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Association Between Restored Proximal Tooth Surfaces and Clinical and Radiographic Periodontal Parameters: A Cross-Sectional Study

Abdulrahman Alhaddad[1*] and Hunaida Tayeb[2]

[1,2]Oral and Maxillofacial Prosthodontics Department, Faculty of Dentistry, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract: Objective: This study aimed to evaluate the association between restored proximal tooth surfaces and periodontal parameters by comparing radiographic CEJ-to-alveolar crest distance and probing pocket depth with corresponding non-restored tooth surfaces and across different restoration types. **Methods:** This cross-sectional study included 73 participants selected from 500 screened individuals. The main reasons for exclusion were the absence of an eligible proximal restoration, recent periodontal treatment, systemic conditions or medication use known to affect periodontal status and incomplete clinical records or radiographs of inadequate diagnostic quality. A total of 197 restored proximal surfaces and 197 matched non-restored control surfaces were evaluated. Restored tooth surfaces were analyzed and categorized according to restoration type (amalgam, composite, full-coverage crowns and temporary restorations). Probing Pocket Depth (PPD) was measured clinically and radiographic alveolar bone level was assessed using the CEJ-to-alveolar crest distance on digital bitewing radiographs. Restored-minus-control differences were analyzed using linear regression models with participant-clustered robust standard errors to account for multiple surface pairs contributed by individual participants. **Results:** Restored tooth surfaces exhibited significantly greater CEJ-to-alveolar crest distance than matched control surfaces (1.97±1.01 mm versus 1.34±0.93 mm; mean difference, 0.63 mm; $p<0.001$). Probing pocket depth was numerically greater at restored surfaces than at matched controls (3.63±1.34 mm versus 3.40±1.12 mm), although the difference was not statistically significant ($p = 0.070$). The restored-control difference in CEJ-to-alveolar crest distance varied significantly by restoration type ($p = 0.022$), although none of the pairwise comparisons remained statistically significant after Bonferroni adjustment. No significant variation was observed for PPD ($p = 0.292$). **Conclusion:** Within the limitations of this cross-sectional study, restored proximal surfaces were associated with greater radiographic CEJ-to-alveolar crest distances; however, the overall restored-control difference in PPD was not statistically significant. Clinical and radiographic parameters should be interpreted together when evaluating periodontal conditions adjacent to proximal restorations.

Key Words: Dental Restorations, Proximal Surfaces, Periodontal Parameters, CEJ-to-Alveolar Crest Distance, Radiographic Alveolar Bone Level, Probing Pocket Depth

Author Designation:
[1]Consultant of Prosthodontics, [2]Assistant Professor

*Corresponding author:
Dr. Abdulrahman Alhaddad
aalhaddad@kau.edu.sa

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INTRODUCTION

The long-term success of restorative dental treatment depends not only on mechanical durability and esthetic performance but also on its biological compatibility with the surrounding periodontal tissues [1]. The interaction between restorative margins and periodontal structures has been widely recognized as a critical determinant of periodontal health and treatment outcomes [2]. Consequently, restorative procedures must be carefully designed to minimize adverse effects on periodontal structures.

Previous studies have reported associations between dental restorations and periodontal outcomes [3,4]. However, findings have varied across studies and the relationship between restored tooth surfaces and periodontal conditions continues to be an area of clinical interest.

The integrity of the biologic width is essential for maintaining periodontal health. This dimension, consisting of the junctional epithelium and supracrestal connective tissue attachment, serves as a protective barrier for the underlying periodontal structures [5]. Previous reports

have suggested that the relationship between restorations and periodontal tissues is influenced by multiple restorative and biological factors [2,6]. However, the extent to which restored tooth surfaces are associated with clinical and radiographic periodontal parameters remains an important area for investigation.

Previous studies have reported inconsistent associations between restored tooth surfaces and clinical or radiographic periodontal parameters [2,7-10]. Variations in study design, restoration category and outcome measures have limited direct comparisons across investigations.

Although both direct and indirect restorations have been investigated previously [2,9,11,12], direct comparisons among restoration categories remain limited. Furthermore, differences between restored proximal surfaces and matched non-restored surfaces have not been fully clarified.

Despite extensive investigation of the relationship between dental restorations and periodontal conditions, important gaps remain in the literature. Existing studies frequently focus on specific restoration categories or periodontal outcomes, limiting direct comparisons across restoration types [2,9,12-14]. Furthermore, relatively few studies have used within-subject comparisons between restored and corresponding non-restored proximal tooth surfaces. Therefore, further research is needed to evaluate whether restored proximal tooth surfaces are associated with differences in clinical and radiographic periodontal parameters and whether these associations vary according to restoration type.

Therefore, the aim of the present study was to evaluate the association between restored proximal tooth surfaces and clinical and radiographic periodontal parameters by comparing Probing Pocket Depth (PPD) and radiographic alveolar bone levels (CEJ-to-alveolar crest distance) between restored and non-restored tooth surfaces and across different restoration types.

MATERIALS AND METHODS

Study Design and Ethical Considerations

This cross-sectional clinical and radiographic study was conducted to evaluate the association between restored proximal tooth surfaces and clinical and radiographic periodontal parameters. The study protocol was approved by the Research Ethics Committee, Faculty of Dentistry, King Abdulaziz University (Approval No.: 002-13). All procedures were conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrollment. The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cross-sectional studies.

Study Population and Sampling

A total of 500 patients were screened for eligibility at the clinics of the Faculty of Dentistry, King Abdulaziz University (KAUFD) by three calibrated general dentists. After applying the predefined eligibility criteria, 73 participants (51 females and 22 males) were included and contributed 197 restored proximal tooth surfaces. The participant screening and inclusion process is presented in Figure 1. Some participants contributed more than one restored surface; therefore, measurements obtained from the same participant were considered clustered and were not treated as independent observations.

This was an exploratory study based on the available eligible participants during the study period. No formal a priori sample-size calculation was performed. Therefore, the findings should be considered exploratory and hypothesis-generating. All patients who met the eligibility criteria and had the required clinical and radiographic information were included.

The restored surfaces were categorized according to restoration type as amalgam restorations, composite restorations, full-coverage crowns or temporary restorations. For each restored proximal surface, a non-restored proximal surface from the same participant was selected as a matched control according to a predefined hierarchy. When only one proximal surface was restored, as in mesio-occlusal or disto-occlusal restorations, the opposite non-restored proximal surface of the same tooth was selected; thus, a mesial restored surface was compared with the distal surface and a distal restored surface was compared with the mesial surface. When both proximal surfaces were restored, as in mesio-occluso-distal restorations or full-coverage crowns, a non-restored proximal surface of an adjacent tooth was selected. If no suitable adjacent surface was available, the corresponding surface of the contralateral tooth was used. Control selection was based on anatomical criteria and did not consider periodontal measurements. This matching approach permitted within-subject comparisons while minimizing interindividual variability. Nevertheless, because some control surfaces were derived from adjacent or contralateral teeth, complete anatomical equivalence between restored and control sites could not always be achieved (Figure 1).

Eligibility Criteria

Participants were included if they were aged ≥16 years and presented with proximal restorations (Mesio-Occlusal [MO], Disto-Occlusal [DO] or Mesio-Occluso-Distal [MOD]) or fixed prostheses on the first or second permanent molars. Eligible restorations and prostheses had been in function for a minimum of 6 months at the time of evaluation.

Patients were excluded if they were younger than 16 years, did not have an eligible proximal restoration or fixed prosthesis or had received periodontal treatment within the previous 6 months. Additional exclusion criteria included systemic conditions or medication use known to affect periodontal status, incomplete clinical records and radiographs of inadequate diagnostic quality.

Data Collection

A structured questionnaire was used to collect demographic and clinical information, including age, gender, smoking status (11 smokers, 62 non-smokers)

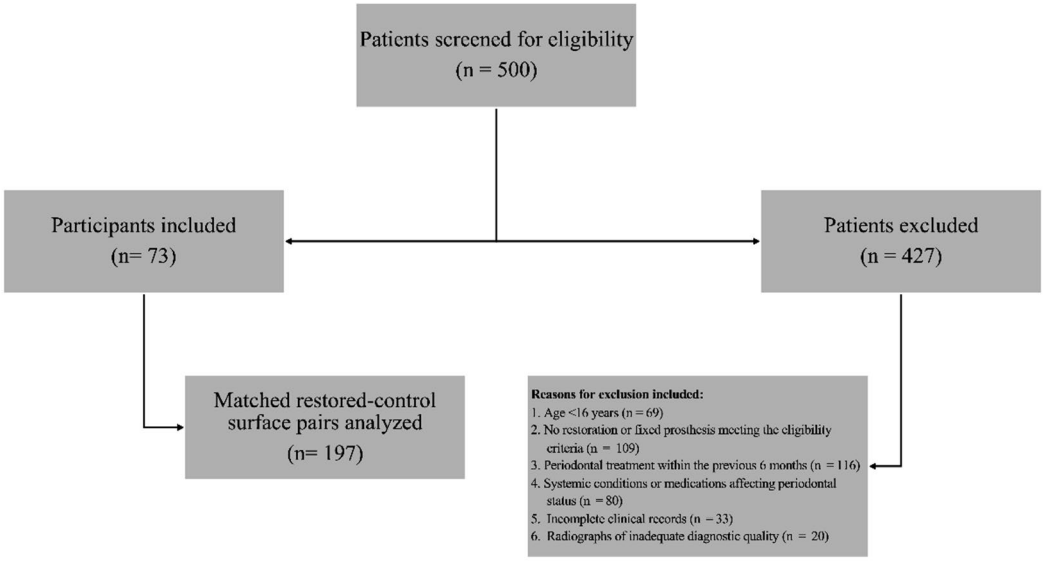

Figure 1: Flow Diagram of Participant Screening, Eligibility Assessment and Inclusion in the Study

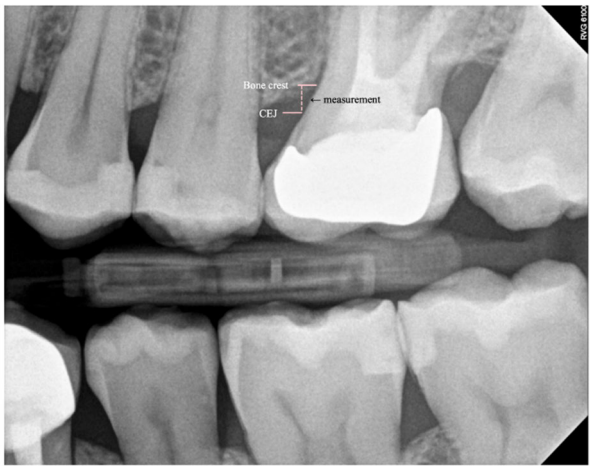

Figure 2: Representative Bitewing Radiograph Demonstrating Measurement of the CEJ-to-Alveolar Crest Distance Used for Radiographic Assessment of Alveolar Bone Level

and oral-hygiene category (27 poor, 40 fair and 6 good). For statistical analysis, smoking status was coded as 1 for smokers and 0 for non-smokers, while oral hygiene was categorized as poor, fair or good and coded as 1, 2 and 3, respectively. The questionnaire was administered by the calibrated examiners at the time of data collection.

Periodontal Assessment

Clinical Assessment: Periodontal assessment was limited to Probing Pocket Depth (PPD) and radiographic evaluation of alveolar bone level using the CEJ-to-alveolar crest distance. Other periodontal parameters, including clinical attachment level, gingival recession, bleeding on probing, plaque accumulation and gingival inflammation indices, were not collected as part of the study protocol. All clinical measurements were performed by a single calibrated examiner at the clinics of the Faculty of Dentistry, King Abdulaziz University, who was blinded to the radiographic findings.

Radiographic Assessment

Radiographic assessment of alveolar bone levels was performed using digital bitewing radiographs. The linear distance (in millimeters) from the cementoenamel junction (CEJ) to the alveolar crest was measured at the mesial and distal tooth surfaces and recorded as the CEJ-to-alveolar crest distance, which served as the radiographic measure of alveolar bone level (Figure 2). Radiographic measurements were obtained using the ruler tool in the R4 imaging software, with calibration conducted prior to measurement to ensure accuracy. All radiographic evaluations were conducted by a single calibrated examiner under standardized conditions. The examiner was blinded to the clinical measurements.

Examiner Calibration

Three general dentists participated in data collection, with their roles defined before study initiation. A designated radiographic examiner performed all CEJ-to-alveolar crest distance measurements following supervised training by a consultant in oral and maxillofacial radiology. A second examiner performed all probing pocket depth measurements following supervised training by a consultant periodontist. The third dentist recorded and entered the clinical and radiographic data using a data-collection form.

Before data collection, the clinical and radiographic examiners completed standardized calibration exercises at the Faculty of Dentistry, King Abdulaziz University, involving repeated assessments of predefined sites. Training and calibration continued until each

examiner achieved at least 90% exact agreement between repeated assessments of the predefined calibration sites.

Statistical Analysis

Statistical analyses were performed using Python version 3.12 (Python Software Foundation). Descriptive statistics were calculated for participant characteristics, restoration characteristics and periodontal measurements. For each matched pair, restored-minus-control (restored-control) differences were calculated separately for CEJ-to-alveolar crest distance and PPD. Because individual participants could contribute more than one matched surface pair, linear regression models with participant-clustered robust standard errors were used throughout the analysis. Mean differences and 95% confidence intervals were estimated for both outcomes. Overall differences among restoration types were assessed using Wald tests, followed by Bonferroni-adjusted pairwise comparisons when the overall test was statistically significant. Restoration-type analyses were considered exploratory and *p* values for the eight within-type comparisons were adjusted using the Holm method. Separate multivariable models for CEJ-to-alveolar crest and PPD differences included age, gender, smoking status, oral-hygiene category, restoration type and restoration duration. Reference categories were female gender, non-smoking status, poor oral hygiene and amalgam restoration. All tests were two-sided, with $\alpha = 0.05$.

RESULTS

A total of 73 participants contributed 197 matched restored-control surface pairs. The distribution of restoration types was 77 (39.1%) amalgam, 65 (33.0%) composite, 44 (22.3%) full-coverage crowns and 11 (5.6%) temporary restorations.

Restored surfaces demonstrated a significantly greater CEJ-to-alveolar crest distance than matched control surfaces (1.97±1.01 mm versus 1.34±0.93 mm). The mean restored-minus-control difference was 0.63 mm (p<0.001). Restored surfaces demonstrated numerically greater probing pocket depth values than matched control surfaces (3.63±1.34 mm versus 3.40±1.12 mm); however, the mean difference of 0.24 mm was not statistically significant after clustering was considered (p = 0.070) (Table 1).

The mean differences in CEJ-to-alveolar crest distance (restored minus control) according to restoration type are presented in Table 2. The restored-minus-control CEJ-to-alveolar crest differences varied significantly overall across restoration categories (Wald F[3,72] = 3.42, p = 0.022). However, none of the six pairwise restoration-type comparisons remained statistically significant after Bonferroni adjustment. The adjusted p-values were 0.460 for amalgam versus composite, 0.617 for amalgam versus crown, 0.906 for amalgam versus temporary, 0.052 for composite versus crown, 1.000 for composite versus temporary and 0.111 for crown versus temporary.

The mean differences in PPD are presented in Table 3. No significant differences in restored-control probing pocket depth were found among restoration types (Wald F [3,72] = 1.27, p = 0.292).

The multivariable model for the CEJ-to-alveolar crest difference is presented in Table 4. The overall model was not statistically significant (Wald F [9,72] = 1.85,

Table 1: Comparison of Periodontal Parameters Between Restored and Control Surfaces

Parameter	Mean±SD (mm)		Mean Difference (mm)	Cluster-adjusted p-value	95% CI
	Restored	Control			
CEJ-to-alveolar crest distance (mm)	1.97±1.01	1.34±0.93	0.63±0.88	<0.001	0.46 to 0.81
Probing pocket depth	3.63±1.34	3.40±1.12	0.24±1.52	0.070	-0.02 to 0.50

Table 2: Mean Difference in CEJ-to-Alveolar Crest Distance (Restored Minus Control) According to Restoration Type

Restoration type	Mean difference±SD (mm)	Cluster-adjusted 95% CI	Holm-adjusted p-value
Amalgam	0.65±0.84	0.45 to 0.85	<0.001*
Composite	0.39±0.82	0.13 to 0.65	0.030*
Crown	1.06±0.92	0.58 to 1.53	0.001*
Temporary	0.27±0.72	-0.28 to 0.83	0.961

*Indicates statistically significant difference (p<0.05), Holm-adjusted p-values refer to within-type restored-control comparisons and were adjusted across the eight exploratory outcome-by-restoration-type comparisons, These p-values reflect within-restoration restored-control comparisons and should not be interpreted as evidence of statistically significant differences between restoration categories

Table 3: Mean Difference in Probing Pocket Depth (Restored Minus Control) According to Restoration Type

Restoration type	Mean difference±SD (mm)	Cluster-adjusted 95% CI	Holm-adjusted p-value
Amalgam	0.26±1.62	-0.18 to 0.70	0.961
Composite	0.45±1.48	0.14 to 0.75	0.030*
Crown	-0.14±1.27	-0.66 to 0.39	1.000
Temporary	0.36±1.96	-1.03 to 1.76	1.000

*Indicates statistically significant difference (p<0.05), Holm-adjusted p-values refer to within-type restored-control comparisons and were adjusted across the eight exploratory outcome-by-restoration-type comparisons, These p-values reflect within-restoration restored-control comparisons and should not be interpreted as evidence of statistically significant differences between restoration categories

Table 4: Multivariable Cluster-Robust Regression Model for Restored-Minus-Control CEJ-to-Alveolar Crest Difference

Predictor	B (mm)	Standardized β	95% CI	p-value
Age, per year	0.010	0.117	-0.004 to 0.023	0.166
Male vs female	-0.108	-0.057	-0.429 to 0.213	0.505
Composite vs amalgam	-0.250	-0.134	-0.527 to 0.027	0.076
Crown vs amalgam	0.369	0.175	-0.033 to 0.771	0.071
Temporary vs amalgam	-0.405	-0.106	-0.957 to 0.147	0.148
Restoration duration, per year	0.035	0.191	0.001 to 0.070	0.047
Smoker vs non-smoker	0.165	0.070	-0.280 to 0.610	0.463
Fair versus poor oral hygiene	-0.144	-0.082	-0.456 to 0.168	0.360
Good versus poor oral hygiene	0.074	0.025	-0.254 to 0.402	0.653

Table 5: Multivariable Cluster-Robust Regression Model for Restored-Minus-Control Probing Pocket Depth Difference

Predictor	B (mm)	Standardized β	95% CI	p-value
Age, per year	0.009	0.061	-0.009 to 0.027	0.343
Male vs female	0.726	0.221	0.181 to 1.272	0.010
Composite vs amalgam	0.185	0.057	-0.352 to 0.721	0.495
Crown vs amalgam	-0.347	-0.095	-0.974 to 0.279	0.273
Temporary vs amalgam	0.079	0.012	-1.144 to 1.302	0.898
Restoration duration, per year	-0.009	-0.029	-0.073 to 0.055	0.776
Smoker vs non-smoker	-0.625	-0.153	-1.113 to -0.137	0.013
Fair versus poor oral hygiene	-0.117	-0.038	-0.583 to 0.350	0.620
Good versus poor oral hygiene	-0.148	-0.029	-1.225 to 0.930	0.785

p = 0.074; adjusted R^2 = 0.111). Restoration duration was positively associated with the restored-control difference (B = 0.035 mm per year; 95% CI, 0.001-0.070; p = 0.047), whereas no significant associations were observed for the other variables included in the model.

The multivariable model for the PPD difference is presented in Table 5. The overall model was not statistically significant (Wald F[9,72] = 1.96, p = 0.057; adjusted R^2 = 0.035). Male gender was associated with a greater restored-control difference (B = 0.726 mm; 95% CI, 0.181-1.272; p = 0.010), whereas smoking was associated with a smaller difference (B = -0.625 mm; 95% CI, -1.113 to -0.137; p = 0.013). No significant associations were observed for the other variables included in the model.

DISCUSSION

The present study evaluated the association between restored proximal tooth surfaces and periodontal parameters using both clinical and radiographic assessments. Restored proximal surfaces exhibited greater radiographic CEJ-to-alveolar crest distances than matched non-restored surfaces, whereas no statistically significant restored-control difference was observed for PPD after accounting for within-participant clustering.

The difference between the radiographic and clinical findings may reflect the distinct periodontal parameters assessed by the two measurements. CEJ-to-alveolar crest distance indicates the radiographic level of the interproximal alveolar crest, whereas probing pocket depth reflects the distance from the gingival margin to the base of the periodontal pocket and is therefore affected by the position of the gingival margin [15]. As clinical attachment level and gingival recession were not recorded, the relationship between the radiographic findings and the observed probing depths could not be fully evaluated.

The presence of a restored-control difference without a distinct pattern attributable to a specific restoration category suggests that the radiographic association may relate to characteristics of individual restorations. Margin location, contour, marginal adaptation and overhangs have been associated with adverse periodontal parameters, potentially through plaque retention and localized inflammation [3,4,14,16]. However, restoration quality, marginal adaptation, contour and margin location were not evaluated in the present study. Therefore, their contribution to the observed findings remains uncertain and cannot be determined from the present data.

The crown subgroup showed the largest descriptive restored-control difference in CEJ-to-alveolar crest distance. This finding is consistent with previous reports describing associations between full-coverage restorations and periodontal parameters [8,17]. In crowned teeth, margin location, restoration contour, emergence profile and marginal adaptation may influence plaque retention and the response of the adjacent periodontal tissues [3,4,11]. In contrast, the crown subgroup showed a small, non-significant negative restored-control probing pocket depth difference. This observation differs from previous reports that described increased probing depths around crowned teeth [10,18]. Although the crown subgroup also showed a greater CEJ-to-alveolar crest distance than its matched control surfaces, the apparent difference between the radiographic and probing findings cannot be explained because gingival recession and clinical attachment level were not assessed.

The radiographic CEJ-to-alveolar crest distance difference observed in the amalgam subgroup is consistent with previous reports of adverse periodontal conditions associated with amalgam restorations [19-22]. Similarly, the radiographic and probing differences in the composite subgroup are in agreement with previous

reports of periodontal changes associated with composite restorations [2,23,24]. Proximal overhangs may contribute to periodontal changes adjacent to amalgam restorations [20-22], whereas marginal integrity and surface characteristics may be relevant to composite restorations [2,23,24]. However, as these restoration-specific characteristics were not evaluated, their potential contribution to the observed differences remains uncertain.

Longer restoration duration was associated with a greater restored-control difference in CEJ-to-alveolar crest distance. Long-term follow-up evidence indicates that periodontal changes adjacent to crowned teeth may be influenced by restoration-specific features, particularly crown-margin location [7].

The greater restored-control PPD difference among male participants may reflect differences in oral-health practices and sex-related biological factors, including hormone-mediated immune and inflammatory responses [25,26]. Smoking was associated with a smaller restored-control PPD difference. Given the well-established adverse effects of smoking on periodontal health [27,28], this finding should not be interpreted as protective; rather, the smaller difference may reflect the influence of smoking on both restored and control surfaces and may also represent a chance finding related to the limited number of smokers included in the study.

This study has several limitations. The cross-sectional design precluded temporal and causal inferences between restorations and periodontal findings. No a priori sample-size calculation was performed and the limited number of participants, particularly the small number of smokers, together with the small temporary-restoration subgroup, reduced the precision of subgroup and multivariable estimates. Radiographic evaluation was based on two-dimensional images obtained at a single time point, while periodontal assessment was limited to PPD without measurements of clinical attachment level, gingival recession, bleeding on probing or site-specific plaque accumulation. Restoration characteristics, including overhangs, margin location, contour and marginal adaptation, were not assessed and oral hygiene was recorded using broad participant-level categories rather than a site-specific plaque index. Formal reliability coefficients such as intraclass correlation coefficients or kappa statistics were unavailable because the original calibration records were not retained. Some control surfaces were obtained from adjacent or contralateral teeth and were therefore not anatomically equivalent to their paired restored surfaces. Finally, although restoration duration, gender and smoking showed statistically significant associations with the corresponding outcomes, these findings require confirmation because neither multivariable model reached statistical significance overall. In addition, the unequal distribution of restoration categories, particularly the small temporary-restoration subgroup, limits comparisons among restoration types.

Despite these limitations, the study combined clinical and radiographic assessments within a matched, within-participant design, reducing variability attributable to differences between participants. Participant-clustered robust standard errors accounted for the correlation among multiple surface pairs contributed by individual participants. Future adequately powered longitudinal studies incorporating site-specific periodontal measurements and direct assessments of restoration quality are needed to determine whether the observed radiographic differences develop over time and how they relate to restoration duration and specific restoration characteristics.

CONCLUSIONS

Within the limitations of this cross-sectional study, restored proximal surfaces were associated with greater radiographic CEJ-to-alveolar crest distances than matched non-restored surfaces, whereas no statistically significant difference was observed in probing pocket depth. Clinical and radiographic parameters should therefore be interpreted together when evaluating periodontal conditions adjacent to proximal restorations.

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