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Original Research Article

Comparative evaluation of remineralization potential of threecommercially available toothpastes in children aged 7-12 years using DIAGNOdent Pen - A randomized control in-vivo study

Aastha Jha[1]*, Rishabh Kapoor[1], Shivani Mathur[1], Shikha Choubey[1], Diksha Bhat[1]

[1]Dept. of Pediatric and Preventive Dentistry, I.T.S Centre for Dental Studies and Research, Muradnagar, Ghaziabad, Uttar Pradesh, India

Abstract

Background: Dental caries is a prevalent issue among children, and the use of remineralizing toothpaste is a common preventive measure. This study compared the efficacy of three different commercially available toothpastes in remineralization of White Spot Lesions in children.
Aim: Inter-comparison of remineralization potential of three toothpastes containing Fluoride, Dicalcium Phosphate Dihydrate, and Nano-Hydroxyapatite Crystal respectively on white spot lesions on permanent maxillary anterior teeth using DIAGNOdent pen.
Materials and Methods: 45 children aged 7-12 years were randomly divided into three different groups according to toothpastes containing different remineralizing agents, with each having 15 subjects. ICDAS II scoring was done for each subject before application of remineralizing toothpaste. DIAGNOdent pen values were recorded on the first appointment, 1 hour after application of toothpastes and after 3 weeks follow-up.
Results: Inter-group comparison, at baseline showed no statistically significant difference, however the mean difference in the DIAGNOdent pen assessment at 3 week follow-up suggested that Nano- hydroxyapatite was better in promoting the remineralizing of WSL.
Conclusion: While all toothpastes showed potential for remineralization, nano-hydroxyapatite toothpaste exhibited better results in remineralizing the WSL over a three-week period of time.

Keywords: Diagnodent pen, Remineralization, white spot lesions, caries diagnosis, Nano-hydroxyapatite

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1. Introduction

Dental caries, the most prevalent chronic bacterial infection globally, is caused by complex interactions among fermentable carbohydrates, acid-producing bacteria, and host factors like salivary flow and and its composition.[1]

White spot lesions are the first visible signs of caries, caused by poor oral hygiene, plaque, bacteria, and acid accumulation. It is a “subsurface enamel porosity from carious demineralization” that presents as a “milky / chalky white opacity” when located on smooth surfaces of teeth. These lesions have a continuous surface layer and porous subsurface area, altering the refractive index. When air dried, the enamel tissue in the demineralized area loses its translucent feature and appear as a white spot lesion.[2,3] Early detection and diagnosis are crucial for reducing caries incidence in children.

Research on tooth remineralization has led to the development of technologies promoting remineralization of enamel, with minimally invasive dentistry principles dictated for effective clinical methods.

Amongst various remineralizing agents, Fluoride has been the most commonly used remineralizing substance that prevents enamel dissolution by producing fluorapatite crystals. This self-limiting surface process minimizes demineralization and enhances remineralization of enamel by preventing from penetrating the lesion's depth. Fluorapatite deposits quickly, creating a resilient surface layer.[4]

However, many parents avoid fluoride due to safety concerns and a dose-dependent relationship, as long-term exposure can develop dental and skeletal fluorosis and change thyroid hormone levels by interfering with deiodinase enzyme activity.[5]

*Corresponding author: Aastha Jha
Email: aasthajha_mds22_25@its.edu.in

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A revolutionary remineralizing agent, biomimetic hydroxyapatite (HAP),$Ca_5(PO_4)_3(OH)$ has been well-documented for safety and bio compatibility. By using enamel crystals to form mineral-mineral bridges and indirectly releasing calcium and phosphate ions, it prevents dental cavities. HAP is safe to consume and, has no documented side effects. HAP causes uniform remineralization of subsurface enamel lesions, effectively preventing dental caries with oral care products.[6]

Another remineralizing agent Dicalcium phosphate dihydrate (DCPD), is a dental compound with unique properties like biocompatibility and bioactivity, making it ideal for dental applications in remineralization and restorative dentistry.[7] DCPD is a promising remineralizing agent for treating dental caries by promoting the deposition of calcium and phosphate onto demineralized tooth surfaces, making the tooth structure resistant to acid attack during low pH.[8] It is bio-compatible, and is being explored for its potential use in dental cements and fillings due to its ability to bond to tooth structure. DCPD, a precursor to hydroxyapatite, is crucial in dental remineralization processes. Remineralization of early caries lesions using saturated DCPD solutions could be effective.[9,10,11]

Detecting white spot lesions is crucial for diagnosing and managing dental caries, with visual inspection being the simplest method. This method is subjective and may vary based on the observer's experience and lighting conditions. Radiographic examination like bitewing and intra-oral radiographs reveal demineralization in enamel, helping detect WSLs that may not be visible clinically.[12] However, this method may not detect early lesions. Quantitative Light-induced Fluorescence (QLF) are non- invasive methods for monitoring white spot lesions (WSLs). QLF uses fluorescent light to visualize demineralized areas as dark spots on the tooth surface. It also quantifies lesion severity and progression revealing demineralization in enamel.[13]

A novel method for detecting early enamel lesions and remineralization is using a DIAGNOdent pen by KaVo, Biberach, Germany. This caries detection instrument uses a laser diode (655 nm, modulated, 1 mW peak power) as an excitation light source and a photo diode with a long pass filter (transmission > 680 nm) as a detector. Long wavelength ambient light is filtered by DIAGNOdent pen. Using laser fluorescence technology, the DIAGNOdent Pen from KaVo works by applying a 655 nm wavelength of light to the tooth's surface, which stimulates the tooth's natural porphyrins and collagen to release fluorescence. This fluorescence is then detected by a sensor within the pen, and the intensity of the signal is correlated with the severity and existence of carious lesions. DIAGNOdent quantitatively measure decay levels, the equipment translates this intensity into a numerical number that is presented on its screen. When combined with tactile and visual exams, it aids in the early detection of lesions and the tracking of dental caries, improving diagnostic capacity in dental practice.[14]

The prevalence of caries in young children, which is still significant today, can be decreased with the introduction of a safe and widely approved active agents for caries prevention.

This study explores the efficacy of fluoride, DCPD, and nano-hydroxyapatite crystals in remineralizing white spot lesions on permanent maxillary anterior teeth. It aims to improve preventive strategies and address the pervasive challenge of dental caries in young children.

Hence, the aim of this study needs inter-comparison of remineralization potential of Fluoride, Dicalcium Phosphate Dihydrate, and Nano-Hydroxyapatite Crystal containing toothpastes on initial white spot lesions on permanent maxillary anterior teeth using DIAGNOdent pen.

2. Materials and Methods

The present study was conducted in the Department of Pediatric and Preventive Dentistry. Before the commencement of the study, the study design was approved by the Institutional Ethical committee under IEC number /IIEC/LD/PEDO/2022-25/001.

The study was designed as a randomized clinical trial where 45 children in the age group of 7-12 years were included. Informed consent was obtained from each subject's parents before enrolling them in the study.

2.1. Selection criteria

A total number of 45 children aged 7-12 years reporting to the outpatient department of Pediatric and Preventive Dentistry were included in the study. They were divided into 3 groups randomly, 15 in each group by using sealed envelope method.

Children aged 7 to 12 whose parents gave permission were included in the study. White spot lesions in children with maxillary anterior permanent teeth were the main focus of the study. Additionally, participants had to be clear of any systemic illnesses. The exclusion criteria for the study was childrenwho had no previous adverse experiences with medical or dental treatments. Additionally, children with active carious lesions, teeth involving the pulp, systemic diseases, intellectual disabilities, psychiatric disorders, or those with dental abscesses or fistulas at the procedure site were excluded. Using the sealed envelope procedure, these children were divided into three groups of fifteen subjects at random. Groups A, B, and C were assigned different types of remineralizing toothpaste: Group A was given fluoride toothpaste, Group B was given dicalcium phosphate dihydrate (DCPD) toothpaste and Group C was given nano-hydroxyapatite toothpaste

In the first appointment after obtaining the filled consent forms by the parents, oral prophylaxis was performed for all

the subjects. During the first appointment itself, the anterior teeth of the included children were dried using a 3-way syringe, and a visual examination of each tooth with a white spot lesion was performed using the ICDAS II scoring system. DIAGNOdent Pen values were recorded for each affected tooth using the type B tip for smooth surfaces, and the results were documented on a pre- approved proforma. The designated toothpaste for each group was then applied to the affected tooth for 3 minutes using a micro applicator tip. Following this, the children were instructed not to eat, drink, or rinse for 1 hour. After the 1-hour period, DIAGNOdent Pen values were recorded again for the treated tooth surface using the type B tip. Each participant was given the remineralizing toothpaste corresponding to their allocated group and was provided with instructions and a demonstration on how to brush their teeth at home. The children were then scheduled for a follow-up appointment after 3 weeks.At the second appointment, DIAGNOdent Pen values for the treated tooth were recorded again to assess the outcomes after the 3-week follow-up.

2.2. Statisctical analysis

All data were entered into a computer by giving coding system, proofed for entry errors. Data was compiled on a MS Office Excel sheet (v 2019, Microsoft Redmomd Campus, RedMond, Washington, United States). Data was subjected to statistical analysis using Statistical Package for Social Sciences (SPSS v 26.0, IBM). Descriptive statistics like Mean, S.D and Mean differences for numerical data had been represented. Intra-group comparison was done using Wilcoxon Signed Ranks Test. Inter-group comparison was done using Kruskal-Wallis Test. The level of significance was kept at 0.05.

3. Results

Prior to the intervention, the baseline DIAGNOdent Pen values were recorded (T_0), DIAGNOdent Pen values recorded after 1 hour of application of remineralizing toothpaste (T_1) and then the DIAGNOdent Pen values at the end of three weeks (T_2) was recorded again.

Table 1 displays the gender-wise distribution across different groups the study includes 24 girls and 21 boys, demonstrating a uniform distribution of gender within the groups.

Table 2 represents the results of inter-group comparison of the three commercially available toothpastes containing Fluoride in Group A, Dicalcium Phosphate Dihydrate in Group B and Nano-hydroxyapatite in Group C. According to this result there is no statistically significant difference in the remineralizing potential of the three toothpastes, (p value 0.409, 0.663 and 0.424 for groups A, B and C respectively). However the mean difference in the DIAGNOdent assessment at 3 week follow-up (T2) suggests that group C i.e., Nano-hydroxyapatite group is better in remineralization, with the mean value of 7.68.

Table 3 illustrates the results of intra-group comparison between Group A, Group B and Group C, at T_{0-}. The results suggest that there is a statistically significant difference from baseline to 3 week follow-up with p value <0.005 in all the three groups.

Table 4 represents the mean ranks of ICDAS II score of the three groups with no statistically significant difference, which means there was less room for any bias.

Table 1: Gender-wise distribution in various groups

	Female	Male	p Value
Group A	7	8	0.627
Group B	9	6	
Group C	8	7	
Total	24	21	

Table 2: Inter-group comparison among Fluoride group, Dicalcium Phosphate Dihydate groupand Nano-hydroxyapatite group at baseline (T0), 1 hour after intervention (T1) and 3 weeks (T2)after intervention.

		N	Mean	Std. Deviation	Std. Error	p value
DIAGNOdent Pen Assessment at T0	**Group A**	15	11.91	3.316	.856	.409
	Group B	15	10.85	3.180	.821	
	Group C	15	10.61	3.600	.929	
DIAGNOdent Pen Assessment at T1	**Group A**	15	10.713	3.4900	.9011	.663
	Group B	15	10.167	3.4330	.8864	
	Group C	15	9.733	3.6384	.9394	
DIAGNOdent Pen Assessment at T2	**Group A**	15	9.24	3.634	.938	.424
	Group B	15	8.85	3.638	.939	
	Group C	15	7.68	3.296	.851	

Table 3: Intra-group comparison of Group A - Fluoride, Group B - Dicalcium Phosphate Dihydrate and Group c - Nano-Hydroxyapatite

		Mean	Std. Deviation	p value
Group A	**T0 - T1**	1.1933	.6606	.000
	T1 - T2	1.4733	1.0640	.000
	T0 - T2	2.667	1.255	.000
Group B	**T0 - T1**	.6800	.6236	.001
	T1 - T2	1.3200	.7073	.000
	T0 - T2	2.000	1.004	.000
Group C	**T0 - T1**	.8733	.5092	.000
	T1 - T2	2.0533	1.5422	.000
	T0 - T2	2.927	1.528	.000

Table 4: ICDAS Score

	N	Mean Rank	Std. Deviation	Std. Error
Group A	15	20.50	.488	.126
Group B	15	25.00	.516	.133
Group C	15	23.50	.516	.133

Figure 1: DIAGNOdent pen (Kavo)

Figure 2: Mee Mee toothpaste containing dicalcium phosphate dehydrate

Figure 3: Dente 91 toothpaste containing nano-hydroxide

Figure 4: Pedifor kidz toothpaste containing 458 ppm fluoride

Figure 5: Initial White spot lesion

Figure 6: DIAGNOdent pen assessment of initial white spot lesions

Figure 7: Application of remineralizing toothpaste

Figure 8: After using remineralizing toothpaste

4. Discussion

White spot lesions (WSLs) are a common early sign of caries, indicating demineralization on the tooth surface. These chalky white spots can progress to cavitation if left untreated. White spot lesions in children, particularly those receiving orthodontic treatment, are increasing, necessitating early detection and prevention strategies to reduce caries incidence.[2,3]

In order to give dentists, epidemiologists, and researchers an evidence-based approach that would enable uniform caries detection and diagnosis in various settings and circumstances, the International Caries Detection and Assessment System (ICDAS) was created in 2002. However in 2005, ICDAS was modified to ICDAS II wherein The ICDAS detection codes for coronal caries range.[15]

Caries diagnosis is made possible by the consistent lesion detection and evaluation provided by ICDAS II. It offers precise and reliable in vivo and in vitro identification of early caries lesions at various stages,as seen in various studies.[16]

One of the recent diagnostic aids to detect initial white spot lesions is DIAGNOdent Pen by KaVo, a caries detection instrument (DIAGNOdent, KaVo, Biberach, Germany) was developed. DIAGNOdent uses a laser diode (655 nm, modulated, 1 mW peak power) as the excitation light source and a photo diode with a long pass filter (transmission > 680 nm) as the detector. An optical fiber transmits excitation light to the tooth, while a concentrically arranged bundle of 9 fibers detects it. The long pass filter filters short wavelength light while transmitting longer wavelength fluorescence rays. To filter outlong wavelength ambient light, the laser diode is modulated and only registers light with the same modulation characteristic.[17]

The DIAGNOdent Pen operates on laser fluorescence technology, emitting a specific wavelength of laser light onto the tooth surface which excites organic components like collagen and porphyrins within the tooth, prompting them to emit fluorescence. A sensor in the pen then detects this fluorescence, with the intensity correlating to the presence and severity of carious lesions. The device converts this intensity into a numerical value displayed on its screen, aiding dentists in quantitatively assessing decaylevels. Used alongside visual and tactile examinations, it helps detect early-stage lesions and monitor dental caries, enhancing diagnostic capabilities in dental practice. It gives a reading and audio feedback which is seen on the display.[18]

The DIAGNOdent pen is a valuable tool in detecting various types of dental caries, including occlusal, proximal, and smooth surface caries. Different tips or probe accessories are used with the DIAGNOdent pen to facilitate caries detection in these different areas of the mouth.[17]

Pediflor Kidz toothpaste (Group Pharmaceuticals Ltd. India), used in this study incorporates fluoride as a remineralizing agent for the first group. Remineralization using fluoride is a widely recognized method for reversing early stages of dental caries and strengthening tooth enamel. Fluoride strengthens tooth enamel, causes reversal of caries, reduces sensitivity, it is cost effective and non-invasive. But, due to the dose-dependent relationship of fluorides and raising health concerns, many parents attempt to avoid fluoride whenever feasible due to worries mostly related to safety issues. Exposure to high levels of F over a long period causes damage to osseous tissue, which results in dental and skeletal fluorosis. Fluoride also alters the thyroid hormone levels by interfering with the activity of de-iodinase enzyme which catalyzes the de- iodination of T4 to T3.[5,6,7,8,10,11,12,13,14,15,16,17,18,19]

In the second group, toothpaste used in this is study was Mee Mee Toothpaste (Mee Mee, India), containing DCPD as remineralizing agent. Remineralization using DCPD is an emerging approach in dental care that shows promise in promoting enamel remineralization and preventing tooth decay. DCPD enhances remineralization of enamel by providing source of calcium and phosphate ions, which is essential for rebuilding the mineral structure. It has low solubility in acidic environments, is bio- compatible and can be optimized to achieve specific mineralisation goals.[20]

The third toothpaste used in the present study was, Dente 91 Toothpaste (Frimline Private Limited, India) containing Nano- hydroxyapatite crystals as remineralizing agent. Remineralization using nano- hydroxyapatite (nHA) is a promising approach in dental care for repairing early enamel lesions and preventing dental caries. nHA is bio-compatible,

it has high remineralization efficacy, strengthens enamel, reduce sensitivity and can be incorporated into various dental formulations, including toothpaste, mouth rinses, varnishes and dental fillings to promote remineralization.[21]

The current study included 45 patients between the age of 7-12 years, and were randomly divided into three groups. three commercially available toothpastes containing fluoride, DCPD and Nano- Hydroxyapatite as remineralizing agents on white spot lesions were used. DIAGNOdent Pen values were taken at three time intervals that were, baseline (T_0), One hour after application of toothpaste (T_1) and after 3 weeks (T_2).

Table 2 presents the results of inter-group comparison of the three commercially available tooth pastes containing Fluoride in Group A, Dicalcium Phosphate Dihydrate in Group B and Nano- hydroxyapatite in Group C. According to the findings of this study, there is no statistically significant difference in the remineralizing potential of the three toothpastes. However the mean difference in the DIAGNOdent Pen assessment at 3 week follow-up (T2) suggests that group C i.e., Nano- hydroxyapatite group is better in reducing the demineralization within 3 weeks' time.

In a study conducted by Grewal N, Sharma N, Kaur N in 2018, Nano-hydroxyapatite exhibited highest remineralization potential in terms of mineral gain followed by amine fluoride and sodium monofluorophosphate dentifrice.,[22] similar to a study conducted by Vijayasankari V, Srinivasan, MR, Shanthi, V in 2019, w h o concluded that commercially available nHAP have the potential to remineralise artificially induced carious lesions.[23]

Table 3 illustrates the results of intra-group comparison between group A, group B and Group C,at T_0-T_1, T_1- T_2 and T_0-T_2. The results suggest that there is a statistically significant difference from baseline to 3 week follow-up with p value <0.005 in all 3 groups.

These results were in congruence with a study conducted by Amaechi BT in 2019, who concluded that 10% hydroxyapatite achieved comparable efficacy with 500 ppm F− in remineralizing initial caries and preventing demineralization.[4]

5. Conclusion

Dental caries is a global health concern, influenced by factors like diet and oral hygiene. Early detectionand management are crucial for preserving dental health. The DIAGNOdent Pen, using laser fluorescence technology, can detect and monitor caries activity. Our study assessed toothpastes with fluoride, DCPD, and nano-hydroxyapatite crystals. Nano-hydroxyapatite toothpaste showed better results in remineralization of initial white spot lesions over a three-week period. Further research is needed to explore long-term effects and clinical implications.

6. Sources of Funding

None.

7. Conflict of Interest

None.

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