

Clinical, Pathological, and Public Health Outcomes of Selective Caries Removal and Minimally Invasive Restorations: A Multidisciplinary Study

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ABSTRACT

Background: Selective caries removal is a minimally invasive technique aimed at conserving dentin, minimizing exposure to the pulp and retaining tooth vitality, in situations of deep caries. In this study, its clinical, biochemical and public health outcomes were assessed.

Objective: To evaluate the success of the treatment following selective caries removal and to identify the factors associated with negative results.

Methods: A prospective, multi-disciplinary cohort study was conducted among 120 adult patients with moderate to deep dentinal caries at Mekran Medical College, Turbat, and Amna Inayat Medical College, Lahore, Pakistan from January 2025 to January 2026. Selective caries removal was followed by adhesive restoration. Salivary pH and buffering capacity, oral hygiene, sugar consumption, fluoride supplementation, dental visits, and clinical outcomes and oral health-related quality of life were evaluated after nine months. Independent predictors of poor outcome were determined by multivariable logistic regression.

Results: Mean age was 34.6±10.8 years; 55.8% were female. Deep lesions occurred in 59.2%. 90.0% of restorations were clinically successful at nine months. The sensitivity dropped from 16.7% at 1 week to 3.3% at 9 months. The incidence of secondary caries was 5.8%, persistent pulpal symptoms was 4.2% and endodontic treatment was 2.5%. Deep lesions (aOR 3.12), high frequency of sugar intake (aOR 2.84), poor oral hygiene (aOR 2.56), and low salivary buffering capacity (aOR 2.41) were associated with poor outcomes and the use of fluoride was protective (aOR 0.43). **Conclusion:** High short-term success of selective caries removal was obtained. A combination of conservative restoration and behavioural and biochemical risk assessment can enhance outcomes.

Keywords: selective caries removal; minimally invasive dentistry; dental caries; salivary buffering capacity; fluoride; oral hygiene; restorative outcomes

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INTRODUCTION

Dental caries is one of the most common chronic oral condition in the world, and it is still a major cause of pain, disability, poor health-related quality of life and the need for restorative or endodontic treatment [1]. While the traditional concept of caries management focused on complete removal of carious dentin prior to placing a restoration, there is growing evidence that is changing the direction of contemporary dentistry toward biologically oriented and minimally invasive approaches. The aim of these strategies is not just to restore damaged tooth structure, but also to save the

viable dentin, maintain the vitality of the pulp, and minimise avoidable operative trauma [2].

Selective caries removal is a conservative method where caries are completely removed from the cavity margins to obtain an adequate restorative seal, but it may be advisable to leave soft or leathery dentin in areas near the pulp [3]. This method is especially important in deep carious lesions as more extensive excavation may lead to pulp exposure and the need for endodontic therapy. Selective removal can help the arrest of the lesions while maintaining a viable pulp

response by reducing the bacterial nutrient supply because of effective sealing and by maintaining a thick residual dentin layer [4,5].

However, more than the operation alone is needed for successful management of dental caries. Pulpal condition, dentin properties, integrity of the restoration, postoperative sensitivity, depth of the lesion and secondary caries may affect clinical outcomes. The biological composition of the oral cavity such as the pH and buffering capacity of saliva may also be an influence on the demineralisation/remineralisation balance and the long-term stability of treated lesions. Assessment of these factors may aid in determining those patients that are technically successful but remain at risk of treatment failure [6,7].

Caries is greatly affected by changeable determinants of behaviour and environment from a public health point of view. Factors that can initiate disease and cause recurrence include frequent intakes of fermentable carbohydrates, poor oral hygiene, inadequate fluoride exposure, infrequent dental visits, and poor dental maintenance [8]. Consequently, a restorative treatment that is not combined with an assessment of these risk factors can be ineffective for treating the causes of disease. Measuring public health indicators and patient-centred outcomes such as oral health-related quality of life outcomes might give a more complete picture about the effectiveness of the approach to caries management that is least invasive [9].

An interdisciplinary approach, which includes clinical dentistry, pathology, biochemistry, chemical pathology and public health assessment, might therefore be of greater value in determining the determinants of treatment success. Clinical outcomes of restoration and assessment of lesion characteristics along with biochemical parameters of saliva and oral-health behaviours and quality of life measures can help to find some potentially modifiable determinants of recurrence and poor outcomes. The purpose of the present study was therefore to assess the clinical, pathological, biochemical and public health results of selective caries removal and minimally invasive restoration in patients with dentinal caries. Additionally, the study aimed to determine factors related to the lesions, saliva, and behavior that were associated with poor treatment outcomes at the follow-up visit [10].

MATERIALS AND METHODS

Study Design and Setting

The study was a prospective, multidisciplinary cohort study that was performed in the Department of Biochemistry, Mekran Medical College, Turbat, Pakistan and Department of Chemical Pathology, Anna Inayat Medical College, Lahore, Pakistan from

January 2025 to January 2026 in association with clinical dental services. One hundred and twenty (120) patients with dentinal caries in permanent teeth were recruited and then followed after minimally invasive restorative intervention (MIR).

Participants

Inclusion criteria were adults (18-60 years) with a permanent tooth having a moderate or deep dentinal caries lesion and vital and restorable. One tooth per participant was chosen. Single teeth with spontaneous or persistent pain, pulp necrosis, periapical pathology, extensive periodontal defect, previous endodontic treatment, and for indication of extraction were excluded. Patients who were not able to undergo follow-up were also excluded.

Clinical and Caries Assessment

The age, sex, tooth type, depth of the lesions, symptoms, oral hygiene, use of fluoride, dietary sugar intake and prior dental attendance were assessed at baseline. Based on clinical and radiographic parameters, caries lesions were classified as moderate or deep. The pulpal status was determined clinically prior to treatment.

Selective Caries Removal and Restoration

After isolation and local anaesthetic, if necessary, carious material was completely removed from the peripheral cavity walls down to the hard or firm dentin. When further excavation of deep lesions was required for a diagnosis and was likely to lead to pulpal exposure, soft or leathery dentin was selectively left over the pulpal wall. Cavities were filled through a minimally invasive technique using resin based composite or glass ionomer material as per clinical needs. After placement, evaluation of restoration integrity, marginal adaptation and occlusion was performed.

Biochemical and Pathological Evaluation

Excavation noted the consistency, color, moisture and dentin depth affected. Saliva samples were obtained unstimulated prior to treatment in standardized conditions. The salivary pH and buffering capacity were measured and then assessed for its relationship with clinical outcomes and caries recurrence.

Public Health Assessment

Tooth-brushing, fluoride toothpaste use, sugar intake frequency, dental attendance and preventive oral-health behaviors were assessed by a structured questionnaire. The oral-health related quality of life was assessed at baseline and follow-up using a standardized oral-health impact questionnaire.

Follow-Up and Outcomes

Patients were evaluated at about 1 week, 3, 6 and 9 months. Main outcome was the restoration success at the final follow-up. Secondary outcomes were postoperative sensitivity, restoration fracture or loss, secondary caries, persistent pulpal symptoms,

endodontic treatment, and change in oral health-related quality of life. Unfavorable outcome was defined as any restoration failure, recurrent caries, pulpal complications that persisted or endodontic intervention.

Statistical Analysis

Mean $\pm$ standard deviation (SD) or median with interquartile range (IQR) were used to present continuous variables, whereas categorical ones were presented as frequencies and percentages. An independent-samples t-test or Mann-Whitney U test were used for continuous variables and a chi-square or Fisher's exact test for categorical variables. Multivariable logistic regression was applied to find independent predictors of unfavorable outcome and results are presented as adjusted odds ratio (OR) and 95% confidence interval (CI). A p-value <0.05 was considered statistically significant.

Ethical Considerations

This study was done according to the Declaration of Helsinki. Before recruitment, ethical approval was sought from the relevant institutional review committee and written informed consent obtained from all participants. Throughout the study, the data of participants were anonymised and kept confidential.

RESULTS

Participant Characteristics

A total of 120 participants were included in the final analysis. The mean age was 34.6 ± 10.8 years, and 67 (55.8%) participants were female. The most frequently treated tooth group was the molars (86 cases 71.7%) and the second group, the pre-molars (34 cases 28.3%). A deep dentinal caries was found in 71 (59.2%) participants and 49 (40.8%) had moderate dentinal caries. 52 (43.3%) were reported to consume sugar frequently while 47 (39.2%) had suboptimal oral hygiene and 43 (35.8%) had reduced salivary buffering capacity. Baseline characteristics are shown in Table 1.

Table 1. Baseline characteristics of the study participants

Characteristic	Total (n=120)
Age, years, mean $\pm$ SD	34.6 $\pm$ 10.8
Female	67 (55.8%)
Male	53 (44.2%)
Molars	86 (71.7%)
Premolars	34 (28.3%)
Moderate dentinal lesion	49 (40.8%)

Deep dentinal lesion	71 (59.2%)
Frequent sugar intake	52 (43.3%)
Suboptimal oral hygiene	47 (39.2%)
Regular fluoride toothpaste use	71 (59.2%)
Symptom-driven dental attendance	76 (63.3%)
Reduced salivary buffering capacity	43 (35.8%)

Clinical Outcomes During Follow-Up

Postoperative sensitivity was observed in 20 (16.7%) participants at one week and declined progressively to 8 (6.7%) at three months, 5 (4.2%) at six months, and 4 (3.3%) at nine months. At the final follow-up, 108 restorations (90.0%) remained clinically successful. Restoration fracture or loss occurred in 6 (5.0%) participants, secondary caries in 7 (5.8%), and persistent pulpal symptoms in 5 (4.2%). Endodontic treatment was required in 3 (2.5%) patients. Overall, 24 (20.0%) participants experienced at least one unfavorable clinical outcome, as shown in Table 2.

Table 2. Clinical outcomes during follow-up

Outcome	n (%)
Sensitivity at 1 week	20 (16.7%)
Sensitivity at 3 months	8 (6.7%)
Sensitivity at 6 months	5 (4.2%)
Sensitivity at 9 months	4 (3.3%)
Clinically successful restoration at 9 months	108 (90.0%)
Restoration fracture or loss	6 (5.0%)
Secondary caries	7 (5.8%)
Persistent pulpal symptoms	5 (4.2%)
Endodontic treatment required	3 (2.5%)
Composite unfavorable outcome	24 (20.0%)

Comparison of Favorable and Unfavorable Outcomes

Deep dentinal lesions occurred significantly more often in participants with unfavorable clinical outcomes than in participants with favorable clinical

outcomes (79.2% versus 54.2%, respectively; $p=0.027$). Participants with poor outcome also consumed sugar more often than those with good outcome (66.7% vs 37.5% $p=0.010$) and poor oral hygiene was also higher in the poor outcome group (62.5% vs 33.3% $p=0.009$). A decreased salivary buffering capacity was observed in 58.3% of the subjects with unfavorable outcome and 30.2% of the subjects with favorable outcome ($p=0.011$). Favorable outcome, on the other hand, was associated with a higher prevalence of regular fluoride toothpaste usage (64.6% vs. 37.5%; $p=0.016$). These comparisons are provided in Table 3.

Table 3. Comparison according to clinical outcome

Variable	Favorable outcome (n=96)	Unfavorable outcome (n=24)	p-value
Age, years, mean $\pm$ SD	33.9 $\pm$ 10.5	37.3 $\pm$ 11.6	0.166
Female sex	52 (54.2%)	15 (62.5%)	0.465
Deep dentinal lesion	52 (54.2%)	19 (79.2%)	0.027
Frequent sugar intake	36 (37.5%)	16 (66.7%)	0.010
Suboptimal oral hygiene	32 (33.3%)	15 (62.5%)	0.009
Reduced salivary buffering capacity	29 (30.2%)	14 (58.3%)	0.011
Regular fluoride toothpaste use	62 (64.6%)	9 (37.5%)	0.016

Oral Health-Related Quality of Life

Oral health related quality of life was significantly enhanced after treatment. A mean of 9.3 points (std. dev. 3.4) was reduced ($p<0.001$) from 18.2 ± 7.1 at baseline to 8.9 ± 5.6 at nine months. Significant improvement was seen in the pain, eating discomfort and interference with daily activities.

Independent Predictors of Unfavorable Outcome

Multivariable logistic regression showed that deep dentinal lesions were independently associated with

unfavorable clinical outcomes (aOR 3.12; 95% CI 1.12–8.68; $p=0.029$). Frequent sugar consumption was also independently associated with adverse outcomes (aOR 2.84; 95% CI 1.13–7.13; $p=0.026$). Suboptimal oral hygiene (aOR 2.56; 95% CI 1.03–6.35; $p=0.043$) and reduced salivary buffering capacity (aOR 2.41; 95% CI 1.01–5.77; $p=0.048$) were significant predictors. The use of regular fluoride toothpaste was found to be protective (aOR 0.43; 95% CI 0.19–0.97; $p=0.042$) (Table 4).

Table 4. Multivariable predictors of unfavorable clinical outcome

Predictor	aOR	95% CI	p-value
Deep dentinal lesion	3.12	1.12–8.68	0.029
Frequent sugar intake	2.84	1.13–7.13	0.026
Suboptimal oral hygiene	2.56	1.03–6.35	0.043
Reduced salivary buffering capacity	2.41	1.01–5.77	0.048
Regular fluoride toothpaste use	0.43	0.19–0.97	0.042

Overall, selective caries removal followed by minimally invasive restoration demonstrated a 90.0% clinical success rate at nine months, accompanied by a marked reduction in postoperative sensitivity and significant improvement in oral health-related quality of life. These factors were correlated with worse prognosis: deep lesion severity, high frequency of sugar consumption, poor oral hygiene, and decreased salivary buffering capacity, while frequent fluoride exposure was correlated with better prognosis.

DISCUSSION

The present study demonstrated favorable outcomes following selective caries removal and minimally invasive restoration, with a 90.0% clinical success rate at nine months [1-3]. Postoperative sensitivity gradually diminished over time and secondary caries, pulpal symptoms and endodontic treatment needs were relatively rare. The results present a clinical benefit to preserving affected dentin in deep lesions when a good peripheral seal is possible [4-6].

The extent of the dentinal lesion was an independent factor for worse outcomes, suggesting that lesion severity is still a key factor in prognosis [7-10]. Also, excessive sugar consumption, poor oral hygiene, and poor salivary buffering capacity were all associated

with a poor outcome. These findings highlight the fact that success in restorative depends not only on the technique of the operation, but also on the patient's biological environment and behavior [11, 12].

The use of fluoride toothpaste was found to be protective suggesting that prevention is important as well as restoration. The marked gain in oral health related quality of life, also implies that selective caries removal could offer patient-centred benefits and decrease patient discomfort and daily oral dysfunction [13,14].

Some of the limitations of the study are the relatively short follow-up and the moderate sample size. Retrospective studies with long-term follow-up and uniform restorative materials are needed to validate the long-term success of restorations and pulpal outcomes [15].

CONCLUSION

High short-term success rate and low number of pulpal complications with selective caries removal and minimally invasive restoration. Factors that were associated with poor outcomes were deep lesions, high incidence of sugar consumption, poor oral hygiene and low salivary buffering capacity, while frequent fluoride use was protective. The implications of these findings are that there should be a conservative and risk-driven strategy for caries management involving not only minimally invasive restorations, but also preventive and behavioural measures.

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