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Assessment of Oral Health Status and Treatment Outcomes in General Dental Practice: A Cross-Sectional Clinical Study

Abstract
There is a very close relationship between oral health status and the clinical success of restorative treatment in the course of routine dental care. Posterior resin-composite restorations are now very common, and while clinical success is dependent on patient oral-health characteristics and restoration-related ones, results can be inconsistent. This study assessed oral-health status and clinical treatment outcomes and identified factors associated with failure of posterior resin-composite restorations. A cross-sectional clinical analysis was conducted using 95 patients contributing 286 posterior restorations. Patient demographic characteristics, oral-hygiene practices, plaque score, restoration age, tooth type, restoration class, clinical performance characteristics, and overall treatment outcome were evaluated. Associations with treatment failure were examined using binomial generalized estimating equations to account for clustering of multiple restorations within patients. Overall, 191 restorations (66.8%) were successful, and 95 (33.2%) failed. Failed restorations were older than successful restorations (3.17 ± 1.48 vs 2.44 ± 1.48 years). Each additional year of restoration age was independently associated with 38% higher odds of failure (adjusted OR 1.38, 95% CI 1.10–1.73; p = 0.005). Plaque score showed a positive but statistically non-significant association with failure (adjusted OR 1.90, 95% CI 0.91–3.96; p = 0.089). Posterior resin-composite restorations demonstrated generally favorable clinical performance, while increasing restoration age was the clearest predictor of failure. These findings support closer clinical monitoring of older posterior restorations to facilitate timely identification of deterioration and inform maintenance decisions.

INTRODUCTION

Oral health is a part of general health, and there are significant links between oral health and physical functioning, social participation and quality of life. Oral diseases are still one of the most common non-communicable diseases in the world and have significant clinical, social and economic burden on both people and health systems [1]. Although most of these conditions are preventable, they remain a global burden, impacting billions of people, and with significant inequities in access to prevention and treatment across and within countries. This problem is so large that more and more attention is paid to incorporating oral health into universal health coverage, and to improving access to essential preventive and restorative dental services [2]. Good oral health is more than just the absence of disease, as oral function, periodontal health and the comfort in eating and speaking are linked closely with individual well-being [3]. In addition, shdefect ared risk factors, inflammatory pathways and the impact of chronic disease may cause an interaction between oral conditions and systemic health and thus highlight the clinical relevance of routine oral assessment [4]. Oral health status also becomes a personal construct through knowledge and oral self-care practices, which in turn can impact clinical markers of oral health and preventive behaviors [5].

The burden of dental caries is one of the most significant and a major cause of restorative treatment in dental practice. Caries is a multifactorial process, a biofilm-mediated, dynamic disease, interacting with the tooth surface, microbial biofilm, dietary exposure and host-related factors [6]. The global epidemiology shows that caries affects people of all ages and that there are still inequalities in disease prevention and access to good oral health care [7]. If a carious lesion or structural necessitates operative treatment, restoring the posterior teeth is a key component in preserving the structure, function and longevity of the teeth. Consequently, direct resin composites are now important materials for posterior teeth. Favorable clinical outcomes of posterior composite restorations throughout the years [8] and improvements in the properties of the materials, adhesive procedures, and the techniques used in their preparation have contributed to their wider use. However, long-term observations show that over time restorations may deteriorate and fail, so continued clinical evaluation is necessary even after they have achieved good long-term success [9]. Material, operator, tooth, patient and time-dependent factors all affect restoration performance and are not determined by a single factor. As a result, clinical factors like marginal integrity, anatomic form, color match, surface characteristics, recurrent caries and others are routinely used to evaluate functional deterioration [10].

The oral-health condition of the patient also could affect the environment in which restorations operate. This is especially important as plaque is a factor that can be altered by effective oral hygiene, which could have a significant impact on the biological conditions around restored teeth [11]. Reliability of assessment and documentation is also necessary in routine practice as inaccuracies in dental records may affect the interpretation of the previous disease, dental treatment and future clinical performance [12]. A restorative view is that the degradation of composite materials and deterioration at material-tooth interfaces can progressively impact on the mechanical and clinical performance of restorations, offering potential mechanisms by which interventions and/or replacement may ultimately be necessary [13].

From previous studies, it has been confirmed that posterior composite restoration has clinical success, and various factors have been shown to help the success of the composite restoration. There is an unmet need for clinically integrated assessments that look at patients' oral-health attributes, as well as at performance of their restorations and treatment outcomes, in the same analytical framework. This distinction is significant since a patient might submit multiple restorations, and observations made by multiple individuals are not necessarily independent. Even when evidence comes from standard clinical practice, it can be useful to see if readily observable characteristics of the patient or restoration can help identify restorations that may be more likely to have an unfavorable outcome. The current study aims to fill this void by adding patient-level oral health data to comprehensive clinical oral health assessments at the restoration level, while at the same time recognizing the clustering of multiple restorations in individual patients. This method is suitable for the design of the study in which 95 patients provided 286 observations of a restoration.

This study aimed to characterize patient and restoration profiles at the site of posterior resin-composite restorations, assess the clinical performance and overall success of these restorations and predict factors related to both the patients and the restorations that were associated with clinical failure in a clinical environment. A specific focus was made on the factors of restoration age, oral-health indicators and patient characteristics, and therefore factors that were independently associated with poor restoration outcomes.

2. METHODOLOGY

2.1 Research Design

The cross-sectional clinical study design was employed to evaluate oral health attributes and outcomes of treatment of patients with direct posterior resin-composite restorations. Patient-level characteristics and restoration-level clinical observations were included in the analysis. The data were also clustered as numerous patients had several restorations each, and this was accounted for in the inferential analysis. A total of 95 patients with 286 observations at the restoration level were used as the analytical sample.

2.2 Data Source

The data for this study were taken from a clinical investigation conducted in selected dental institutions of Nairobi, Kenya [14] for patients with direct posterior resin-composite restorations. These data merged a patient-level profile of demographic and oral health characteristics with a restoration-level profile of clinical information, such as restoration age, tooth type and cavity characteristics, clinical performance ratings, and treatment outcomes. This clinical structure was linked to

allow oral-health measures and restoration performance to be measured and provided the capability to maintain the clustering of several restorations under individual patients.

2.3 Study Population and Variables

A total of 95 patients with a total of 286 observations at the level of the restoration (observations at restoration level) were included in the analytical sample. Patient-level variables included age, gender, occupation, flossing, toothbrush use, brushing frequency, teeth grinding, dental facility, and plaque score. The variables used for restoration level were restoration age, type of tooth, class of restoration, color match, anatomic form, marginal integrity, secondary caries, proximal contact and overall treatment outcome. The main outcome was clinical status of each restoration (successful or failed), with failed being the event of interest for regression analysis. The clinical performance was assessed by the Alpha, Beta, and Charlie ratings obtained for the clinical criteria that were available. Plaque score and restoration age were analyzed as continuous variables, and the demographic, behavioral, and restoration characteristics were analyzed as categorical variables when appropriate.

2.4 Data Preparation and Clinical Outcome Assessment

All the data were checked for completeness, consistency, missing observations and exact duplicate records before analysis. Completely empty fields were excluded from the analytical dataset. One observation per patient was used to summarize patient characteristics and the restoration level was used to analyze restoration characteristics and treatment outcomes. For variables with missing clinical assessments, percentages were calculated using available observations, while missing values were reported separately and were not reassigned to substantive clinical categories. The recorded criteria, which included color match, anatomic form, marginal integrity, secondary caries and proximal contact, were used for the assessment of clinical performance. The overall treatment outcome was dichotomized; successful restoration was considered the reference outcome, and failed restoration was considered the event. There were 286 restorations (191 successful and 95 failed) in the primary analytical dataset. Means and standard deviations, and medians and interquartile ranges (where applicable) were used to summarise continuous variables. Frequencies and percentages were used to summarise categorical variables. The analyses were performed on the patient and restoration characteristics as appropriate to the variable type, taking into account the clustered data structure where applicable, to compare the characteristics among patient groups by different treatment outcomes. Binomial generalized estimating equations (GEE) with an exchangeable working correlation structure were used to estimate associations with treatment failure, considering the multiple restorations contributed by the same patient. The odds ratios (ORs) with 95% confidence intervals (CIs) were estimated using separate GEE models for each of the individual candidate predictors and reported as crude associations. The final multivariable GEE model comprised the variables of gender, occupation, plaque score and restoration age. Adjusted associations were reported in terms of adjusted odds ratios (aORs) with 95% confidence intervals (CI) and p values. Complete data on the outcome and selected model covariates were available for all 286 restorations from 95 patients, which were included in the final model. The multicollinearity between predictors in the adjusted model was examined via variance inflation factors and the linearity of continuous predictors on the logit scale was examined for plaque score and restoration age. Within-patient correlation was estimated to describe the intra-patient correlation of restoration outcomes. After the exact duplicates of the restoration level records were removed, a sensitivity analysis was undertaken to see if the removal had a significant impact on the main estimates, and the GEE was refitted without the exact duplicate records. All of the statistical tests were two-tailed, and a p-value of < 0.05 was deemed statistically significant.

3. RESULTS

3.1 Participant Characteristics and Oral Health Profile

The study included 95 patients with a mean age of 38.68 ± 11.29 years and a median age of 38.00 years (IQR: 30.00–45.50). There was a near 50/50 split between male and female participants with 48 (50.5%) males and 47 (49.5%) females. The majority of the participants were employed (47.4%) or self-employed (36.8%) while 15.8% were unemployed. There was a wide range of oral hygiene practices, with 81.1% reporting that they did not floss, but almost all participants (97.9%) reported using a toothbrush. The most common brushing habit was twice daily (66.3%) followed by once daily (30.5%). 5.3% reported grinding their teeth, which was not very common. The mean plaque score was 0.81 ± 0.35, with a median of 0.75 (IQR: 0.66–0.92). The three dental facilities were used to recruit patients and the highest number attended the UoN Dental School (46.3%), while the lowest number were from KNH (24.2%). The demographic, oral hygiene and oral health status of the participants are presented in Table 1.

Table 1. Characteristics and oral health status of study participants (n = 95)

Characteristic	Category	Value
Age, years	Mean ± SD	38.68 ± 11.29
	Median (IQR)	38.00 (30.00–45.50)
Plaque score	Mean ± SD	0.81 ± 0.35
	Median (IQR)	0.75 (0.66–0.92)
Gender	Male	48 (50.5%)
	Female	47 (49.5%)
Occupation	Employed	45 (47.4%)

	Self employed	35 (36.8%)
	Unemployed	15 (15.8%)
Flossing	No	77 (81.1%)
	Yes	18 (18.9%)
Toothbrush use	Yes	93 (97.9%)
	No	2 (2.1%)
Brushing frequency	Twice daily	63 (66.3%)
	Once daily	29 (30.5%)
	> Twice daily	3 (3.2%)
Teeth grinding	No	90 (94.7%)
	Yes	5 (5.3%)
Dental facility	UoN Dental School	44 (46.3%)
	UoN Dental Plaza	28 (29.5%)
	KNH	23 (24.2%)

3.2 Restoration Characteristics and Clinical Treatment Outcomes

Among the 95 patients, a total of 286 posterior restorations were evaluated, which is about three restorations per patient. The mean restoration age was 2.68 ± 1.52 years, with a median of 3.00 years (IQR: 1.00–4.00). A total of 71.3% of all the restorations evaluated were molars and 28.7% were premolars. The most prevalent restoration class was the meso-occlusal (50.7%), followed by the occlusal (43.7%), while mesio-occluso-distal and Class V were relatively rare. Clinical assessment showed differences in the assessed criteria for the assessment of restoration. Beta was rated as the top answer for color match (46.9%), followed by Alpha (38.5%) and Charlie (14.7%). The anatomic form and marginal integrity also had a majority of Beta ratings (69.2%, 59.1%, respectively). Of those restorations that had secondary caries evaluations available, 82.9% were rated as Alpha and 17.1% Beta. Of restorations that could be measured, 57.7%, 22.3% and 20.0% had tight, open and loose contacts, respectively. Overall, 191 restorations (66.8%) were considered successful and 95 (33.2%) were considered failed. The restoration characteristics and clinical outcomes are presented in Table 2. Percentages for secondary caries and proximal contact categories were calculated among restorations with available assessments; missing values are presented as percentages of the total 286 restorations.

Table 2. Restoration characteristics and clinical treatment outcomes (n = 286 restorations)

Characteristic	Category	Value
Restoration age, years	Mean ± SD	2.68 ± 1.52
	Median (IQR)	3.00 (1.00–4.00)
Tooth type	Molar	204 (71.3%)
	Premolar	82 (28.7%)
Restoration class	Meso-occlusal	145 (50.7%)
	Occlusal	125 (43.7%)
	Mesio-occluso-distal	14 (4.9%)
	Class V	2 (0.7%)
Color match	Beta	134 (46.9%)
	Alpha	110 (38.5%)
	Charlie	42 (14.7%)
Anatomic form	Beta	198 (69.2%)
	Alpha	68 (23.8%)
	Charlie	20 (7.0%)
Marginal integrity	Beta	169 (59.1%)
	Alpha	88 (30.8%)
	Charlie	29 (10.1%)
Secondary caries	Alpha	218 (82.9%)
	Beta	45 (17.1%)
	Missing	23 (8.0% of total)
Proximal contact	Tight	124 (57.7%)
	Open	48 (22.3%)
	Loose	43 (20.0%)
	Missing	71 (24.8% of total)
Overall treatment outcome	Successful	191 (66.8%)
	Failed	95 (33.2%)

3.3 Overall Treatment Outcome and Clinical Performance Ratings

There was a moderate overall outcome profile, with about two-thirds of the assessed restorations being clinically successful and one-third being considered failed. The results of treatment are presented overall in Figure 1A, which indicates that 66.8% of treatments were successful, whereas 33.2% were not. In the selected USPHS criteria, the Beta ratings were more noticeable in anatomic form and marginal integrity, with color match showing a more variable distribution of Alpha, Beta and Charlie ratings. The distribution of USPHS ratings is seen in Figure 1B, and it is estimated that 46.9% of color match, 69.2% of anatomic form, and 59.1% of marginal integrity assessments have been performed with the Beta rating.

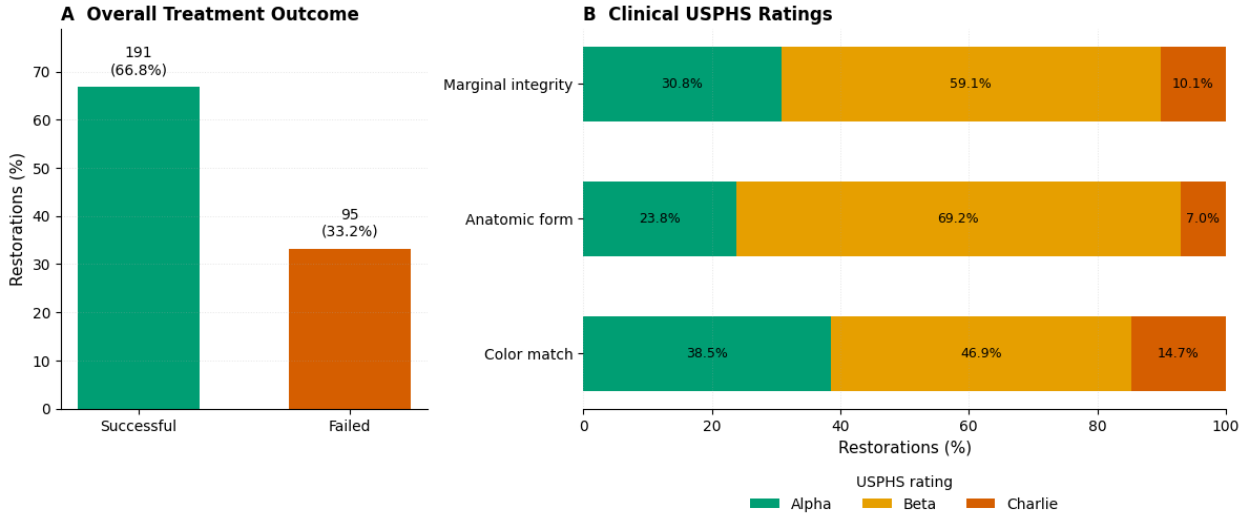

Figure 1. Clinical performance of posterior composite restorations. (A) Overall treatment outcome. (B) Clinical USPHS ratings for color match, anatomic form, and marginal integrity.

3.4 Restoration Age and Plaque Score According to Treatment Outcome

There was a significant difference in the restoration age depending on the clinical outcome. The mean age of failed restorations was 3.17 ± 1.48 years, while it was 2.44 ± 1.48 years in successful restorations. The bivariate analysis with clusters showed a significant association between restoration age and treatment failure (p = 0.002). Treatment outcome by restoration age is presented in Fig. 2A, which illustrates an increasing age of restoration in failed treatments. The difference in plaque scores was smaller between groups of outcomes. The mean plaque score of the successful restorations was 0.78 ± 0.31, while the mean plaque score of failed restorations was 0.84 ± 0.39. This association was not statistically significant in the cluster-adjusted bivariate analysis (p = 0.170). The distribution of the plaque scores is presented in Figure 2B, and there is a significant overlap between the successful and the failed restorations

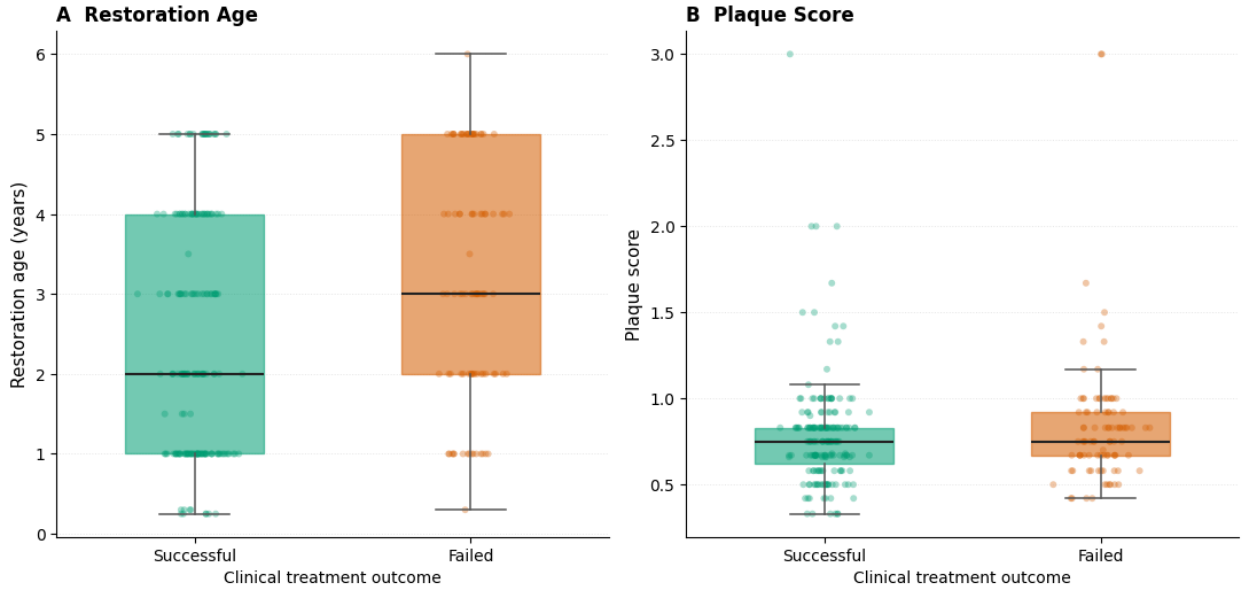

Figure 2. Oral health and restoration characteristics according to clinical treatment outcome. (A) Restoration age among successful and failed restorations. (B) Plaque score among successful and failed restorations.

3.5 Factors Associated with Clinical Treatment Failure

Binomial generalized estimating equation analysis was used to identify factors associated with treatment failure while accounting for clustering of multiple restorations within individual patients. In the crude analysis, restoration age was significantly correlated with failure, with a 40% increase in odds of failure (OR 1.40; 95% CI 1.13–1.74; p = 0.002) with each additional year of restoration age. The gender association was not statistically significant (OR 1.83, 95% CI 0.97–3.45), with female gender showing higher estimated odds of failure than male gender (p = 0.062). The crude model also showed a positive association between plaque score and failure (OR 1.59, 95% CI 0.82–3.09; p = 0.170). Adjustment for gender, occupation, plaque score, and restoration age did not alter the independent association of restoration age with treatment failure. The odds of failure increased by 38% with every restoration year (adjusted odds ratio [OR] 1.38, 95% confidence interval [CI] 1.10-1.73, p = 0.005). Plaque score showed an increased adjusted effect estimate (adjusted OR 1.90, 95% CI 0.91–3.96), although this was not statistically significant (p = 0.089). Neither gender nor occupation was independently associated with treatment failure. The crude and adjusted GEE estimates for the factors in the final multivariable model are shown in Table 3.

Table 3. Factors associated with clinical treatment failure using generalized estimating equations

Predictor	Comparison	Crude OR (95% CI)	Crude p-value	Adjusted OR (95% CI)	Adjusted p-value
Gender	Female vs Male	1.83 (0.97–3.45)	0.062	1.61 (0.85–3.06)	0.142
Occupation	Self-employed vs. employed	1.14 (0.58–2.23)	0.711	1.21 (0.61–2.41)	0.591
	Unemployed vs Employed	0.49 (0.17–1.45)	0.199	0.52 (0.18–1.50)	0.228
Plaque score	Per 1-unit increase	1.59 (0.82–3.09)	0.170	1.90 (0.91–3.96)	0.089
Restoration age, years	Per 1-year increase	1.40 (1.13–1.74)	0.002	1.38 (1.10–1.73)	0.005

3.6 Adjusted Effect Estimates and Model Robustness

The adjusted effect estimates showed that only restoration age had a 95% confidence interval that did not include the null value. Among the predictors included in the adjusted model, restoration age was the only factor whose 95% confidence interval excluded the null value of 1.0. The confidence intervals for gender, occupation, and plaque score all included 1.0, indicating no statistically significant independent associations with treatment failure. The adjusted odds ratios and 95% confidence intervals from the final GEE model with independent association between increasing restoration age and clinical treatment failure are shown in Figure 3.

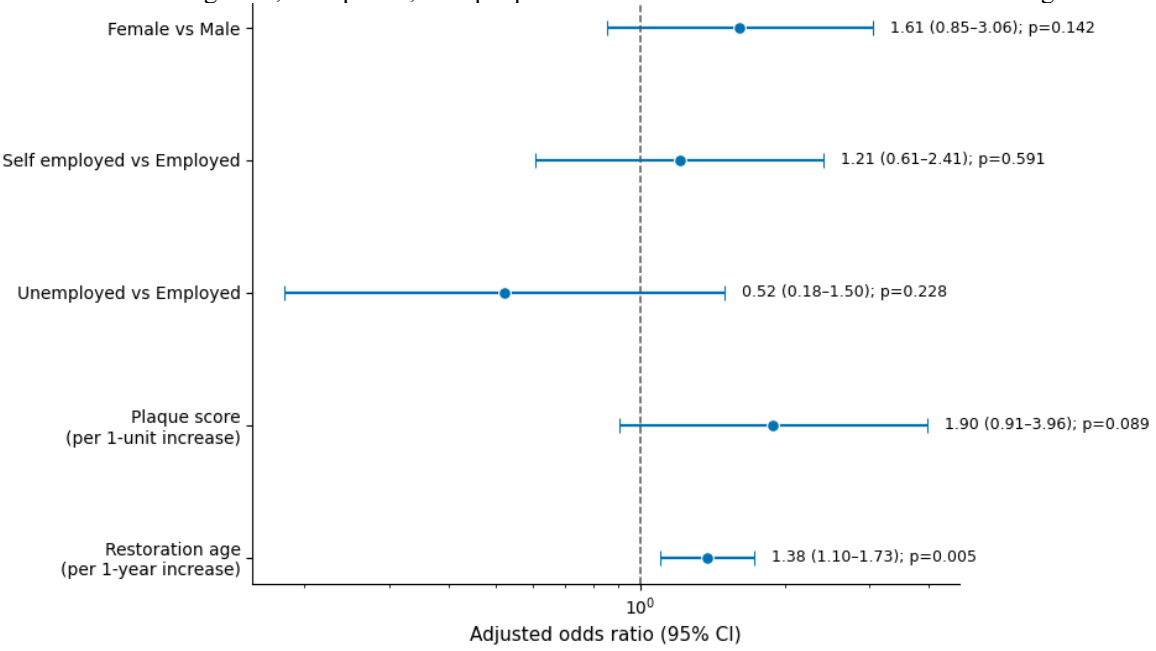

Figure 3. Adjusted associations of patient and restoration characteristics with clinical treatment failure.

The final specification was supported by the use of model diagnostics. Variance inflation factors (VIFs) were between 1.30 and 3.35, which indicates no serious multicollinearity issues. The linearity-in-the-logit assessment provided no statistically significant evidence of departure from linearity for plaque score (p = 0.078) or restoration age (p = 0.282). Within-patient correlation was estimated at 0.251, which justifies the assumption of clustering of multiple restorations within patients. Results from the duplicate-record sensitivity analysis were

consistent with the main finding. After removal of 24 exact duplicate restoration-level records, the sensitivity dataset comprised 262 restorations from all 95 patients. The association between restoration age and treatment failure remained consistent with the primary analysis (aOR 1.40, 95% CI 1.12–1.74; p = 0.003). The consistency suggested that exact duplicate records did not significantly affect the association between restoration age and clinical failure that was observed.

4. Discussion

The clinical results showed that the posterior resin-composite restorations had a generally good performance, with 66.8% being successful and 33.2% failing. The distribution of USPHS ratings also indicated that most restorations were in the clinically acceptable range, for color matching, anatomic form and marginal integrity, with Charlie ratings found in various areas. This pattern indicates that the extent of deterioration did not follow a uniform trend for all clinical characteristics and that restoration performance should be considered as a multi-dimensional phenomenon and not simply as a 2-level measure of success or failure. The most important factor that was correlated with treatment failure was restoration age. The adjusted odds of failure per additional year of restoration age were an increase of 38% for every additional year of restoration age; Failed restorations were also older than successful restorations. This association remained unchanged after accounting for the measured patient-level characteristics, suggesting that restoration age was not simply proxied by the measured characteristics. Plaque score was associated with failure; however, the CI was still very broad and overlapped with the null value, suggesting that there was not enough evidence to determine that plaque score is an independent factor in the current sample. Gender and occupation as independent risk factor for treatment outcome were not found as well. Removing the exact duplicate records in the sensitivity analysis yielded a similar estimate of restoration age, thus lending credibility to the main result.

The oral-health profile in this study is similar to other data that indicate that oral-health behaviors are highly diverse among dental patients and may shape the clinical context of a successful dental-restorative-treatment process. Cross-sectional studies among dental patients in China have also been associated with oral-health-related quality of life as a measure of oral health, beyond just clinical outcomes [15], indicating the importance of other oral self-care practices on the evaluation of oral health. Having also been found to influence the treatment experience and consequently dental behavior after dental rehabilitation, patient-related factors might play a role in shaping the experience of dental treatment [16]. This is corroborated by hospital-based data indicating dental caries prevalence and relationships with behavior and sociodemographic factors in dental patients [17]. Oral-health related quality of life (OHRQoL) may also be affected by anxiety and avoidance of dental care, which may influence when the deterioration is picked up and treated [18]. The clinical significance of maintaining a good oral environment around restored teeth has also been linked to QOL outcomes, and periodontal health has also been associated with QOL outcomes [19].

The results of the restoration match more closely today's clinical assessments of posterior restorative materials. Limited clinical trials of these resin-based restorative materials have demonstrated good performance in areas including marginal adaptation, anatomic form and surface characteristics over a short period of time, but may deteriorate over time [20]. More data available for shorter periods of observation will give less support to the current association with the restoration age. A 12-year retrospective study of posterior composite restorations has shown that failures occur during long-term service, and that time is a risk factor [21]. Clinical studies conducted in dental universities have also pointed out factors related to the restoration and the patient that will affect the survival of posterior composite restorations, which substantiates the idea that posterior composite restoration survival is multifactorial and not solely dependent on the choice of the material [22]. Long-term comparisons of indirect resin-composite and ceramic posterior restorations also show that even with clinical success, failures appear to be more important with longer follow-up time and indicate that such restorations can perform well for years [23]. These results, combined with the current observation that restoration age was the strongest independent failure predictor, are statistically significant.

Results indicate that restoration age is a good clinical tool to use in a routine recall examination. Even if the patient is asymptomatic, older posterior composite restorations may need to be evaluated closely for marginal deterioration, anatomic changes, secondary caries, and/or loss of the proximal contact. The high number of B categories in a number of USPHS domains also allows for further monitoring of many restorations that have measurable differences from ideal condition but are not clinically serviceable. Plaque control should continue as part of the routine restorative follow-up, regardless of the lack of an independent statistically significant relationship in the adjusted model. Incorporating an oral-hygiene assessment along with restoration-specific assessment can be helpful in identifying biological and mechanical factors that may interact to affect future restorative deterioration. Therefore, a risk-based recall strategy that uses the restoration age and clinical condition in addition to the oral-health status of the patient may be more informative than demographic information in determining a maintenance strategy.

There are a couple of caveats. As the cross-sectional design allowed for assessment of associations but not the temporal sequence of deterioration in restoration, they were not suitable for this purpose. There were relatively small numbers of observations in some of the clinical categories, and in some cases, there were not enough observations for detailed comparisons between the different, less common clinical categories of restorations. There was also missing data for some clinical variables (proximal contact, secondary caries), but the data were not reassigned.

Further studies should compare similar patient and restoration parameters in a prospective fashion over a set time period and repeated clinical evaluations. More

detailed assessment of the plaque-related effects, restoration classes, material properties, operator factors and patient-level oral-health and restoration longevity would be possible with larger multicenter patient cohorts. It would also be important to determine if the increased failure rate for the different restoration ages indicates a uniform time-related risk in various clinical situations with longitudinal follow-up.

5. Conclusion

The results of posterior resin-composite restorations were generally satisfactory: about two-thirds of them were successful at the time of the evaluation. The strongest predictor (after adjusting for patient characteristics and plaque score) of unfavorable outcome was restoration age, with each additional year being associated with a significant increase in the likelihood of clinical failure. Plaque status, gender, and occupation, on the other hand, were not independently associated with failure, although plaque score trended upwards but not significantly. Many restorations were still serviceable with clinically acceptable USPHS ratings, with measurable changes from ideal conditions for all color match, anatomic form and marginal integrity. The results suggest that older posterior restorations should be monitored more closely during normal dental treatment, and that the following should be considered: marginal deterioration, secondary caries, proximal contact and oral hygiene. A structured, risk-based follow-up approach may facilitate earlier identification of deteriorating restorations and support timely maintenance or replacement decisions in general dental practice.

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