Minimally Invasive Technique of Masking Nonpitted Fluorosis on Young Permanent Incisors: A Clinical Trial

Shikha Dogra¹, Virinder Goyal², Neeru Singh³, Meenu Bhola⁴, Anil Gupta⁵, Shalini Garg⁶

ABSTRACT

Aim: Analysis of masking potential of the resin infiltration technique with dental milestones guaranteed caries infiltration concept (DMG ICON) on nonpitted white spot lesions due to fluorosis in newly erupted permanent maxillary incisors for better esthetics and psychological well-being in children.

Materials and methods: This prospective interventional study was conducted on 60 newly erupted maxillary central incisors with mild, nonpitted white spot lesions of fluorosis till grade IV of the Thylstrup and Fejerskov (TF) index. The resin infiltration technique with DMG ICON (DMG, Hamburg, Germany) was used to mask lesions along with the analysis for color change using Euclidean distance, i.e., the ΔE (Delta E) unit of the CIE $L^*a^*b^*$ color space formula where $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$ using the image-analyzing software. Data were analyzed statistically by the SPSS software.

Results: Fifty-one tooth samples (85%) showed complete masking of white spot lesions of fluorosis postoperatively to resin infiltration with net ΔE values less than or equal to 3.7 whereas lesions in nine tooth samples (15%) were not masked completely with net $\Delta E > 3.7$. Statistically highly significant results were obtained with the Wilcoxon signed-ranks test (p value < 0.001).

Conclusion: The minimally invasive resin infiltration technique using DMG ICON is highly efficient and satisfactory for masking of nonpitted white spot lesions of dental fluorosis in newly erupted permanent central incisors as per the analysis for color change using the image-analyzing software.

Clinical significance: The outcome of masked and blended white spot lesions of fluorosis with the sound enamel in the smile zone with the resin infiltration technique was found to be a child-friendly, noninvasive, single-sitting approach with stabilized results in follow-up visits.

Keywords: Dental fluorosis, DMG ICON, Resin infiltration, White spot lesion.

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INTRODUCTION

White spot lesions due to dental fluorosis pose serious esthetic problem in newly erupted permanent incisors. As a child approaches early adolescence, there is an alteration in the attitude and self-perception under the influence of peer pressure. This affects their emotional stability and self-confidence. Hence, this age group is more concerned about esthetics and they seek quick intervention, which should be permanent and less invasive. Also the awareness of modern Indian parents toward dental esthetics is increasing and they demand natural appearance of teeth with tooth-colored restorations for their children.¹⁻³ The resin infiltration concept supports the concept of preventive dentistry by restoring the tooth in a least invasive way for regaining healthy, functional, and esthetic smiles.⁴ The present study was conducted in high fluoride belt area of state Punjab in India, with the fluoride content in drinking water >1.5 ppm.⁵

Dental fluorosis, if nonpitted, appears clinically as initial white spot lesion areas. This may range from narrow to pronounced opaque white lines following perikymata to irregularly shaped chalky white to cloudy opacities over the tooth surface. This appearance till grade IV of the Thylstrup Fejerskov index of dental fluorosis occurs due to change in the refractive index of the subsurface hypomineralized porous enamel with respect to the intact hypermineralized surface layer.^{6,7} Various minimally invasive suggested treatment modalities for esthetic treatment of such defects are microabrasion, tooth whitening procedures with bleaching agents, along with invasive procedures such as composite restorations and veneers. Microabrasion and composite veneering

^{1,5,6}Department of Pediatric and Preventive Dentistry, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India

²Department of Pediatric and Preventive Dentistry, Surendera Dental College and Research Institute, Sri Ganganagar, Rajasthan, India

³Department of Pediatric and Preventive Dentistry, Faculty of Dental Sciences, Desh Bhagat University, Mandi Gobindgarh, Punjab, India

⁴Department of Pedodontics and Preventive Dentistry, Dasmesh Institute of Research and Dental Sciences, Faridkot, Punjab, India

Corresponding Author: Shikha Dogra, Department of Pediatric and Preventive dentistry, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, India, Phone: +91 9205716200, e-mail: mdsshikha87@gmail.com

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procedures require removal of the surface layer of the enamel. Also patients with composite veneers always report either with dislodgement of the composite layer or its discoloration with passage of time. Further, microabrasion and bleaching procedures pose problems of postoperative sensitivity, long-term follow-up, and young patient compliance.^{8,9}

Combating all these problems, the resin infiltration concept was introduced in the literature as therapeutic treatment of white spot lesions due to incipient caries and postorthodontic decalcifications. This is claimed to be a young patient-friendly, minimally invasive,

definitive, and corrective therapy with a low-viscosity resin having a high penetration coefficient for nonpitted white spot lesions in newly erupted permanent incisors in young children. It works by occluding subsurface microporosities, thereby reversing healthy enamel color and translucency.⁸⁻¹⁰

Hence, the present study was planned with the aim to analyze the masking potential of resin infiltration with dental milestones guaranteed caries infiltration concept (DMG ICON) on nonpitted white spot lesions due to fluorosis in the esthetic zone with the goal of improving self-confidence and psychological development in these children.

MATERIALS AND METHODS

This clinical controlled prospective interventional study was conducted in the Department of Pediatrics and Preventive Dentistry, Dasmesh Institute of Research and Dental Sciences, Faridkot, Punjab, India (district Faridkot of state Punjab, which is an endemic area of fluoride in northern India), with the fluoride content in drinking water >1.5 ppm.⁵

Sample Selection

In this study, about 200 children with dental fluorosis between 6 years to 12 years of age reporting in the routine dental OPD with chief complaint of unesthetic white spots on newly erupted teeth were screened over a period of 2 years (from November 2012 to November 2014). Afterward, the present study was conducted on a convenient sample of 40 patients with nonpitted white spot lesions in the esthetic zone of the anterior maxillary region as per the inclusion and exclusion criteria explained below. Among these children, 60 tooth samples of 30 patients were subjected for resin infiltration with DMG ICON to analyze its masking effect postoperatively. Ethical clearance was obtained from the institutional ethical committee and an informed written consent was sought from the parents of the patients for their enrolment in the study.

Inclusion Criteria

Maxillary anterior tooth samples with mild, nonpitted white spot lesions of fluorosis till grade IV of the Thylstrup and Fejerskov (TF) index. Selected samples of fluorosed teeth were differentiated from nonfluoridic opacities by the Russell's criteria.^{7,11}

Exclusion Criteria

Children who were physically or mentally challenged, with severe systemic disease, non fluoridic opacities as per the Russell's criteria, past dental history for esthetic intervention done for dental fluorosis, or allergy to dental materials or restorations.^{7,10,11}

Standardized Photographic Technique

Photographs were taken with the Canon 550-D camera [(SP AF90 mm F 2.8 Di 1:1 Macrolens; Tamron, Saitama, Japan) and flash (MT 24-EX twinlight; Canon)]. The camera settings were done at a shutter speed of 1/200, F29, ISO 400, and auto white balance.⁸ To avoid interference with the external source of light, all photographs were taken in a darkroom and the intensity of light was maintained constant using a photometer. The patient was asked to sit on a dental chair and each time the photograph was taken, the distance and angulation of the camera from the patient was kept constant.

Operative Procedure, i.e., Resin Infiltration with DMG ICON

Pretreatment digital photographs were taken as per described standardized conditions after the selected tooth sample was

isolated using a rubber dam (for ΔE_1 values to be taken as control) and retracted with a waxed dental floss, i.e., without clamp (Figs 1A, 2A, 3A, 4A).¹²⁻¹⁴ This was followed by resin infiltration with DMG ICON (DMG, Hamburg, Germany) as per manufacturer's instructions.

The tooth surface was cleaned with prophylactic paste and rubber cup. Icon etch containing 15% hydrochloric acid (15% HCl) was applied to erode the surface layer of the tooth and left for 2 minutes followed by rinsing and air-drying for 30 seconds. Then, Icon dry containing 99% ethanol was applied for 30 seconds followed by air-drying. This was followed by application of Icon infiltrant for 3 minutes to allow its penetration into the lesion area to maximum depth. Excess of Icon infiltrant was removed by cotton roll and dental floss from the proximal area followed by light-curing (3M ESPE, St. Paul, Minnesota) for 40 seconds. Icon infiltrant application was again repeated for 1 minute and light-cured for 40 seconds. The finally treated tooth surface was polished using polishing discs.^{8,9}

Immediate posttreatment digital photographs were taken as per the described standardized conditions (Fig. 1B, 2B, 3B, 4B).

Record and Data Analysis of Color Change Postoperatively

Pretreatment and posttreatment photographs on the day of application were transferred in Adobe Photoshop Software 7.0 (Adobe Systems, San Jose, California) in the computer. $L^*a^*b^*$ coordinators of color were recorded using the grid in this software for both lesion area and the sound enamel in each tooth sample preoperatively and postoperatively.^{8,15}

This was followed by analysis for color change using Euclidean distance, i.e., the ΔE (Delta E) unit of CIE $L^*a^*b^*$ color space formula, i.e., $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$. The ΔE unit quantifies minimal noticeable color change to the naked eye by calculation of the sum of differences in L^* (lightness/darkness), a^* (green-red), and b^* (blue-yellow) coordinators in the above-described equation.¹⁶⁻¹⁸ In the oral cavity, under standardized conditions, net ΔE values less than or equal to 3.7 indicate complete blending of lesion area with the adjacent sound tooth enamel, i.e., complete masking of the lesion postoperatively to esthetic intervention, which is clinically not visible to the human eye. But net $\Delta E > 3.7$ depicts mismatching of colors, i.e., the lesion is clinically visible hence not masked esthetically.^{8,17,19}

Hence, pretreatment ΔE values (i.e., ΔE_1 values, i.e., control) and posttreatment ΔE values (i.e., ΔE_2 values) between lesion area and the sound tooth enamel of 60 samples using the above equation were calculated. This data were subjected to the statistical analysis based on net ΔE values of color change for 60 study samples (net ΔE values were calculated by analyzing difference of their ΔE_2 and ΔE_1). Clinically, esthetic stability of masked tooth samples with high patient satisfaction were observed at 1-year follow-up (1-year follow-up photographs were taken as shown in Figs 1C, 2C, 3C, 4C).

RESULTS

As per the described standardized photographic technique in the methodology, both pretreatment and posttreatment photographs of each tooth sample were transferred and projected to the grid of the image-analyzing software, i.e., Adobe Photoshop Software 7.0 (Adobe Systems, San Jose, California) in the computer.^{8,15}

In this grid, the specific point on the divided tooth part of the sound enamel was chosen to record most accurate values of $L^*a^*b^*$ coordinators of tooth color, which were kept constant pre and postoperatively, whereas $L_1a_1^*b_1^*$ were designated to preoperative coordinators of tooth color for the selected site of lesion area. For

Fig. 1: Clinical photographs showing resin infiltration with DMG ICON to mask white spot lesions on permanent maxillary incisors: (A) First patient preoperative; (B) Immediate postoperative; (C) 1-year follow-up

Fig. 2: Patient showing: (A) Preoperative; (B) Immediate postoperative; (C) 1-year follow-up

Fig. 3: Clinical photographs showing resin infiltration with DMG ICON to mask white spot lesions on permanent maxillary incisors: (A) Third patient preoperative; (B) Immediate postoperative; (C) 1-year follow-up

Fig. 4: Patient showing: (A) Preoperative; (B) Immediate postoperative; (C) 1-year follow-up

Fig. 5: Graph showing pretreatment values ΔE_1 and posttreatment values ΔE_2 of n (60) teeth where net $\Delta E \leq 3.7$ (51) and > 3.7 (9)

Table 1: ΔE_1 (pretreatment values, i.e., control), ΔE_2 (posttreatment values), net ΔE values of n (60) teeth

Tooth sample	ΔE_1 values (control)	ΔE_2 values	Net ΔE values
1	8.12	5.09	3.03
2	6.16	3	3.16
3	8.66	8.06	0.6
4	7.34	5.38	1.96
5	12.84	10.67	2.17
6	11.66	9	2.66
7	13.45	12.84	0.61
8	10.34	8.54	1.8
9	4.13	3.31	0.82
10	4.24	2.82	1.42
11	5.38	2.23	3.15
12	4.58	3	1.58
13	8.48	5.19	3.29
14	8.6	6.4	2.2
15	5.19	4.47	0.72
16	6.4	3.31	3.09
17	10.48	7.07	3.41
18	11.48	8.3	3.18
19	3.46	3.31	0.15
20	6.08	4.47	1.61
21	6.16	3.31	2.85
22	11.04	7.34	3.7
23	5.91	5.74	0.17
24	12.52	10.72	1.8
25	9.43	6.7	2.73
26	9.43	8.66	0.77
27	10.24	7.34	2.9
28	8.06	6.16	1.9
29	12.68	8.18	4.5
30	7.87	3.16	4.71
31	14.49	11.78	2.7
32	12.68	5.19	7.49
33	9.43	6	3.43
34	3.74	2.82	0.92
35	6.78	2.82	3.96
36	13.15	8.6	4.55
37	6.4	6	0.4
38	10.34	7.68	2.66
39	3.6	3.16	0.44
40	11.87	3.6	8.27
41	6.7	3.6	3.1
42	10.04	9.05	0.99
43	6.16	3.31	2.85
44	5.91	1.33	4.58
45	9.21	6.08	3.13
46	4.58	3.16	1.42
47	3.74	3	0.74
48	5.47	4.12	1.35
49	9.43	6.4	3.03
50	5.83	5.09	0.74

Contd...

Contd...

Tooth sample	ΔE_1 values (control)	ΔE_2 values	Net ΔE values
51	4.35	3.16	1.19
52	8.66	5.38	3.28
53	5.47	4.89	0.58
54	7.14	4.47	2.67
55	14.17	11.22	2.95
56	6.4	5	1.4
57	10.81	3	7.81
58	8.36	5.47	2.89
59	11.91	6.16	5.75
60	6.32	3.16	3.16

each tooth sample, preoperative ΔE_1 was calculated using the CIE $L^*a^*b^*$ color space formula equation $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$. Preoperative coordinators of tooth color for lesion area, i.e., $L_1a_1^*b_1^*$ and calculated ΔE_1 values (Table 1) of 60 tooth samples were taken as control. Similarly, after resin infiltration, postoperative coordinators of tooth color for lesion area, i.e., $L_2a_2^*b_2^*$, were obtained using the image-analyzing software and postoperative ΔE_2 values (Table 1) were calculated using the above equation (where $L^*a^*b^*$ coordinators of tooth color for the sound tooth enamel were kept constant).

As shown in (Table 2), pretreatment ΔE_1 values (control) were found in the range from 3.46 to 14.49 with mean 8.226 ± 3.034 and posttreatment ΔE_2 values ranged from 1.33 to 12.84 with mean 5.641 ± 2.644 . The net ΔE value was calculated for each tooth sample by calculating difference of postoperative ΔE_2 and preoperative ΔE_1 ($\Delta E_2 - \Delta E_1$) for 60 tooth samples (Table 1). Postoperatively to resin infiltration, 85% study tooth samples ($n = 51$) showed complete masking of white spot lesions of fluorosis esthetically with net ΔE values less than or equal to 3.7, whereas lesions in 15% tooth samples ($n = 9$) had incomplete masking with net $\Delta E > 3.7$ (i.e., net $\Delta E = 3.7-5$ in $n = 5$, net $\Delta E = 5-7$ in $n = 1$ and net $\Delta E > 7$ in $n = 3$), as shown in (Table 1 and Fig. 5), where net ΔE values were found to be in range of 0.15–8.27 with mean 2.584 ± 1.772 (Table 2). These data were analyzed statistically with the Statistical Analysis Software SPSS (Statistical Package for Social Sciences by Armonk, New York) using the “Wilcoxon signed-ranks test,” which showed p value < 0.001 , i.e., highly significant (Table 2). Clinically, stability of esthetically masked lesions in these tooth samples was found to be up to patient satisfaction at 1-year follow-up (Figs 1A, 2A, 3A, 4A).

DISCUSSION

Fluorotic white spot lesions on the labial surface of newly erupted permanent anterior teeth pose an obvious esthetic and psychological challenge in growing children. The esthetic management of these lesions without transforming the original form of the tooth could be a challenge for pediatric dentists. The perception of tooth color to the naked eye is the outcome of transmitted incident light after its absorption through mineralized dental hard tissues and subsequent scattering from the tooth surface.¹⁶ Clinical presentation of mild fluorosis as nonpitted white spot lesions on newly erupted permanent incisors occurs due to change in the refractive index of the enamel in lesion area (1.33) with respect to the sound enamel of the affected tooth (1.66).^{8,9,20}

The resin infiltration technique with DMG ICON works on the principle of the “Chameleon effect” by occluding subsurface micropores in hypomineralized fluorosed lesions after curing of the

Table 2: Mean values of color change (highly significant masking effect was observed postoperatively to resin infiltration with p value < 0.001)

Color change	n	Range	Mean $\pm$ SD	Std. error	z value	p value
Preoperative ΔE_1	60	3.46–14.49	8.226 $\pm$ 3.034	0.392	6.736	<0.001***
Postoperative ΔE_2	60	1.33–12.84	5.641 $\pm$ 2.644	0.341		
Net color change ($\Delta E_2 - \Delta E_1$)	60	0.15–8.27	2.584 $\pm$ 1.772	0.229		

infiltrated low-viscosity resin having a refractive index comparable to that of the enamel (1.52), which achieves required blending of the masked lesion with the sound enamel.^{8,9,20} Additionally, the resin infiltrate has low contact angle, high surface tension, and high coefficient of penetration to complete lesion depth favoring its flow by capillary-driven forces into subsurface microporosities leading to the required refractive index for effective masking.²¹

In this study, the masking of 60 tooth samples with fluoridic white spot lesions in the esthetic zone (as per the inclusion criteria) was done by the resin infiltration technique with DMG Icon. Clinically, selection of tooth samples for resin infiltration in the present study was attempted in accordance to the TF index of dental fluorosis.¹⁰ It is more sensitive than the Dean's index to provide elaborated clinical presentation of various grades of dental fluorosis (specially in endemic areas) in correlation with histological aspects of the affected enamel, further increasing its validity and reliability.⁷ Various studies have shown that the image-analyzing software analyzing standardized clinical photography is more objective and reliable in quantifying lesion color and size. Even spectrophotometers and colorimeters are sensitive to measure tooth color change, but colorimeters are less accurate than spectrophotometers because they have significant edge loss, which leads to error in color measurement with variation in inter instrument reliability.¹⁵ Hence by the application of color science in dentistry, we can analyze the minimal noticeable change in tooth color using colorimeters, spectrophotometers, and image-analyzing softwares for *in vivo* studies.^{15,16} All these techniques can evaluate minimal noticeable color change to the human eye by obtaining Euclidean distance, i.e., ΔE (Delta E), from the CIELAB color space formula using equation $\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$, where coordinators of physical intensity of color have perceptual meaning, i.e., L^* (lightness/darkness), a^* (green–red), and b^* (blue–yellow).^{16–18}

Keeping in mind the basis of the resin infiltration concept as a noninvasive procedure, following strict manufacturer's instructions neither we have repeated the etching step for complete removal of the surface layer for its complete erosion nor we have increased etching and application time of Icon infiltrant. Although few percentages of tooth samples (15%) in this study showed inappropriate results postoperatively, yet 85% of study samples have shown successful masking of lesions esthetically with highly significant results statistically (p value < 0.001). High patient satisfaction in terms of esthetic stability of masked lesions in these tooth samples was observed clinically at 1-year follow-up (Figs 1A, 2A, 3A, 4A), which has predicted resin infiltration as single-sitting, quick, noninvasive, painless treatment of these lesions while maintaining shape, size, form, and function of the sound tooth structure without its additional loss in an economical manner than conventional approaches without relapse of treated lesions.

DMG ICON used in present study contains 15% HCl (rather than 37%) as Icon etch to erode the surface hypermineralized layer for exposure of subsurface microporosities. Thereby, in accordance to the modern era of minimally invasive dentistry, Icon etch removes only about 40 μ m of the surface layer, whereas initial

tooth reduction in microabrasion removes about 360 μ m of the surface enamel. Following this step, neither cavitation occurred nor any manual tooth reduction is required in contrast to composite restorations or veneers and microabrasion.^{8,9,21,22}

Further complete desiccation was achieved by application of Icon dry containing 99% ethanol for 30 seconds to remove water filled in exposed micropores of the etched surface of the lesion to facilitate the diffusion of Icon Infiltrant, i.e., the low-viscosity resin into the lesion body to occlude subsurface microporosities.^{8–10} In comparison to this fact, bleaching techniques treat only superficial layers of the enamel, not from inside of the complete lesion body, therefore their results are dramatic, inconsistent, and time-consuming.^{9,23}

In this clinical control trial prospective interventional study, 51 tooth samples (85%) showed complete masking of white spot lesions of fluorosis postoperatively to resin infiltration with net ΔE values less than or equal to 3.7, whereas these lesions in nine tooth samples (15%) were not masked completely with net ΔE > 3.7 (Table 1, Fig. 5), which was in accordance with the literature review of the resin infiltration technique. Auschill et al. did esthetic evaluation of mild to moderate fluorosis stains by resin infiltration with DMG ICON in 2015. After follow-up of 6 months, they found resin infiltration to be an agreeable option for these lesions than other invasive, conventional procedures but they emphasized that long-term outcomes of this technique need to be determined by further studies.²⁴ Also Gugnani et al. analyzed esthetic changes in nonpitted fluorosis stains in 2017 by comparative postoperative effects of resin infiltration, in office bleaching and combination therapies. They reported that resin infiltration alone or in combination with bleaching therapy showed better results than bleaching therapy alone in these defects.¹⁰ In 2018, Di Giovanni et al. did a systemic review of interventions for dental fluorosis in six clinical trials and they found highest percentage of success in esthetic improvement with resin infiltration technique alone or its combination with bleaching therapy followed by bleaching alone, which was least with microabrasion.²³ Theodory et al. in 2019 conducted an *in vitro* study to compare the masking ability and penetration capacity amongst three resin composite sealers i.e., Biscover LV (Bisco), Optiguard (Kerr Hawe), Permaseal (Ultradent and resin infiltrant i.e., DMG ICON with control group as no treatment. Procedures were done in shallow artificial caries lesions of seventy five extracted human molars. They concluded that resin infiltrant DMG ICON showed the deepest penetration of all resins on analysis of clinical photographs based on 100-mm visual analogue scale (VAS).²⁵ Further long-term camouflage effects of resin infiltration (Icon, DMG, Hamburg, Germany) was reassessed by Knosel et al. in an *in vivo* study of 20 subjects. They found that assimilation of the infiltrated white spot lesion to the color of the sound adjacent enamel by resin infiltration was suitable for the long-term improvement in the esthetic appearance of postorthodontic white spot lesions.²⁶ Also Garg and Chavda managed three cases of mild to moderate fluorosis by combination of bleaching and the resin infiltration technique followed by quantification of color change

using the Adobe photoshop software using the CIEDE2000 formula and they achieved satisfactory masking of these lesions, which was stable till 12 months of follow-up.²⁷

Hence, our results advise the use of the resin infiltration technique to successfully mask white spot lesions of dental fluorosis ranging from grade I to IV of the TF index with stable esthetic masking of these lesions at 1-year follow-up. This child-friendly technique aid in developing a better psychology in growing children.

CONCLUSION

The minimally invasive resin Infiltration technique using DMG ICON is highly efficient in masking nonpitted white spot lesions of dental fluorosis in newly erupted permanent central incisors, which enhances the esthetics, self-confidence, and psychological well-being in children.

CLINICAL SIGNIFICANCE

The outcome of masked and blended white spot lesions of fluorosis with the sound enamel in the smile zone with the resin infiltration technique was found to be a child-friendly, noninvasive, single-sitting approach with stabilized results in follow-up visits.

Limitations of Study

- Resin infiltration is a technique-sensitive procedure and an inefficient isolation may lead to complete failure of the procedure.
- The masking effect of resin infiltration does not work for deep lesions caused by fluorosis.
- The present study reports stable masking of fluorotic nonpitted lesions over a period of 2 years; further studies of longer duration are required to assess this masking effect further.

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