International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Comparative Evaluation of Enamel Surface Microroughness in White Spot Lesions Treated with ICON Resin Infiltration and Opalustre Microabrasion

Ralitsa Bogovska-Gigova

Abstract: ***Objective**: This in vitro study aimed to compare the surface microroughness (Ra) of enamel white spot lesions before and after treatment with ICON resin infiltration and Opalustre microabrasion. **Methods**: Sixty extracted human permanent third molars with white spot lesions (ICDAS II code 02) were randomly assigned to three groups (n=20 each): control (untreated), ICON resin infiltration, and Opalustre microabrasion. ICON treatment involved etching with 15% hydrochloric acid, dehydration, resin infiltration, and light-curing. Opalustre microabrasion used 6.6% hydrochloric acid with silicon carbide particles, applied three times, followed by polishing. Surface roughness (Ra) was measured using a profilometer at three points per lesion, and mean Ra values were analyzed using one-way ANOVA with post-hoc Tukey's HSD tests ($p<0.05$). **Results**: Mean Ra values were 0.56 ± 0.17 µm for the control group, 0.22 ± 0.24 µm for the ICON group (60.7% reduction), and 0.31 ± 0.21 µm for the Opalustre group (44.6% reduction). Both treatments significantly reduced Ra compared to the control group ($p<0.001$). ICON achieved significantly lower Ra values than Opalustre ($p=0.002$). **Conclusion**: ICON resin infiltration and Opalustre microabrasion both reduce the microroughness of white spot lesions, with ICON producing a smoother surface. These findings suggest that ICON is more effective in improving surface characteristics, potentially reducing bacterial adhesion and enhancing long-term oral health outcomes.*

Keywords: white spot lesions, enamel microroughness, ICON resin, Opalustre treatment, minimally invasive dentistry

1. Introduction

White spot lesions, the earliest clinical manifestation of dental caries, present as opaque, white, or occasionally brownish patches on the smooth surfaces of permanent teeth, resulting from subsurface enamel demineralization. This process is initiated by acid production from bacterial metabolism of dietary sugars within dental plaque, leading to mineral loss from the enamel (1). Although the enamel surface remains intact at this stage, white spot lesions signify a critical opportunity for intervention to arrest or reverse damage, preventing progression to cavitated lesions. These lesions are not only a marker of active caries but also an esthetic concern, particularly in pediatric populations (2, 3).

The American Academy of Pediatrics and the American Dental Association recommend evidence-based strategies to promote remineralization and protect enamel integrity, including twice-daily brushing with fluoride toothpaste for two minutes, limiting sugary foods and beverages to three meals and two healthy snacks daily, and regular dental check-ups (4, 5). Fluoride is instrumental in enhancing enamel resistance to acid dissolution and facilitating remineralization (4-6). Dietary guidance emphasizes non-cariogenic choices such as cheese, raw vegetables, and fresh fruits over sticky or sugary options like candy or dried fruit (1). For high-risk individuals, particularly children, professional application of 5% sodium fluoride varnish is highly effective in arresting and reversing white spot lesions, as supported by systematic reviews and clinical guidelines (5, 7, 8). Adjunctive therapies, such as casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) pastes, may further enhance remineralization when used with fluoride (9).

Advanced microinvasive techniques, such as ICON resin infiltration, offer promising options for both caries arrest and esthetic improvement. This method involves etching the lesion with hydrochloric acid, drying, and infiltrating with low-viscosity resin to occlude microporosities, effectively halting caries progression and masking lesion appearance (10, 11). Randomized controlled trials and meta-analyses demonstrate that resin infiltration outperforms fluoride varnish and CPP-ACP, reducing lesion area by 46.6% compared to 26.6% and 28.6%, respectively, over 12 months (12). The American Dental Association supports resin infiltration for noncavitated lesions on approximal and smooth surfaces, particularly when esthetic outcomes are prioritized (5). In contrast, Opalustre microabrasion, which combines hydrochloric acid and abrasive particles to remove superficial enamel, is primarily indicated for esthetic enhancement of shallow lesions but is less effective for deeper demineralization or caries arrest (13, 14). Comparative studies highlight resin infiltration's superior performance in improving surface roughness, microhardness, and esthetic masking compared to microabrasion (8).

The choice of treatment modality depends on lesion depth, activity, esthetic priorities, patient age, caries risk, and resource availability. Fluoride varnish and sealants remain the cornerstone for caries prevention and arrest, while resin infiltration is preferred for deeper, esthetically concerning lesions (15). Microabrasion is best suited for superficial, well-demarcated lesions with esthetic indications. Despite these advancements, gaps in long-term outcome data and direct comparisons between modalities underscore the need for individualized, risk-based management and periodic monitoring (15).

Healthy enamel exhibits the lowest microroughness, with surface roughness (Ra) values typically around 0.04–0.10 µm. White spot caries lesions show a marked increase in microroughness, with Ra values rising to 0.50–0.61 µm due to subsurface demineralization and increased porosity (16-19). Dental restorations' microrouphness may vary - highly polished composite resins and ceramics can approach the smoothness of healthy enamel (Ra ≈ 0.10–0.20 µm), but less polished or aged restorations may exhibit higher roughness, sometimes exceeding 0.20 µm (16-20). Microroughness is clinically important because increased surface roughness promotes bacterial adhesion, especially of cariogenic species such as Streptococcus mutans (20, 21). Rough surfaces provide niches for biofilm accumulation, increasing the risk of secondary caries and periodontal inflammation. Smooth surfaces, as seen in healthy enamel and well-polished restorations, are less conducive to bacterial colonization and are easier to clean, supporting overall dental health. Treatments for white spot lesions, such as ICON resin infiltration and Opalustre microabrasion, reduce microroughness but do not fully restore the surface to the smoothness of healthy enamel. ICON achieves lower roughness than Opalustre, but both remain rougher than sound enamel, and their surfaces may become rougher after acid or mechanical challenges (16-19). Thus, minimizing microroughness is a key goal in restorative and preventive dentistry to reduce bacterial adhesion and improve long-term oral health outcomes (22, 23). This study contributes to evidence-based caries management by evaluating the clinical relevance of surface roughness reduction, guiding practitioners in selecting appropriate interventions for early enamel lesions.

Aim: The aim of this article is to compare the microroughness of enamel white spot lesions before and after treatment with ICON resin infiltration and Opalustre microabrasion.

2. Materials and Methods

Sixty extracted human permanent third molars were selected for the study. Each tooth was examined under 8x magnification using a microscope (Semorr DOM 3000E) to confirm the presence of initial carious lesions (white spot lesions) classified as code 02 (ICDAS II) on smooth surfaces. Teeth with restorations, fractures, cracks, erosion, or abrasion were excluded. Informed consent for the use of extracted teeth in research was obtained from patients prior to extraction. The teeth were stored in a 0.1% thymol solution at 4°C to inhibit microbial growth until experimental procedures began.

The 60 teeth were randomly divided into three groups (n = 20 per group):

- **Control Group**: White spot lesions left untreated.
- **ICON Group**: White spot lesions treated with ICON resin infiltration (DMG, Hamburg, Germany).
- **Opalustre Group**: White spot lesions treated with Opalustre microabrasion (Ultradent Products, South Jordan, UT, USA).

In the ICON group, white spot lesions were treated following the manufacturer's protocol. The lesion surface was etched with 15% hydrochloric acid (ICON-Etch) for 120 seconds, rinsed with deionized water for 30 seconds, and air-dried. An ethanol-based solution (ICON-Dry) was applied for 30 seconds to dehydrate the lesion, followed by air-drying. ICON-Infiltrant resin was applied, allowed to penetrate for 3 minutes, and light-cured for 40 seconds using a 1000 mW/cm² LED curing lamp. Excess resin was removed, and a second layer of infiltrant was applied for 1 minute and light-cured.

In the Opalustre group, microabrasion was conducted using Opalustre slurry (6.6% hydrochloric acid with silicon carbide particles) applied with a low-speed rubber cup for 60 seconds per application, following manufacturer instructions. The process was repeated up to three times, with rinsing and drying between applications, until the desired surface appearance was achieved. Treated surfaces were polished with a fine-grit polishing paste.

Surface microroughness (Ra, in micrometers) was measured using a profilometer (SRT-6210S, Shenzhen Graigar Technology Co., Shenzhen, China) equipped with a 5 µm radius needle tip, a 0.08 mm cutoff length (λc), a 0.25 mm transverse length, a measurement speed of 0.25 mm/sec, and a Gaussian filter. Ra values, representing the arithmetic mean roughness, were recorded at three points within the lesion area and averaged for each sample. The instrument was calibrated before each measurement session to ensure precision.

Data analysis was performed using SPSS software (SPSS Inc., Chicago, IL, USA). The normality of Ra values was evaluated with the Shapiro-Wilk test. Differences in mean Ra values among the control, ICON, and Opalustre groups were analyzed using one-way analysis of variance (ANOVA), followed by post-hoc Tukey's HSD tests for pairwise comparisons. The statistical significance threshold was set at $p<0.05$.

3. Results

Table 1 presents the values of the microroughness of the examined teeth.

Table 1: Microrouphness of the examined samples

Group	Mean Ra (µm) ± SD	Percentage Reduction in Ra	*p*-values
Control (1)	0.56 ± 0.17		$p_{1,2}<0.001$
ICON Resin Infiltration (2)	0.22 ± 0.24	60.7%	$p_{2,3}=0.002$
Opalustre Microabrasion (3)	0.31 ± 0.21	44.6%	$p_{1,3}<0.001$

As shown in Table 1, the mean Ra values indicate the mean surface microroughness values for the control, ICON, and Opalustre groups. Both treatment groups significantly reduced Ra compared to the control group, with ICON achieving a greater reduction (60.7%) than Opalustre (44.6%). The ICON group exhibited significantly lower Ra values than the control group ($p<0.001$) and the Opalustre group ($p=0.002$). The Opalustre group also showed significantly lower Ra values than the control group ($p<0.001$). These results indicate that ICON resin infiltration produces a smoother surface than Opalustre microabrasion, though both treatments improve surface roughness compared to untreated lesions.

4. Discussion

This in vitro study investigated the efficacy of ICON resin infiltration and Opalustre microabrasion in reducing the surface microroughness (Ra) of enamel white spot lesions, a critical factor influencing bacterial adhesion and caries progression. The results demonstrate that both treatments significantly reduce Ra compared to untreated lesions, with ICON resin infiltration achieving a greater reduction (60.7%) than Opalustre microabrasion (44.6%). Furthermore, ICON-treated surfaces were significantly smoother than those treated with Opalustre, aligning with previous findings that resin infiltration produces superior surface characteristics (8, 16, 18).

The elevated microroughness of untreated white spot lesions (0.56 ± 0.17 µm) reflects the increased porosity and surface irregularities caused by subsurface demineralization, which facilitates bacterial adhesion, particularly of cariogenic species like Streptococcus mutans (20, 21). ICON resin infiltration penetrates microporosities using a low-viscosity resin, occluding porous structures and creating a smoother, more uniform surface (10, 11). The significant reduction in Ra to 0.22 ± 0.24 µm suggests that ICON not only enhances esthetic outcomes but also reduces the risk of biofilm accumulation, supporting its role in caries arrest and prevention (5, 12). In contrast, Opalustre microabrasion, which mechanically removes superficial enamel, achieved a more modest Ra reduction to 0.31 ± 0.21 µm. This is likely due to the abrasive nature of the treatment, which, despite polishing, leaves a rougher surface compared to ICON (14, 18). The polishing step following microabrasion did not significantly improve roughness, consistent with prior studies indicating limited additional benefits from post-abrasion polishing (16, 17).

Comparisons with existing literature corroborate these findings. Atomic force microscopy and profilometry studies have consistently shown that ICON-treated surfaces exhibit lower Ra values than those treated with microabrasion, though neither treatment fully restores the smoothness of healthy enamel (Ra ~ 0.04–0.10 µm) (16, 18, 19). The smoother surface achieved with ICON may be attributed to the resin's ability to fill subsurface porosities, creating a more homogenous surface than the mechanical removal of enamel by Opalustre (10, 18). However, both treatments remain susceptible to increased roughness under acid or pH cycling challenges, suggesting that long-term durability requires further investigation (16, 19). This susceptibility underscores the importance of combining these treatments with preventive measures, such as fluoride varnish application and dietary counseling, to maintain enamel integrity (5, 7).

The clinical implications of these findings are significant. Smoother surfaces limit bacterial retention sites, potentially decreasing the risk of secondary caries and periodontal inflammation (20, 22). ICON's superior performance in reducing microroughness makes it a preferred option for deeper, esthetically concerning white spot lesions, particularly in patients prioritizing both caries arrest and esthetic outcomes (5, 15). Opalustre, while effective for superficial lesions with primarily esthetic indications, may be less suitable for deeper lesions due to its limited impact on subsurface demineralization and higher resultant Ra values (13, 14). The choice of treatment should therefore consider lesion depth, esthetic goals, and patient-specific factors such as caries risk and compliance with oral hygiene practices.

5. Conclusion

ICON resin infiltration outperforms Opalustre microabrasion in reducing the microroughness of white spot lesions, producing a smoother surface that may enhance resistance to bacterial adhesion. Both treatments offer valuable options for managing early caries, but their application should be tailored to individual patient needs, with periodic monitoring to ensure sustained outcomes.

Funding: None

Conflict of interest: None

References

[1] David M. Krol, Kaitlin Whelan, THE SECTION ON ORAL HEALTH; Maintaining and Improving the Oral Health of Young Children. *Pediatrics* January 2023; 151 (1): e2022060417. https://doi.org/10.1542/peds.2022-060417

[2] Fontana M, Gonzalez-Cabezas C, Tenuta LMA. Evidence-based approaches and considerations for nonrestorative treatments within modern caries management: Integrating science into practice. J Am Dent Assoc. 2024 Dec;155(12):1000-1011. https://doi.org/10.1016/j.adaj.2024.09.007

[3] Amaechi BT. Remineralisation - the buzzword for early MI caries management. Br Dent J. 2017 Aug 11;223(3):173-182. https://doi.org/10.1038/sj.bdj.2017.663

[4] Melinda B. Clark, Martha Ann Keels, Rebecca L. Slayton, SECTION ON ORAL HEALTH, Patricia A. Braun, Susan A. Fisher-Owens, Qadira Ali Huff, Jeffrey M. Karp, Anupama Rao Tate, John H. Unkel, David Krol; Fluoride Use in Caries Prevention in the Primary Care Setting. Pediatrics December 2020; 146 (6): e2020034637. https://doi.org/10.1542/peds.2020-034637

[5] Slayton RL, Urquhart O, Araujo MWB, Fontana M, Guzmán-Armstrong S, Nascimento MM, Nový BB, Tinanoff N, Weyant RJ, Wolff MS, Young DA, Zero DT, Tampi MP, Pilcher L, Banfield L, Carrasco-Labra A. Evidence-based clinical practice guideline on nonrestorative treatments for carious lesions: A report from the American Dental Association. J Am Dent Assoc. 2018 Oct;149(10):837-849.e19. https://doi.org/10.1016/j.adaj.2018.07.002

[6] Evans RW, Dennison PJ. The Caries Management System: an evidence-based preventive strategy for dental practitioners. Application for children and adolescents. Aust Dent J. 2009 Dec;54(4):381-9. https://doi.org/10.1111/j.1834-7819.2009.01165.x

[7] Dai Z, Liu M, Ma Y, Cao L, Xu HHK, Zhang K, Bai Y. Effects of Fluoride and Calcium Phosphate Materials on Remineralization of Mild and Severe White Spot Lesions. Biomed Res Int. 2019 Jun

16;2019:1271523. https://doi.org/10.1155/2019/1271523

[8] Holve S, Braun P, Irvine JD, Nadeau K, Schroth RJ; AMERICAN ACADEMY OF PEDIATRICS COMMITTEE ON NATIVE AMERICAN CHILD HEALTH AND SECTION ON ORAL HEALTH, CANADIAN PAEDIATRIC SOCIETY FIRST NATIONS, INUIT, AND MÉTIS HEALTH COMMITTEE. Early Childhood Caries in Indigenous Communities. Pediatrics. 2021 Jun;147(6):e2021051481. https://doi.org/10.1542/peds.2021-051481

[9] Güçlü ZA, Alaçam A, Coleman NJ. A 12-Week Assessment of the Treatment of White Spot Lesions with CPP-ACP Paste and/or Fluoride Varnish. Biomed Res Int. 2016;2016:8357621. doi: 10.1155/2016/8357621. Epub 2016 Oct 11. Erratum in: Biomed Res Int. 2018 Dec 24;2018:1816959. https://doi.org/10.1155/2018/1816959

[10] Bourouni S, Dritsas K, Kloukos D, Wierichs RJ. Efficacy of resin infiltration to mask post-orthodontic or non-post-orthodontic white spot lesions or fluorosis - a systematic review and meta-analysis. Clin Oral Investig. 2021 Aug;25(8):4711-4719. https://doi.org/10.1007/s00784-021-03931-7

[11] Faghihian R, Shirani M, Tarrahi MJ, Zakizade M. Efficacy of the Resin Infiltration Technique in Preventing Initial Caries Progression: A Systematic Review and Meta-Analysis. Pediatr Dent. 2019 Mar 15;41(2):88-94. PMID: 30992105.

[12] Wang Q, Zhou Y, Cui T, Li J, Lo ECM, Hao G, Zhi Q. Comparative evaluation of four treatments for postorthodontic white spot lesions: a randomized controlled trial. Clin Oral Investig. 2023 Oct;27(10):5957-5968. https://doi.org/10.1007/s00784-023-05209-6

[13] Alrebdi AB, Alyahya Y. Microabrasion plus resin infiltration in masking white spot lesions. Eur Rev Med Pharmacol Sci. 2022 Jan;26(2):456-461. https://doi.org/10.26355/eurrev_202201_27870

[14] Chabuk MM, Al-Shamma AM. Surface roughness and microhardness of enamel white spot lesions treated with different treatment methods. Heliyon. 2023 Jul 18;9(7):e18283. https://doi.org/10.1016/j.heliyon.2023.e18283

[15] Urquhart O, Tampi MP, Pilcher L, Slayton RL, Araujo MWB, Fontana M, Guzmán-Armstrong S, Nascimento MM, Nový BB, Tinanoff N, Weyant RJ, Wolff MS, Young DA, Zero DT, Brignardello-Petersen R, Banfield L, Parikh A, Joshi G, Carrasco-Labra A. Nonrestorative Treatments for Caries: Systematic Review and Network Meta-analysis. J Dent Res. 2019 Jan;98(1):14-26. https://doi.org/10.1177/0022034518800014

[16] Chabuk MM, Al-Shamma AM. Surface roughness and microhardness of enamel white spot lesions treated with different treatment methods. Heliyon. 2023 Jul 18;9(7):e18283. https://doi.org/10.1016/j.heliyon.2023.e18283

[17] Inna T, Krajangta N, Rakmanee T. The Staining Susceptibility and Surface Roughness of Teeth Restored by Microabrasion and Resin Infiltration: An In Vitro Study. Polymers (Basel). 2024 Dec 18;16(24):3523. https://doi.org/10.3390/polym16243523

[18] Yazkan B, Ermis RB. Effect of resin infiltration and microabrasion on the microhardness, surface roughness and morphology of incipient carious lesions. Acta Odontol Scand. 2018 Oct;76(7):473-481.

[19] Gurdogan EB, Ozdemir-Ozenen D, Sandalli N. Evaluation of Surface Roughness Characteristics Using Atomic Force Microscopy and Inspection of Microhardness Following Resin Infiltration with Icon®. J Esthet Restor Dent. 2017 May 6;29(3):201-208. https://doi.org/10.1111/jerd.12279

[20] Esteves-Oliveira M, Passos VF, Russi TMAZC, Fernandes ARR, Terto CNN, Mendonça JS, Campus G, Wierichs RJ, Meyer-Lueckel H, Lima JPM. Randomized in situ evaluation of surface polishing protocols on the caries-protective effect of resin Infiltrant. Sci Rep. 2022 Nov 30;12(1):20648. https://doi.org/10.1038/s41598-022-25091-8

[21] Arslan S, Zorba YO, Atalay MA, Özcan S, Demirbuga S, Pala K, Percin D, Ozer F. Effect of resin infiltration on enamel surface properties and Streptococcus mutans adhesion to artificial enamel lesions. Dent Mater J. 2015;34(1):25-30.

[22] Liu G, Yang L, Gao L, Ma Y, Wu X, Wang X, Hao Z. Durability of infiltrated resin application on white spot lesions after different challenges: An ex vivo study. J Prosthet Dent. 2024 Mar;131(3):500-507. https://doi.org/10.1016/j.prosdent.2022.02.003

[23] Neres ÉY, Moda MD, Chiba EK, Briso A, Pessan JP, Fagundes TC. Microhardness and Roughness of Infiltrated White Spot Lesions Submitted to Different Challenges. Oper Dent. 2017 Jul/Aug;42(4):428-435. https://doi.org/10.2341/16-144-L