that there are no conflict of interests in connection with this article.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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