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Modified resin infiltration of non-, micro- and cavitated proximal caries lesions in vitro

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ABSTRACT

Objective: Infiltrant resin (IR) is currently indicated for non-cavitated caries lesions. However, modifying the technique might expand its indication spectrum to micro-cavitated lesions. The present study aimed to evaluate the penetration/filling ability of a newly developed micro-filled infiltrant resin (MFIR) in non-, micro- and cavitated natural caries lesions.

Materials and methods: Proximal lesions in 120 extracted human teeth with ICDAS-2 (n = 30), 3 (n = 45) and 5 (n = 45) lesions were etched with 15% hydrochloric acid gel for 2 min and allocated to one of the following treatments; **IR:** lesions (ICDAS-2, 3 and 5; each n = 15) were treated with commercial infiltrant resin for 3 min. **MFIR:** experimental MFIR [55 wt% IR plus 45 wt% organic fillers] was applied to lesions (ICDAS-2, 3 and 5; each n = 15) for 3 min. **IR + FC:** IR was applied for 3 min, light-cured, and cavities (ICDAS-3 and 5; each n = 15) filled with flowable composite (FC). Percentage infiltration of the demineralized enamel (Inf.%) and percentage filling of the cavity (Fill.%) were analyzed using dual-fluorescence staining and confocal microscopy.

Results: No significant differences in Inf.% (range of medians: 57%-100%) were observed between different treatments ($p > 0.05$; Kruskal-Wallis) within each ICDAS-code. Fill.% of cavities was significantly higher in groups MFIR (median in ICDAS-3/-5: 100%/100%) and IR + FC (100%/100%) than IR (25%/38%) ($p < 0.05$).

Conclusion: MFIR showed similar penetration into natural lesions as the commercial infiltrant, but better ability to fill cavitated areas.

Clinical relevance: MFIR and IR + FC might provide a new micro-invasive treatment for small cavitated proximal lesions.

1. Introduction

In recent years, due to better understanding of the caries process as well as declining caries prevalence in many countries [1], caries management shifted towards being preventive and minimally invasive [2]. Proximal lesions are frequently observed in adolescents and young adults [3,4]. Non-invasive approaches based on fluoride application, oral hygiene improvement and diet control are highly recommended as first treatment option for non-cavitated proximal lesions. However, quite often, due to increased lesion extension or lack of patient cooperation such measures alone are not effective to arrest the caries process and subsequent surface breakdown might occur, causing micro-cavitation[5,6].

For proximal lesions the conventional “drill and fill”-approach requires destruction of substantial amount of sound tooth structures to get access to the lesion [7]. Furthermore, once the first restoration is placed, the tooth enters a cycle of repeated restorative treatments which might negatively affect the integrity and survival of the tooth [8–10]. Resin infiltration (potentially in combination with non-invasive measures) has offered a clinically effective micro-invasive treatment for non-cavitated proximal lesions [11–14], saving healthy tooth structures from that extensive cutting required for accessibility. The basic principle of resin infiltration is to perfuse the demineralized enamel pores with a low-viscosity light-cured resin (infiltrant) driven by capillary forces. After photo-polymerization, infiltrant resin (IR) occludes diffusion pathways for cariogenic acids and dissolved minerals leading to arrest of the lesion progression [15,16].

While clinically proven efficacious for non-cavitated lesions [12,13,17], the indication spectrum and the therapeutic certainty could be increased if small cavitated proximal lesions were treatable as well using this technique. One approach could be to combine the infiltrant resin with a subsequent application of a flowable composite resin to fill

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the cavitated lesion parts. Another more recent approach is a combination of the infiltrating properties of infiltrants with the consistency of flowable composite resins. This could be achieved by adding filler particles to the low-viscosity resin matrix [18]. Such modified microfilled infiltrant resins (MFIRs) have been suggested to overcome the mentioned problems, allowing both, lesion penetration and cavity filling. In a previous experiment, MFIRs with organic fillers showed similar penetration into artificial non-cavitated enamel lesions [19] and cavitated natural occlusal lesions like commercially available unfilled IR [19,20].

The International Caries Detection and Assessment System (ICDAS) was developed to allow the clinicians to diagnose the caries at different stages [21] and consequently, selecting the appropriate treatment option. For proximal lesions, visual assessment is not always easy to perform, therefore radiographic assessment might be necessary for diagnosis process.

Modification of the resin infiltration technique by either changing the properties of the used resin or altering the application procedure might give the opportunity to use the technique for treatment of small cavitated proximal lesions. Therefore, it was the aim of the present in vitro study to evaluate the penetration and filling ability of an MFIR in natural lesions with different ICDAS-codes. We tested the null hypothesis that neither filling technique/material nor the cavitaiton has an effect on the penetration and the filling ability of the resin materials into the natural caries lesions.

2. Materials and methods

Ethical approval was obtained to collect extracted human teeth (Ethical committee, Charité – Universitätsmedizin Berlin; EA4/102/14), which were then cleaned, rinsed and stored in 0.1% Thymol solution until use. Donors were informed that the teeth were collected for research purposes and a signed consent was obtained before extraction. Lesion activity and ICDAS scoring of proximal lesions in extracted molars and premolars was assessed by two examiners using 1.75x magnification lens (HA and SP). Only active proximal lesions (n = 120) with ICDAS-2 (distinct visual change in enamel) (n = 30), −3 (localized enamel break down) (n = 45) and −5 (distinct cavity with visible dentin) (n = 45) were selected for this study [21]. All proximal lesions were etched with 15% hydrochloric acid (Icon etch, DMG, Hamburg, Germany) for 2 min and then rinsed with demineralized water for 30 s. To examine resin infiltration using dual fluorescence and confocal microscopy, enamel lesions were stained with 0.1% ethanol solution of Rhodamine B isothiocyanate (RITC, Sigma Aldrich, Steinheim, Germany) for 12 h [22]. Afterwards, teeth were randomly allocated to three experimental groups: infiltrant resin (IR), micro-filled infiltrant resin (MFIR) and a combined application of infiltrant resin and flowable composite filling (IR + FC).

In IR and MFIR groups; non-cavitated lesions (ICDAS-2; n = 15/group) were resin-infiltrated (IR or MFIR) for 3 min and then light cured for 60 s (400 mW/cm2, Bluephase C8; Ivoclar Vivadent, Schaan, Liechtenstein), while in the cavitated lesions (ICDAS-3 and −5; n = 15/group) resin materials (IR or MFIR) were applied in excess ensuring complete filling of the cavities and allowed to penetrate into the lesions for 3 min. Subsequently, transparent matrices (SuperMat; KerrHawa, Bioggio, Switzerland) were used to restore proximal contours before final polymerization for 60 s. In the IR + FC group; IR was first applied into cavitated lesions (ICDAS-3 and −5; n = 15/group) for 3 min. The excesses resin was removed from the cavity by gentle air blowing for 30 s. After light curing of IR for 60 s, cavities were filled with FC (EcuSphere; DMG, Hamburg, Germany). Proximal contours were again formed with transparent matrices before second polymerization for 60 s.

Experimental MFIR was prepared by mixing a commercially available IR (Icon, DMG) with an experimental pre-polymerized organic filler powder (DMG) in a weight ratio of 55% and 45%, respectively.

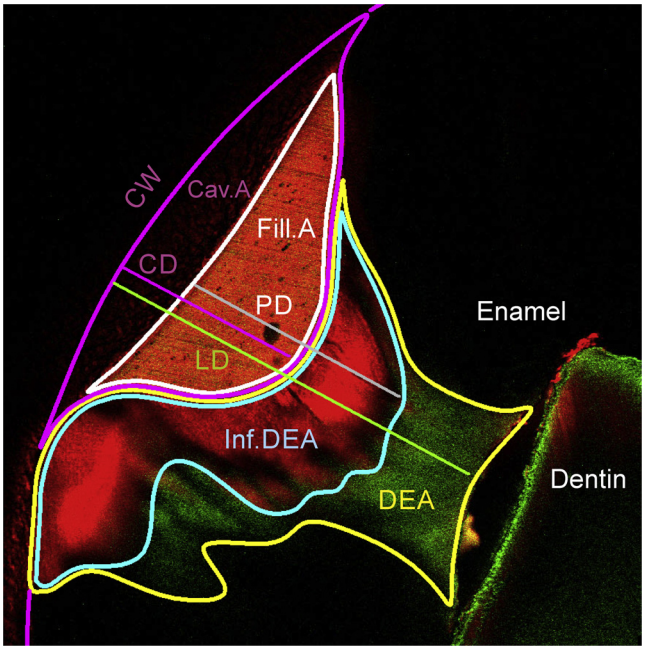

Fig. 1. Representative CLSM image of resin infiltrated ICDAS-3 lesion showing the cavity and demineralized lesion dimensions. In dual fluorescence staining, non-infiltrated demineralized enamel and dentin appeared in green (NaFluo dye) while the infiltrated parts of the lesion and the filling resin appeared in red (RITC dye). Sound enamel appeared in black. DEA: demineralized enamel area, Inf.DEA: infiltrated demineralized enamel area, Cav.A: cavity area, Fill.A: filled area of the cavity, LD: lesion depth, PD: penetration depth, CD: cavity depth, CW: cavity width. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Median (Q1/Q3) of infiltration variables for IR and MFIR applied to ICDAS-2 lesions.

	ICDAS 2		
Variable	IR	MFIR	p^a
DEA (mm^2)	0.864(0.593/1.376)	0.806(0.573/1.402)	0.910
Inf.DEA (mm^2)	0.619(0.456/0.833)	0.545(0.315/0.966)	0.571
Inf.%	73(62/80)	69(47/87)	0.701
LD (µm)	792(474/862)	732(492/960)	0.982
PD (µm)	537(361/622)	450(350/699)	0.701
n	15	15	

[a] No significant differences were observed ($p > 0.05$; Mann–Whitney *U* test). DEA: demineralized enamel area, Inf.DEA: infiltrated demineralized enamel area, Inf.%: percentage infiltration of the demineralized enamel, LD: lesion depth, PD: penetration depth, *n*: number of specimens.

The organic filler particles were specially prepared for this project in DMG laboratories from a thermally polymerized mix of aliphatic methacrylate monomer and fumed silica particles. After polymerization, the hardened filler mixture was milled and filtered to obtain required particles sizes (mean: 42 µm, range: 0.5–200 µm).

One gram of MFIR was freshly prepared for five specimens immediately before resin application. For the purpose of exact visualization of the filled cavity space, resin materials were also labeled with 0.1% RITC.

After resin application, roots of the teeth were cut and the crowns were completely embedded in methacrylate resin (Technovit 4071, Heraeus Kulzer, Hanau, Germany). From each lesion a 1 mm thick section was cut perpendicular to the tooth surface (Band Saw EXAKT 300 CL; EXAKT Advanced Technologies, Norderstedt, Germany). The cut sections were fixed to microscopic slides (Plexiglas, patho-service,