

Selective versus complete caries removal in deep posterior lesions: a six-month prospective pilot

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Research

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Abstract

Aim: To compare selective caries removal (SCR) and complete caries removal (CCR) in vital permanent posterior teeth with deep carious lesions.

Materials and Methods: This single-centre prospective comparative pilot study included 60 adults assigned to SCR or CCR (n = 30 each). Standardised diagnosis, isolation, excavation, adhesive restoration and six-month clinical/radiographic follow-up were performed. Primary outcomes were positive pulp sensibility and restorative success. No formal sample-size calculation or prospectively registered statistical analysis plan was available; results were interpreted as pilot estimates.

Results: Mean age was 47.55 ± 13.30 years and 83.3% of treated teeth were molars. Intraoperative pulp exposure occurred in 40.0% of cases without a between-group difference. Immediate postoperative sensibility remained positive in 98.3%. At six months, positive pulp sensibility and restorative success were 90.0% after SCR and 73.3% after CCR (absolute difference 16.7 percentage points; 95% CI -3.3 to 35.6; two-sided $p = 0.095$). An exploratory one-sided analysis gave $p = 0.045$.

Conclusions: SCR showed a clinically relevant six-month pilot signal, with numerically higher pulp sensibility and restorative success than CCR, but the two-sided comparison was not statistically significant. Larger prospectively registered studies with longer follow-up are required.

Key points

- Scientific rationale: selective caries removal preserves the pulp-dentine complex by combining a sound peripheral seal with controlled retention of affected dentine near the pulp.
- Key finding: at six months, positive pulp sensibility and restorative success were numerically higher after selective removal (90.0%) than after complete removal (73.3%).
- Practical relevance: selective removal may be a useful minimally invasive option for eligible vital posterior teeth, pending confirmation in larger prospectively registered studies with longer follow-up.

Introduction

Dental caries is a dynamic, biofilm-mediated disease in which repeated episodes of demineralisation may progress to cavitation and pulpal involvement. Contemporary management therefore seeks to control disease activity while preserving sound and potentially repairable tissue, pulp health and long-term tooth function. This shift from a purely surgical model underpins minimally invasive dentistry and the move away from routine removal of all demineralised dentine.^{1,2,3,4,5,6,7,8,9,10,11,12,13,14}

Dental caries is currently understood as a dynamic, multifactorial and biofilm-mediated disease process, resulting from an imbalance between pathological and protective factors that regulate repeated cycles of demineralisation and remineralisation at the tooth surface. When this ecological imbalance persists,

mineral loss may progress through enamel and dentine, leading to cavitation and, in deep lesions, potential pulpal involvement. Within this process, carious dentine should be interpreted as a biological continuum rather than a uniform infected mass. The outer infected zone usually has a high bacterial load, irreversibly altered collagen and poor mechanical integrity, whereas the inner affected zone is less contaminated, retains a partly intact collagen scaffold and may remineralise after an effective seal. Clinically, soft dentine deforms and is removed with little resistance; leathery dentine can be lifted with an excavator; firm dentine resists removal; and hard dentine resists penetration and may give a scratchy sensation. These tactile categories guide excavation and support minimally invasive decision-making, but they do not represent exact histological boundaries.^{15,16,17,18}

The dentine-pulp complex may respond to lesion progression through tubular sclerosis, reduced permeability and tertiary dentine formation. The magnitude of this response depends on lesion activity, progression rate, remaining dentine thickness, patient age and pulpal status. Consequently, lesions of similar radiographic depth may not behave identically, and the operative endpoint should integrate symptoms, sensibility findings, radiographic proximity to the pulp, tactile characteristics and the feasibility of obtaining a durable coronal seal.

Visual-tactile assessment remains the principal clinical method for defining the excavation endpoint. Detector dyes and fluorescence devices may assist when the boundary between heavily infected and potentially remineralisable dentine is uncertain, particularly in extensive lesions, but neither replaces clinical judgement. Dyes can stain demineralised collagen beyond irreversibly infected tissue, while fluorescence may be affected by hydration, pigmentation, residual restorative material and the selected diagnostic threshold.^{17,19,20,21,22,23,24}

Current strategies include complete caries removal to hard dentine, stepwise excavation and selective caries removal (SCR) to firm or soft dentine according to lesion depth. In deep lesions, SCR removes carious tissue to hard dentine at the enamel-dentine junction and cavity periphery but permits soft-to-leathery or firm dentine to remain over the pulpal wall when further excavation risks exposure. Stepwise excavation follows a similar biological rationale but requires re-entry, whereas complete caries removal (CCR) seeks hard dentine throughout the cavity in one visit.^{25,26,27,28,29,30,31,32,33,34}

The success of SCR depends on a sound peripheral sealing zone that supports adhesion and deprives residual bacteria of fermentable substrate. Preserved affected dentine may then undergo sclerosis and mineral gain within a sealed environment. Adhesive systems and liners may support this interface, but they cannot compensate for inadequate isolation, soft peripheral dentine or loss of the coronal seal.^{19,35,36,37,38,39,40,41,42,43,44,45,46,47,48} Evidence favours conservative excavation, although definitions, operative endpoints, restorative protocols and follow-up vary.^{49,50} This study compared SCR and CCR in vital permanent posterior teeth with deep lesions, focusing on six-month pulp sensibility, restorative success and intraoperative exposure.

Materials and methods

Study design and participants

This single-centre prospective comparative pilot study included 60 adults aged 18–75 years with a vital permanent premolar or molar affected by a deep carious lesion and suitable for direct restoration. It was designed to generate clinical pilot estimates and assess feasibility rather than to provide confirmatory evidence of treatment superiority. Exclusion criteria were negative sensibility, symptoms consistent with irreversible pulpitis, periapical disease, need for endodontic treatment, non-restorability, severe periodontal involvement or inability to attend follow-up. The Research Ethics Committee of the University of Salamanca approved the protocol on 20 March 2025 (registration 1265). The study followed the Declaration of Helsinki and all participants provided written informed consent.

Group allocation and clinical protocol

After eligibility assessment, participants were assigned to SCR ($n = 30$) or CCR ($n = 30$) according to the clinical allocation procedure used at the study site. Allocation concealment was not documented and no prospectively registered allocation sequence was available; the study is therefore reported as a prospective comparative pilot study rather than as a confirmatory randomised trial. Both groups were treated in the same setting and reviewed using the same schedule. Preoperative assessment comprised medical and dental history, clinical examination, digital periapical radiography and cold sensibility testing. The response was interpreted with symptoms and radiographic findings to confirm suitability for conservative treatment. Participant flow is shown in Fig. 1.

Treatment was completed under rubber dam isolation. After conservative access, carious tissue was removed using low-speed tungsten carbide burs, diamond burs and hand excavators. Detector dye was used only as an adjunct; the endpoint was based on tactile resistance, visual appearance, cavity location and pulpal proximity. In SCR, the enamel-dentine junction and peripheral walls were cleaned to hard dentine or sound enamel, while soft-to-leathery or firm affected dentine could remain on the pulpal or axial wall. In CCR, excavation continued to hard dentine throughout the cavity. After verification of the peripheral seal, 2% chlorhexidine was applied for 60 seconds. A universal adhesive and resin composite were used, with resin-modified glass ionomer cement as a base or liner when clinically indicated. Margins, contacts and occlusion were checked.

Outcomes and statistical analysis

The primary outcomes were positive cold sensibility, used as a clinical indicator of pulp vitality, and restorative success at six months. Secondary outcomes were intraoperative exposure and immediate postoperative sensibility. Restorative success required an intact restoration, no recurrent caries requiring replacement and no pulpal or periapical signs requiring endodontic treatment. Clinical examination, cold testing and periapical radiography were performed immediately after treatment and at six months.

Data were analysed using IBM SPSS Statistics 29.0. Continuous data were summarised using means, standard deviations, medians and ranges; categorical data using frequencies and percentages. Groups were compared using chi-square or Fisher's exact tests, and within-group sensibility changes using McNemar tests. Two-sided p values were used for the principal interpretation. Because the clinical hypothesis was directional, a one-sided p value is reported only as an exploratory, hypothesis-generating analysis; no prospectively registered statistical analysis plan was available. The absolute difference in proportions and an exploratory 95% confidence interval calculated using Newcombe's method were used to describe effect size. No formal a priori sample-size calculation was undertaken; results are therefore interpreted as pilot estimates. A generative artificial intelligence tool was used solely for language editing and adaptation to journal style; the authors reviewed and verified the scientific content and retain full responsibility for the manuscript.

Results

Participants and intraoperative findings

All 60 participants completed follow-up and were analysed. Mean age was 47.55 ± 13.30 years (median 49.50); 34/60 (56.7%) were male. Molars represented 50/60 teeth (83.3%) and premolars 10/60 (16.7%). Age, sex and tooth type were not significantly associated with the primary outcomes.

Intraoperative pulp exposure occurred in 24/60 teeth (40.0%): 13/30 (43.3%) in the SCR group and 11/30 (36.7%) in the CCR group ($p = 0.598$). All teeth had a positive preoperative response and 59/60 (98.3%) remained positive immediately after treatment.

Six-month outcomes

At six months, positive pulp sensibility and restorative success were both recorded in 27/30 SCR teeth (90.0%) and 22/30 CCR teeth (73.3%). Unfavourable outcomes were therefore 3/30 (10.0%) and 8/30 (26.7%), respectively. The absolute difference favouring SCR was 16.7 percentage points (95% CI -3.3 to 35.6). The principal two-sided comparison was not statistically significant ($p = 0.095$); an exploratory one-sided analysis gave $p = 0.045$. The principal outcomes are summarised in Table 1 and paired sensibility changes in Table 2.

Table 1
Main clinical outcomes at six months.

Outcome	SCR (n = 30)	CCR (n = 30)	Two-sided p value	Clinical interpretation
Intraoperative pulp exposure	13/30 (43.3%)	11/30 (36.7%)	0.598	No between-group difference
Immediate positive sensibility	30/30 (100.0%)	29/30 (96.7%)	0.313	High immediate tolerance
Six-month positive sensibility	27/30 (90.0%)	22/30 (73.3%)	0.095	Pilot signal favouring SCR
Six-month restorative success	27/30 (90.0%)	22/30 (73.3%)	0.095	Pilot signal favouring SCR
CCR, complete caries removal; CI, confidence interval; SCR, selective caries removal. Six-month differences should be interpreted as pilot estimates. The exploratory one-sided p value for the two six-month outcomes was 0.045 and was not used for confirmatory inference.				

Table 2
Paired changes in pulp sensibility over time.

Comparison	Group	Positive-to-negative changes	McNemar p value	Interpretation
Preoperative vs immediate	Overall	1/60 (1.7%)	1.000	No relevant immediate loss
Preoperative vs six months	Overall	11/60 (18.3%)	0.001	Significant overall deterioration
Preoperative vs six months	SCR	3/30 (10.0%)	0.250	Non-significant change
Preoperative vs six months	CCR	8/30 (26.7%)	0.008	Significant deterioration
Immediate vs six months	SCR	3/30 (10.0%)	0.250	Non-significant change
Immediate vs six months	CCR	7/30 (23.3%)	0.016	Significant delayed deterioration
CCR, complete caries removal; SCR, selective caries removal.				

Paired analysis showed one positive-to-negative change immediately after treatment and 11/60 at six months (McNemar $p = 0.001$). Six-month deterioration was 3/30 after SCR ($p = 0.250$) and 8/30 after CCR ($p = 0.008$), indicating that delayed loss of response was mainly observed in the CCR group.

Discussion

This pilot study found a consistent numerical six-month difference favouring SCR: positive pulp sensibility and restorative success were 90.0% after SCR and 73.3% after CCR, while adverse outcomes were 10.0% and 26.7%. The 16.7-point absolute difference was clinically relevant, but its 95% confidence interval (-3.3 to 35.6) included no difference and the principal two-sided comparison did not reach conventional statistical significance. The results should therefore be interpreted as a clinically relevant pilot signal rather than proof of superiority.

The direction of effect agrees with the multicentre trial by Bjørndal et al., which included 314 adults with lesions extending through at least 75% of dentine. At 12 months, stepwise excavation reduced pulp exposure by 11.4 percentage points and increased by 11.7 points the proportion of teeth retaining an unexposed vital pulp without apical radiolucency compared with direct complete excavation.³¹ Stepwise excavation differs from one-visit SCR, but both avoid aggressive pulpal-wall excavation. The 16.7-point difference in the present cohort is therefore biologically compatible with this larger trial, although the smaller sample and shorter follow-up limit precision.

Longer-term evidence from Maltz et al. also supports conservative excavation. Their multicentre study initially treated 299 permanent molars; 213 teeth were assessed at 36 months, when adjusted survival was 91% after partial removal and 69% after stepwise excavation.³² At 60 months, 229 teeth contributed data and estimated success remained higher after partial removal (80%) than after stepwise excavation (56%).⁵⁰ These studies used stepwise excavation rather than CCR as the comparator, but they demonstrate that a single conservative procedure can maintain favourable outcomes for several years. They also caution against extrapolating the present 90% six-month result unchanged to longer follow-up.

Restorative performance is supported by Jardim et al., who evaluated 172 restorations at five years: 95 after selective removal to soft dentine and 77 after stepwise excavation. Survival was 79% and 76%, respectively, with no significant difference between 61 amalgam and 111 resin-composite restorations.⁴⁹ The higher success observed here is expected because follow-up was only six months and the outcome combined restoration integrity with pulpal and periapical events. Nevertheless, the comparison indicates that controlled retention of affected dentine does not necessarily compromise restoration longevity when the cavity periphery and coronal seal are sound.

Systematic reviews and meta-analyses similarly report that selective or stepwise excavation reduces pulp exposure or subsequent intervention compared with non-selective removal without reducing clinical success.^{26,27,28} The likely mechanism is ecological and biological: a hard peripheral seal isolates residual organisms from dietary substrate, while retained dentine reduces operative trauma and preserves tissue capable of sclerosis, tertiary dentine formation and mineral gain.^{17,18,19,42,43,44} This may explain why immediate postoperative responses were similar but delayed deterioration was concentrated in the CCR group.

The overall exposure rate of 40.0% did not differ between groups, unlike studies reporting lower exposure with conservative excavation.^{27,31,33,34} This secondary result should not be interpreted as

equivalence. The study was not powered for exposure, lesion depth was not stratified in detail and tactile decisions near the pulp are operator-dependent. Detector dye can assist, but neither colour nor staining defines an exact histological boundary; calibrated tactile criteria and, where appropriate, objective adjuncts should be used in future studies.^{20,21,22,23,24}

Limitations include the sample of 60 patients, six-month follow-up, single-centre design, absence of prospective registration and formal sample-size calculation, and an allocation procedure that was not concealed or fully standardised. These limitations reduce the strength of causal inference and mean that the results should not be considered confirmatory. The selective use of resin-modified glass ionomer cement and the combined biological-restorative endpoint also limit attribution of effect solely to excavation. Future controlled studies should use concealed allocation where feasible, calibrated definitions of soft, leathery, firm and hard dentine, separate pulpal and restorative outcomes, and follow-up at 12, 36 and 60 months.

Taken together, the present findings and studies involving 172–314 treated teeth with follow-up from 12–60 months indicate that SCR may offer a favourable balance between disease control and tissue preservation when the pulp is clinically healthy and a sound peripheral seal can be achieved. Conservative excavation has been associated with fewer pulpal complications or higher tooth and restoration survival, without evidence that controlled retention of affected dentine compromises restorative performance.^{26,27,28,31,32,49,50} The advantage of SCR is therefore not incomplete treatment, but site-specific excavation: hard dentine at the margins for predictable adhesion and preservation of potentially remineralisable dentine near the pulp. Within the limitations of this pilot study, the convergence of biological rationale, comparative evidence and the observed six-month outcomes supports SCR as a promising minimally invasive option for appropriately selected vital permanent posterior teeth, while definitive confirmation requires adequately powered, prospectively registered controlled trials.

Conclusions

In vital permanent posterior teeth with deep carious lesions, SCR showed numerically higher six-month pulp sensibility and restorative success than CCR, generating a clinically relevant pilot signal. The observed 16.7-point reduction in adverse outcomes supports further investigation of a biologically conservative strategy based on a sound peripheral seal and preservation of dentine close to the pulp. However, the confidence interval included no difference and the two-sided comparison was not statistically significant. These findings justify further adequately powered, prospectively registered controlled studies with standardised endpoints and longer follow-up.

Declarations

Ethics declarations

Ethics approval and consent to participate:

The Research Ethics Committee of the University of Salamanca approved the study on 20 March 2025 (registration number 1265). The study complied with the Declaration of Helsinki and all participants provided written informed consent.

Consent for publication:

No identifiable personal data, clinical photographs or individual participant images are presented. Results are reported in aggregated and anonymised form.

Trial registration

This prospective pilot clinical study was not registered prospectively in a public clinical-trial registry. It is therefore presented as a pilot comparative study, and this limitation should be considered when interpreting causal and statistical claims.

Competing interests

The authors declare no competing interests.

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No specific funding was received for this study.

Author contributions

A.I.-P. contributed to conceptualisation, clinical procedures, clinical data acquisition, data curation, interpretation of findings and drafting of the manuscript. J.F.-F. contributed to methodology, literature contextualisation, interpretation of findings and critical revision of the manuscript. V.V.-R. and B.H.-D. contributed to interpretation of restorative and conservative dentistry findings and critical revision for important intellectual content. D.G.-G. contributed to methodology, supervision, interpretation of findings, corresponding-author coordination and critical revision of the manuscript. J.L.-M. contributed to study design, senior supervision, interpretation of findings and critical revision of the manuscript. All authors approved the final version and accept accountability for the work.

Data availability:

The datasets contain clinical data subject to ethical and data-protection restrictions. De-identified data may be available from the corresponding author on reasonable request, subject to ethics approval and applicable regulations.

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Figures

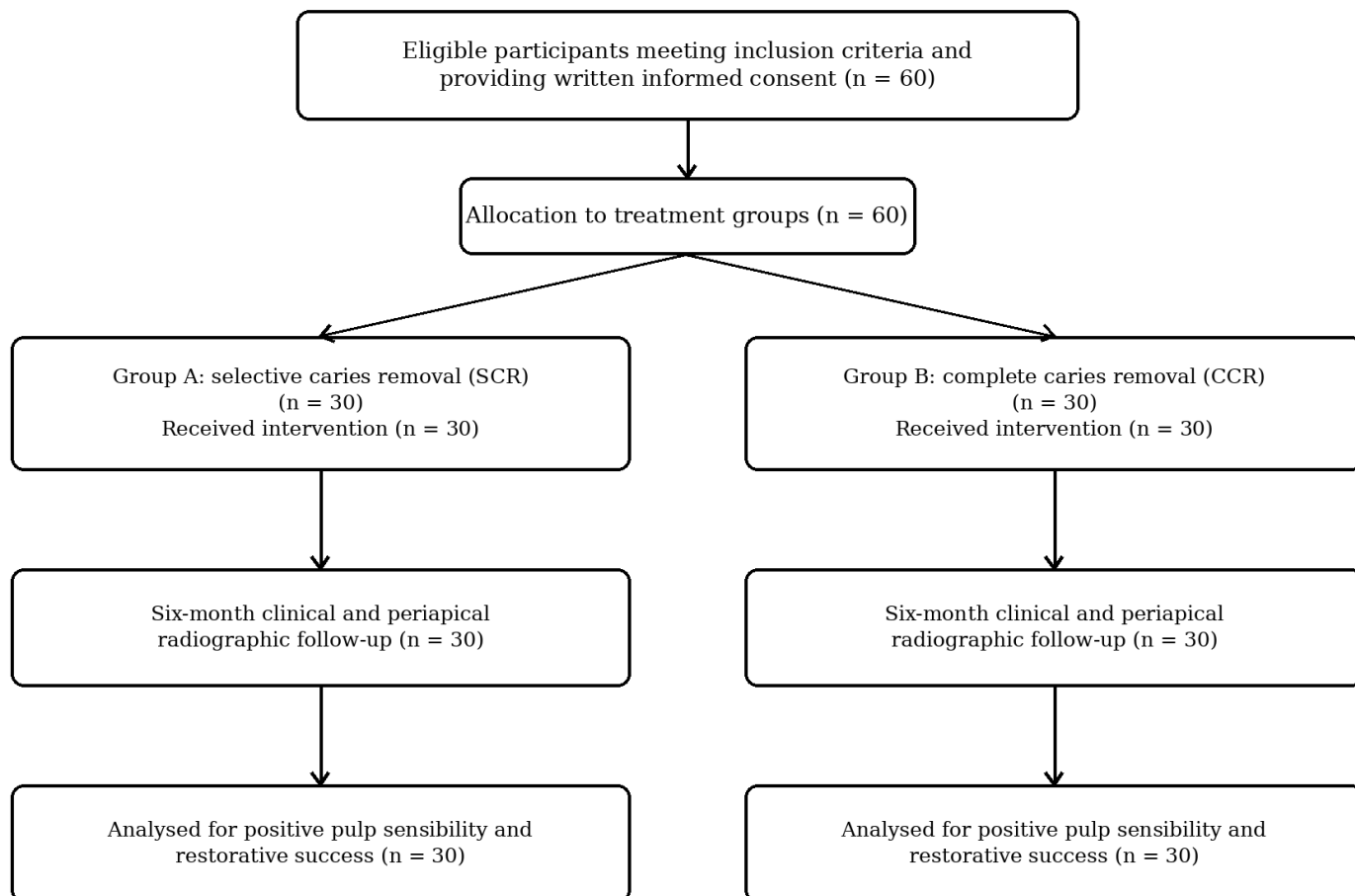


Figure 1

Participant flow diagram. Sixty eligible participants were assigned to SCR (n = 30) or CCR (n = 30), received the assigned intervention, completed six-month clinical and periapical radiographic follow-up and were analysed. CCR, complete caries removal; SCR, selective caries removal.

Supplementary Files

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