The effect of resin infiltration vs. fluoride varnish in enhancing enamel surface conditions after interproximal reduction

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To assess the effect of resin infiltration vs. fluoride varnish in enhancing enamel surface conditions after interproximal reduction (IPR). After IPR procedures, 84 human enamel specimens were divided into three groups, group A/ group B was treated by fluoride varnish/resin infiltration according to the manufacturers’ instructions, group C were treated with nothing. All the specimens were pH-cycled twice daily in 37°C bath for 30 days. Surface micro-hardness, density and mineral loss were measured before and after the pH cycling. The data were analyzed and compared using ANOVA. Both treatments A and B increased the surface microhardness of enamel after IPR (p<0.05). Both before and after pH cycling, the surface microhardness of A was significantly harder than B. The density of A was higher than B before pH cycling (p<0.05). Fluoride varnish and resin infiltration may provide an enamel protection from acid challenge.

Keywords: Fluoride varnish, Resin infiltration, Interproximal reduction, Stripping, Enamel demineralization

INTRODUCTION

Interproximal reduction (IPR) is a commonly used clinical technique to reshape tooth and obtain space2). It removes about 0.5 mm outer enamel on the interproximal surfaces of teeth2). A recent study found that 46% of the general dentists and 67% of the orthodontists routinely performed IPR3). However, the IPR procedures leave various grooves and furrows on enamel leading to a significantly increased surface roughness4,5), and these furrows can still be clearly visible even one year later6). Since it is almost impossible to thoroughly remove these grooves and furrows left on the enamel surface after IPR using conventional cleaning and polishing methods4,5, this increases the susceptibility of stripped enamel to bacterial adhesion and biofilm accumulation, which is then shielded from the mechanical clearance of brushing and floss4,5, and thereby may promote the development of demineralization or calculus10,11). It has been confirmed that IPR damages the intactness of surface layer enamel and impairs tooth’s resistance against the aggressive environment of the oral cavity5,12). The stripped enamel surface was found more susceptible to demineralization and more sensitive to hot and cold temperatures than intact surfaces11,13). Other studies, however, on the other hand, suggested that IPR did not lead to increased caries risk in anterior and posterior teeth14,15). Although whether IPR increases the susceptibility of the abraded enamel to demineralization is still a matter of debate, it should be kept in mind that a reduction of a tooth’s enamel coating might lead to impaired resistibility to acid, erosion, and attrition4,5). An adequate post-processing to enhance the enamel surface integrity using appropriate product is crucial for a long-term good prognosis of the stripped teeth.

Fluoride varnish has been recommended to help prevent the development of enamel demineralization and erosion16,17), as it is effective to improve the surface integrity by either covering the small fissure sites or facilitating remineralization18,19). Resin infiltration, which was developed to obstruct the diffusion pathways for acids in order to protect internal enamel, has become available recently. The low-viscous resin could penetrate into deep porosities and creates a diffusion barrier on the surface, and within, enamel thus occluding pathways for acid entry into the enamel20). It has been reported that resin infiltration is effective in the treatment of caries lesions, but the effect of resin infiltration on enhancing enamel integrity and protecting stripped enamel from demineralization is still not clear.

The aim of this study is to assess the resulting enamel surface conditions, including topography, micro-hardness, and demineralization resistance, after using fluoride varnish and resin infiltration after IPR.
MATERIALS AND METHODS

Specimen preparation
Sixty human permanent premolars were obtained from Dental Hospital of Luzhou Medical University, and selected by a dental investigator using the following exclusion criteria: the presence of staining, demineralization, decay, fluorosis, tetracycline staining, crack, enamel defects or restorations. After extraction, the teeth were immediately cleaned with tap water and stored in 0.1% thymol solution at 4°C for less than a week before being used in the experiments. All participants involved in this study have signed the informed consent. Ethical approval was obtained from the Medical Ethics Committee at Luzhou Medical College (No.: 2012002) which has been conducted in full accordance with the World Medical Association Declaration of Helsinki.

All the IPR procedures were carried out by the same dental investigator. Each tooth was ground using air-rotor stripping bur kit (Drendel+Zweiling, Lemgo, Germany) on both interproximal enamel surfaces under water-cooling. Each bur was used for five preparations then replaced. To ensure equal reduction of all teeth, an enamel reduction of 0.5 mm measured by vernier caliper was performed on each enamel surface. To simulate in situ conditions, additional polishing using Sof-lex (3M, ESPE, St Paul, MN, US) was accomplished for 20 s. The teeth were then coronally sectioned by D&Z disk (Drendel+Zweiling, Berlin, Germany), and both interproximal sides were used in the experiments.

Specimen screening and baseline evaluation
After completion of IPR, baseline comparisons were performed by measuring surface microhardness (SMH) of the stripped surfaces using a Knoop diamond indenter as described below. Using these data, 84 specimens that had similar baseline SMH (300–330 KHN) were selected for inclusion in the study (Fig. 1).

Treatment interventions
The 84 specimens selected for the study were labeled with numbers and randomly divided into three groups of 28 (2 test groups and 1 control group) (Fig. 2). Before treatment interventions, the selected specimens of all groups were thoroughly cleaned with demineralized water. All the treatments were performed by a trained dental investigator.

Fluoride varnish group (n=28): fluoride varnish (22,600 ppm fluoride, Duraphat, Colgate-Palmolive, NY, USA) was applied to the ground surfaces with micro-brushes by painting and dabbing repeatedly to form a varnish layer according to the Duraphat instructions.

Resin infiltration group (n=28): the resin infiltration (Icon, DMG, Hamburg, Germany) was performed according to the manufacturer’s instructions. The ground surfaces were etched for 2 min with 15% hydrochloric acid (Icon Etch, DMG) and then rinsed with air-water-spray for 30 s. These surfaces were desiccated by air-blowing for 10 s, followed by application of ethanol (Icon Dry, DMG) for 30 s, and air-blowing again for 10 s. Then, the resin infiltrant (Icon Infiltrant, DMG) was applied with a sponge applicator provided by the Icon resin infiltration system and left for 3 min. Excess resin was removed by flossing. Subsequently, the resin was light-cured for 60 s. The infiltration step was repeated once with a penetration time of 60 s to infiltrate remaining porosities. The prepared specimens were then polished with Astropol HP (Ivoclar Vivadent, NY, USA) for 20 s according to the Icon Etch instructions.
Control group \((n=28)\): the specimens were not treated after IPR procedures.

The resulting enamel surface on each specimen was restricted to 3×3 mm by coating the surrounding surfaces with two layers of acid-resistant nail varnish before pH cycling experiments.

**pH cycling experiments**
The prepared specimens were pH-cycled as previously described\(^2\). Briefly, the specimens were firstly incubated in artificial saliva (pH 6.8) for 11 h, and then immersed individually in 90 mL of acidic buffer (50 mmol/L acetic acid, 1.5 mmol/L potassium dihydrogen orthophosphate, pH 4.5) for 1 h to make a total of 12 h from initial treatment. The cycle was repeated twice daily in 37°C bath under a low-speed (50 rpm) shaken condition for 30 days. Fresh acidic buffer was used for each cycle and the specimens were washed with demineralized water between each cycling. The artificial saliva used in the study was prepared using ISO/TR1027 standard\(^2\).

**Scanning electronic microscopy**
Five specimens were randomly selected from each group, cleaned with ethanol, gold-coated, and examined using a scanning electron microscope (SEM, FEI-inspect, The Netherlands).

**Micro-hardness measurements**
Surface microhardness (SMH) of specimens was determined with a Knoop diamond indenter (Duramin-2, Struers, Copenhagen, Denmark) at 50 g load for 15 s dwell time. Five indentations spaced 50 µm perpendicularly from each other were made at the center of the exposed window were made in order to determine the Knoop hardness number (KHN) of each specimen.

**Mineral loss measurements**
Evaluation of mineral loss of specimens was performed using a Siemens Inveon Micro-CT/PET Scanner (Siemens, Munich, Germany). The micro-CT X-ray source was set at 80 kV and 500 µA. The scanning time was 50 min per specimen with each scanning slice of 18 µm. Four areas on each specimen were randomly selected for the measurement of density and calculation of mineral loss.

**Table 1** The surface microhardness (SMH) and percentage of SMH reduction (SMHR%) of enamel treated in different ways and subjected to pH-cycling.

| Treatments                  | Before pH-cycling* | After pH-cycling* | SMHR%  |
|-----------------------------|--------------------|-------------------|--------|
| Control \((n=28)\)*         | 303.4±16.7         | 129.4±10.1        | 57.4±3.7 |
| Fluoride varnish \((n=28)\)*| 317.3±15.0         | 205.7±11.7        | 35.2±2.3 |
| Resin infiltration \((n=28)\)* | 336.4±19.1       | 227.3±12.6        | 32.4±2.1 |

Mean±SD. *The SMH values of all groups significantly decreased after pH-cycling \((p<0.05)\). * Differences between groups for SMH and SMHR% were significant \((p<0.05)\).

**RESULTS**

**Surface topography**
The surface topography of enamels after IPR was shown in SEM images (Fig. 1A). Though stripping caused many grooves on the enamel, the treatments of fluoride varnish and resin infiltration produced surfaces that displayed covered grooves by the intervention materials (Figs. 1 B and C). After pH cycling, many pits and fissures were seen in the control group (Fig. 1D), while the treated enamels displayed relatively less pits and fissures after pH cycling (Figs. 1 E and F).

**Surface microhardness (SMH)**
Both treatments increased the SMH of enamel after IPR compared with the control group \((p<0.05)\) (Table 1 and Fig. 3). The SMH of enamel treated with resin...
infiltration was significantly harder than those treated with fluoride varnish (p<0.05).

After pH-cycling, the surface microhardness reduction (SMHR) and calcium demineralization occurred in all three groups (Table 1 and Fig. 3). The two treated groups showed significantly higher SMH and lower SMHR% compared with the control group after pH-cycling (p<0.05). The SMH of resin infiltration group was the highest, followed by the fluoride varnish group, and the control group was the lowest (p<0.05).

**Density and mineral loss**

The density of enamel surfaces treated with resin infiltration was the highest, followed by fluoride varnish group, and the density of the control group was the lowest before pH-cycling (p<0.05) (Table 2, Figs. 4 and 5).

After pH-cycling, the density of enamel of all groups significantly decreased (p<0.05) (Table 2 and Fig. 5). Differences between the control group and the treated groups for density of enamel and mineral loss were significant (p<0.05), while differences between the two treated groups were not significant (p>0.05).

**DISCUSSION**

IPR, also known as interdental stripping or interproximal enamel reduction, is increasingly applied during orthodontic treatments to obtain space or reshape teeth, especially in patients wearing clear aligners. IPR could eliminate the undesirable results of extraction treatment and maintain alignment in the long-term stability. However, IPR inevitably damages the intactness of the surface layer of enamel and increases biofilm accumulation. An appropriate post-processing to enhance enamel surface condition is crucial for a long-term good prognosis of the stripped teeth. In this study, the treatments of resin infiltration and fluoride varnish for enamel after IPR enhanced the surface micro-hardness and provided protection from an erosive pH-cycling.
IPR causes grooves and furrows resulting in a significant increment of enamel roughness regardless of the IPR instruments used. The SEM images of enamel surfaces after IPR in this study also displayed a roughened enamel surface, which is in agreement with those previous reports. Although the application of fluoride varnish and resin infiltration could not completely fill up these grooves and furrows, the treated surfaces were relatively smoother than the controls, especially after the pH-cycling.

Fluoride varnish has been widely used as a caries-preventive intervention for more than three decades. It can not only act as a physical barrier avoiding the contact of the acid with the underlying enamel but also release fluoride during the dissolution of the varnish in the mouth. The varnish is also the agent of choice in function of its easy application and safety compared with other topical fluoride agents such as gels and rinses. And a recent in situ study has found that fluoride varnish (5% NaF) could significantly remineralize the enamel and provide 50.1% surface hardness recovery. Though the mechanical protection of varnish coating may be removed by toothbrushing or mastication in the oral cavity, it may also be expected that this loss will occur to a lesser extent in grooves and furrows in the approximal tooth surfaces.

Low fluoride concentrations can prevent enamel demineralization; high fluoride concentrations, such as those achieved with fluoride varnish (22,600 ppm fluoride) used in this study, can also inhibit bacterial metabolism and acid production through interference with the enzyme enolase. It was found that the fluoride varnish with a high concentration caused a significant reduction of the depth of the demineralized enamel in situ. Teeth can benefit from one application of fluoride varnish; and frequent application such as every three to six months might be more efficient in practice, especially for high caries risk patients.

Resin infiltration has been shown to significantly increase micro-hardness and reduce mineral loss of bovine enamel after a demineralization challenge. Because the low-viscous light-curing resin can not only cover the grooves left by IPR but also infuse into the enamel creating a diffusion barrier within it, thus occluding pathways for acid entry into the enamel. In contrast, the fluoride varnish may create a relatively shallower layer coating. And in this study, the surface properties, both hardness and density, of enamel that treated by resin infiltration was indeed significantly higher than those treated with fluoride varnish. Our findings are in agreement with a recent study which compared the effect of resin infiltration (Icon) and fluoride varnish (5% NaF, amorphous calcium phosphate) on enamel surface properties, in which they have also found that the surface microhardness treated by resin infiltration (318.2±43.9 VHN) was significantly higher than those treated by fluoride varnish (109.6±47.4 VHN). Further studies comparing the penetration depth of resin infiltration and fluoride varnish in enamel would provide more information for understanding the differences between these two treatments.

Though both fluoride and resin showed a good enamel protection from acid challenge in the study, resin infiltration provided a relatively better effect in terms of microhardness that can resistance to mechanical erosion. This is consistent with a precious study in which resin infiltration significantly increased both micro-hardness and demineralization resistance of enamel caries lesions. Resin infiltration might thus be recommended after IPR especially for patients with dental erosion. And twice application of the infiltrant was recommended to increase these effects.

Polishing is generally suggested after IPR. However, polishing alone cannot remove the deep surface irregularities that created by IPR whereas it also removes enamel materials to some extent. In contrast, the treatments with fluoride varnish and resin infiltration are relatively non-invasive. Therefore, a post-processing treatment such as fluoride varnish and resin infiltration is suggested to enhance enamel surface conditions after interproximal reduction. Further in situ and in vivo studies are necessary to confirm the results of the present study.

CONCLUSION
Fluoride varnish and resin infiltration may provide an enamel protection from acid challenge, with a clinical implication that fluoride varnish and resin infiltration have potential as a finishing agent after IPR.

ACKNOWLEDGMENTS
This study was supported by the Combined Research Project of Sichuan Science and Technology, Luzhou Government and Luzhou Medical College (LZ-LY-59), and National Natural Science Foundation of China (No.81301476).

COMPETING INTERESTS
The authors have declared that no competing interests exist.

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