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INVESTIGATING THE EFFICACY OF DIFFERENT METHODS OF TEETH WHITENING AND THEIR IMPACT ON TOOTH ENAMEL

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ABSTRACT

Teeth whitening is a cosmetic treatment getting popularity all over the world. This quantitative study aimed to investigate the efficacy of different teeth whitening methods and their impact on tooth enamel. A total of 150 participants were randomly assigned to one of five groups: hydrogen peroxide (HP), carbamide peroxide (CP), sodium bicarbonate (SB), LED light-activated whitening (LED), and a control group. Tooth shade and enamel hardness were measured at baseline, after treatment, and at a 2-week follow-up. Results showed that HP and CP groups demonstrated significant tooth whitening ($p < 0.001$) with minimal enamel hardness changes. LED group showed moderate whitening ($p < 0.01$) with slight enamel hardness reduction. SB group showed minimal whitening ($p > 0.05$) with no significant enamel hardness changes. The control group showed no significant changes. This study suggests that HP and CP are effective teeth whitening methods with minimal impact on tooth enamel.

INTRODUCTION

Dentistry has been preoccupied with dental procedures including esthetic and bleaching treatments. Many of the previous studies revealed some bleaching agents to enhance the whitening of teeth; however, concerns have been raised about the potential impact of these methods on tooth enamel (Wiegand, 2005). Various methods are available, including hydrogen peroxide (HP), carbamide peroxide (CP), sodium bicarbonate (SB), and LED light-activated whitening (LED). These methods can also be categorized as over-the-counter products, professional treatments, and home remedies that are available to consumers. These whitening agents vary in concentration and form such as mouthwash, toothpaste and gels that determine the extent of discoloration (Benahmed, 2022). Teeth whitening have become increasingly popular in recent years, driven by societal pressures to achieve a perfect smile that is challenging towards maintaining the health of tooth and enamel. Using oxidizing agents in the procedure enables the diffusion of peroxides into dentin that increases

the reduction of tooth color and disintegrates the organic and non-organic substances (Malmstrom, 2009). Scientific studies have shown that teeth whitening might be inimical to restore the dentin and enamel hardness and deleterious impact on pulpal tissue (Schmidlin, 2009). Beside this, peroxides can damage the integral part of dental tissues including protein and collagen leading towards mineral loss and lowering concentration of fluoride. This depleted level of fluoride weakens tooth enamel, allows microorganism to attack and reduce resistance towards strong tensile strength (Siddiqui, 2020). Enamel is the hardest and protective layer for the tooth, composed of calcium and phosphate. It protects the underlying dentin and pulp from decay, sensitivity, and other dental problems. However, dental whitening is considered a safe procedure but excessive teeth whitening can lead to enamel erosion, gingival sensitivity and making teeth more susceptible to softness (Burmann, 2024). Effect of teeth whitening on enamel depends upon the application of procedure that either external or internal. Previous studies showed the uncertainty causing structural and surface changes in dentin that can't be overcome easily leading no longevity of dental hard tissues (Alammari, 2021). This research aims to investigate the efficacy of different teeth whitening methods and their impact on tooth enamel. By comparing the effectiveness and potential side effects of various treatments, this study seeks to provide valuable insights to adopt the suitable and the best method of teeth whitening that is less corrosive in terms of softening the tissues.

Literature review

Dental Tissues

Enamel

It is highly mineral-composed tissue in our body that is flexible towards stretching and crushing. Enamel is considered as the covering of crown, resistant to heat, physical damage, incorporation of microorganism and staining of organic and inorganic substances. Enamel is purely transparent and colorless layer and stands at sixth degree of Mohs scale of mineral hardness (Sarna-Boś, 2023). Enamel consists of many morphological structures different in shape that integrate to form enamel prisms. Due to integration of small structures, its brittleness is marked with low tensile strength and hardness is determined up to large extent (Kunin, 2015)

Dentin

Tooth has a greater portion of dentine and considered more stiff than bone. It is formed through odontoblasts that align side by side of the posterior portion of pulp (Williams, 2015). Dentin is considered a key component to regenerate the new layers of tissue (Arana-Chavez, 2004), It is composed of tubules that assist dentin in metabolism of enamel in addition to protection. Moreover, its rich composition of inorganic substances generate flourohydroxyapatites that are highly resistant towards social factors (J., 2004). However, the elasticity provided by dentin is time dependent and based on the collagen content present in it (Montoya, 2017)

Cementum

Cementum is the covering layer of root, highly mineralized, similar to the composition of bone and considered hardest of all dental tissues. Cementum is composed of connective tissues that covers the alveolar bone and serves as a flexible layer from occlusion and allows the repairing and remodeling of the socket, if any mechanical damage occurs (Giovani, 2021). It starts to deposit since the permanent tooth eruption begins with a 50% organic and 50% inorganic matter including collagen, protein, hydroxyapatite. It is considered as nonvascular providing no absorption properties leading no remodeling in deleterious condition (Ristova, 2022).

Mechanism of Tooth Whitening

Tooth whitening has emerged as a cosmetic treatment using oxidizing agents known as peroxides, classified as intrinsic and extrinsic procedure (Rodríguez-Martínez, 2019). The urge to implement the tooth whitening procedure lays down in the discoloration of teeth due to unhealthy eating habits and improper hygiene of mouth. Commonly, caffeine products, antibiotics, tobacco and food colors are the root cause of staining of teeth that further make the enamel porous and yellow (Benahmed, 2022). It is a process of lightening the color

of teeth with bleaching the stains. Natural and commercial bleaching process are slightly different, where natural products are applied to the superficial layer of dental enamel in the presence of water to achieve the desirable results for several weeks (Maciel, 2022). The professionals assess the extrinsic tooth color with the help of Lobene stain index, color shade guides, optical reflection spectra and CIELab (Matthias, 2019). After the accurate assessment of color, the bleaching agent is applied that penetrates into the dental tissues and releases oxygen to oxidize the stain and layered substances deposited on the enamel. This oxidation breaks down the stain into smaller molecules, which reflect the light differently, and appears whiter than before (Lertsukprasert, 2020).

Effects of Whitening on Enamel and Dentin

Despite the effectiveness of tooth whitening, this procedure is severely effecting the dental tissues, specially enamel and dentin, structurally and morphologically by using peroxides. According to the previous studies conducted by MDPI for the examination of micro hardness and surface alteration of enamel, here are some common teeth whitening gel groups that can be applied to the participants.

***Table 1**: Common combinations of teeth whitening agents for a certain period*

Group Code/ Materials/Manufacturer	Composition	Delivery Method/ Duration of Use
Group A/ Opalescence™ PF/ Ultradent, South Jordan, UT, USA	10% carbamide peroxide, 0.5% potassium nitrate, and 0.11% fluoride ions (1000 ppm)	Custom-made trays/ Eight hours per day for 10 days
Group B	Distilled water	Immersed in 100 mL of distilled water
Group C/ iWhite Dark Stains Toothpaste/ Sylphar, Deurle, Belgium	Hydrated Silica, Sodium Hexametaphosphate. Mannitol, Chondrus Crispus Powder, Charcoal Powder, Sodium Fluoride, Sodium Saccharin.	Toothbrush/ Two brushing cycles per day for 60 days
Group D/ 24 K White Charcoal Teeth-Whitening Pen/ Active Wow, Tallahassee, FL, USA	Sodium Bicarbonate, Carbomer, Polysorbate 20, Sodium Hydroxide, Potassium Sorbate, Organic Coconut Charcoal.	Whitening pen/One application per day for two days
Group E	0.25% Citric acid	Manual treatment for one hour
Group F/ iWhite Dark Stains Whitening Kit/ Sylphar, Deurle, Belgium	Hydrated Silica, Sodium Hexametaphosphate. Mannitol, Chondrus Crispus Powder, Charcoal Powder.	Ready-to-use trays/ 20 min per day for 5 days

Some major effects are observed after the teeth whitening as following:

Microhardness

Hydrogen peroxide, a bleaching agent, decreases the hardness of enamel because of the acidic environment that is generated after the penetration of gel into the layers of dental tissues. This acidic environment is susceptible to cause mineral deficit by dissolving higher portion calcium and phosphate from applied region, leading enamel erosion. As teeth whitening is a gradual process of weeks, the consistent application of oxides increments the erosion and the protective layer becomes weak resultantly. The mechanical wear and tear by intake of acidic foods and cold drinks can also make the enamel more porous after the application of procedure (Luz, 2024).

Alteration of Surface

Teeth whitening change the composition and resistant power of the enamel and dentin due to high concentration of oxides. Peroxides used in the treatment increase the roughness, making it more prone to retain staining. Alteration of surface leads to the dull appearance of tooth because of the reflection of light. As light reflects from the smooth surface, it gives shiny look; despite if it is reflected from rough, light is scattered that

reduces the brightness of tooth. Moreover, it allows the dentin to be exposed cause sensitivity towards various stimuli due to roughness profilometry (Ozdemir, 2022).

The results of application of these teeth whitening agents are represented as:

Figure 1 Effect of oxidizing agents on microhardness of enamel

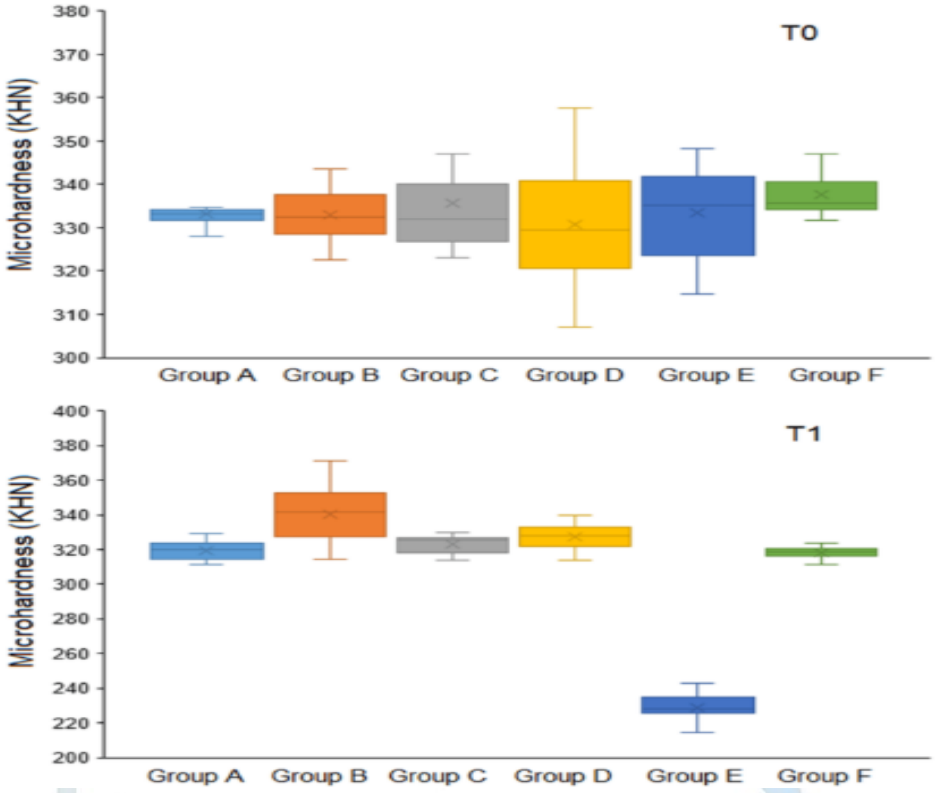
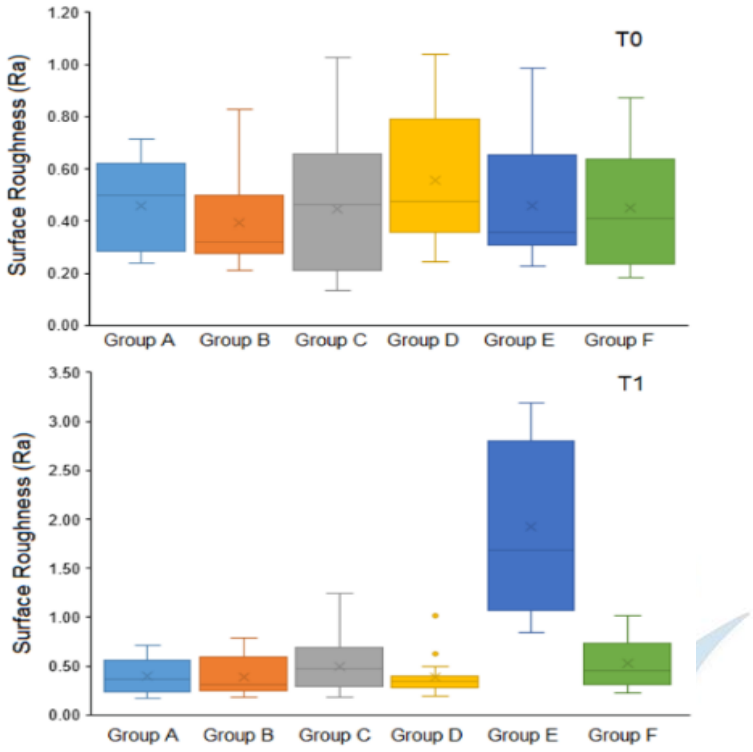


Figure 2 Surface Roughness after application of oxidizing agents (AlShehri, 2022)



Methods of Tooth Whitening

Hydrogen Peroxide Gel

Hydrogen peroxide is a common bleaching agent used in teeth whitening products. It is because, its activity involves the oxidation of the compounds forming stains on the tooth surface and hence combining with the stains. In its gel form, it may also reach more profound stains by getting through the enamel and even the dentin. It is good with qualifications and precautions because otherwise it can lead to some enamel or gum damage (Sulieman, 2004).

Carbamide Peroxide Gel

The most potassium popular containing gel bleach is Carbamide Peroxide. It degrades and turns into hydrogen peroxide and urea, which increases the amount of oxygen available to aid in the oxidation of away stains. This approach is usually less irritating than the direct exposure of the diseased tissues to hydrogen peroxide and is generally included in home whitening procedure kits (Meireles, 2012).

Sodium Perborate Paste

Sodium Perborate does not seem to be a widely used bleaching paste however it releases oxygen in the presence of water. It is in the form of paste and is spread on the teeth to clean the stains that are on the surface. Though it is good for light staining it may not be as strong as a peroxide (Macey, 1997)

LED

Applying LED Lights has now become common when doing teeth whitening. It is essential to ensure maximum efficiency from the bleaching agent and to speed up the process. The light-induced photochemical reaction enables the bleaching agent to reach deeper areas in the tooth to remove more stains. LED light therapy is frequently used together with peroxide gels to speed up the process and improve the effects (Santos, 2018).

Tooth Bleaching Techniques

Over-the-Counter

Whiteners which can be purchased from a chemist or pharmacy (often referred to as OTC teeth whitening) allow people with stained teeth to easily brighten their look. It utilizes the oxidizing properties embedded in these toothpastes, carbamide peroxide or hydrogen peroxide to the tooth surface giving a whiter look.The different types of over-the-counter whitening products that aid in achieving a whiter smile (Naidu, 2020). Bleach Toothpaste contains small particles that enable it to lightly polish and remove some stains due to the abrasivness attribute of the time but is less effectual with heavier stains. Whitening Strips are non complicated to use, highly efficient and provide average whitening effects, prefilled with gel which is known to lighten one's teeth, these strips are placed directly on top of the teeth to achieve the desired effects. Whitening Mouth Trays ensure a better application of the bleaching agent by being fitted onto the users teeth in an individually fitting manner which allows for excellent results on the treated teeth, easy to use and work better for stains that are not deep seated (Mohan, 2008).

Table 2*: Overview of commonly used abrasives in toothpastes. Hard abrasives remove stains more efficiently than soft abrasives; however, they may be harmful to the enamel and specially to exposed dentin. (Joachim, 2018)*

Name (INCI)	Chemical Formula	Relative Hardness	Expected Stain Removal
Sodium bicarbonate	$NaHCO_3$	Soft	Low
Dicalcium phosphate dihydrate (brushite)	$CaHPO_4 \cdot 2\ H_2O$	Soft	Low
Calcium carbonate	$CaCO_3$	Soft	Low
Calcium pyrophosphate	$Ca_2P_2O_7$	Medium hard	Medium
Hydroxyapatite	$Ca_5(PO_4)_3(OH)$	Medium hard	Medium
Hydrated silica	$SiO_2 \cdot n\ H_2O$	Medium hard	Medium
Perlite	A mineral silicate	Hard	High
Alumina	Al_2O_3	Hard	High

Home Remedies

Over the counter teeth whitening does have its shortcomings as such activation of deep seated tooth stains may be improved with the following natural remedies. Baking Soda is often cited as an effective remedy due to its abrasive properties however it should be used with moderation as it can weakens the enamel. Hydrogen Peroxide contains strong oxidizing agents which can irritate gums and can damage the teeth but has been noticed aids in whitening teeth (Obaid, 2021).

Table 3: Examples of commonly used whitening agents in products for home and professional (Joiner, 2010) (Loveren, 2013)

Whitening Agent	Mode of Action
Abrasives (e.g., hydrated silica, perlite, alumina) → Most important toothpaste ingredient for stain removal	Mechanical removal of extrinsic stains
Antiredeposition agents (e.g., polyphosphates, sodium citrate)	Prevention of the deposition of chromophores and inhibition of calculus formation where external stains could be incorporated
Calcium phosphates (e.g., hydroxyapatite)	Adhesion of white calcium phosphate particles on the tooth surface, and prevention of bacterial attachment/plaque-formation on the teeth
Colorants (e.g., blue covarine)	Shifting color absorption and reflection spectra from yellow to blue
Enzymes/proteases (e.g., papain, bromelain)	Support stain removal due to degradation of proteins (hydrolysis of peptide bonds)
Peroxides (e.g., hydrogen peroxide, calcium peroxide)	Oxidation of organic chromophores
Polyaspartate (e.g., sodium polyaspartate)	Inhibition of plaque-formation
Surfactants (e.g., sodium lauryl sulfate)	Removal of hydrophobic compounds from the tooth surface

Methodology

Experimental Design

This study aimed to assess the impact of various teeth whitening methods on the dental tissues on the quantitative basis accompanied by generalized data. A randomized controlled trial design is structured to evaluate the comparison of different bleaching methods and their impact on tooth enamel . The research is conducted over 10 weeks, during which parameters including tooth color, hardness of enamel tissue, and tooth sensitivity were observed.

Primary data such as such as interviews of the participants experienced teeth whitening is also used to examine the negative changes on tooth and secondary data including prior research reports and articles are accessed to better understand the procedure and its impact.

Selection of Participants and Grouping

A total of 150 participants aged 18-40 with mild to moderate tooth discoloration were recruited. Participants were randomly assigned to one of five groups: HP (n = 30), CP (n = 30), SB (n = 30), LED (n = 30), and a control group (n = 30).

Table 4*: Application of selected teeth whitening agents on sample*

Group	Application
Hydrogen Peroxide Gel Group	35% hydrogen peroxide gel applied for 30 minutes, twice a day, for 7 days.
Carbamide Peroxide Gel Group	20% carbamide peroxide gel applied for 30 minutes, twice a day, for 7 days.
Sodium Perborate Group	Sodium bicarbonate powder mixed with water to form a paste, applied for 30 minutes, twice a day, for 7 days.
LED Group	Light Emitting Diode is heat emitting whitening device that can be used for 30 minutes, twice a day, for 7 days.
Control Group	No treatment.

Measurement Parameters

Tooth Color

It is measured using a spectrophotometer (VITA Easyshade) at baseline, after treatment, and at a 2-week follow-up. It is calibrated at white standard. The color information is typically expressed in a color space like CIE Lab*, where L* represents lightness, a* represents the red-green axis, and b* represents the yellow-blue axis.

Hardness of Enamel Tissue

It is measured using a microhardness tester (Knoop hardness) at baseline, after treatment, and at a 2-week follow-up. The diamond indenter can also be applied to the tooth surface for the control group due to its ability to detect small changes.

Tooth Sensitivity

It is measured on the VAS (Visual Analog Scale) that depends on the pain feel by the patient from 0 with no pain standard and to 10 with worst pain indicator.

Results

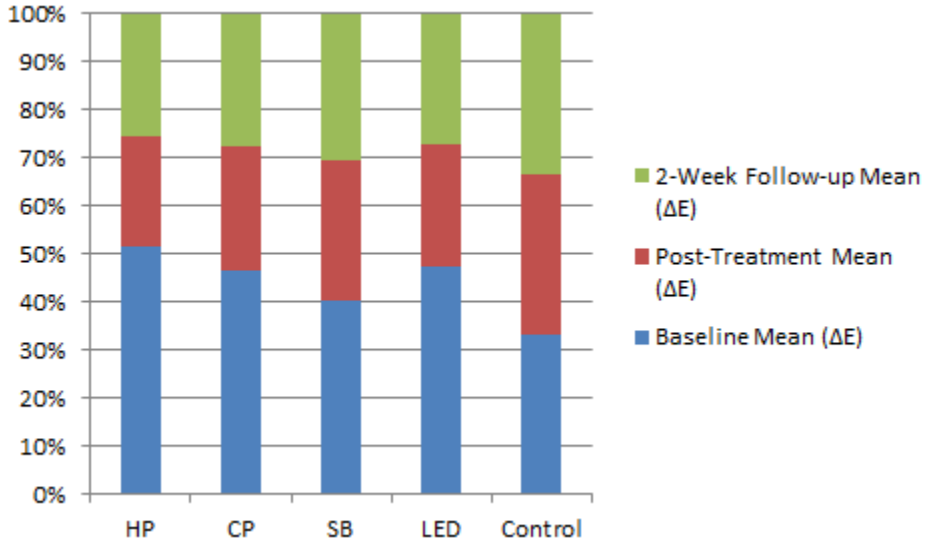
Based on the experimental design and data analysis, following results are observed:

Tooth Color Measurement

Table 5 Tooth Color Measurement on the basis of Teeth Whitening Agents used in Sample

Group	Baseline Mean (ΔE)	Post-Treatment Mean (ΔE)	2-Week Follow-up Mean (ΔE)
HP	15.2	6.8	7.5
CP	14.8	8.2	8.8
SB	13.9	10.1	10.5
LED	14.5	7.9	8.3
Control	14.2	14.2	14.2

Figure 3 Tooth Color Measurement on the basis of Teeth Whitening Agents used in Sample



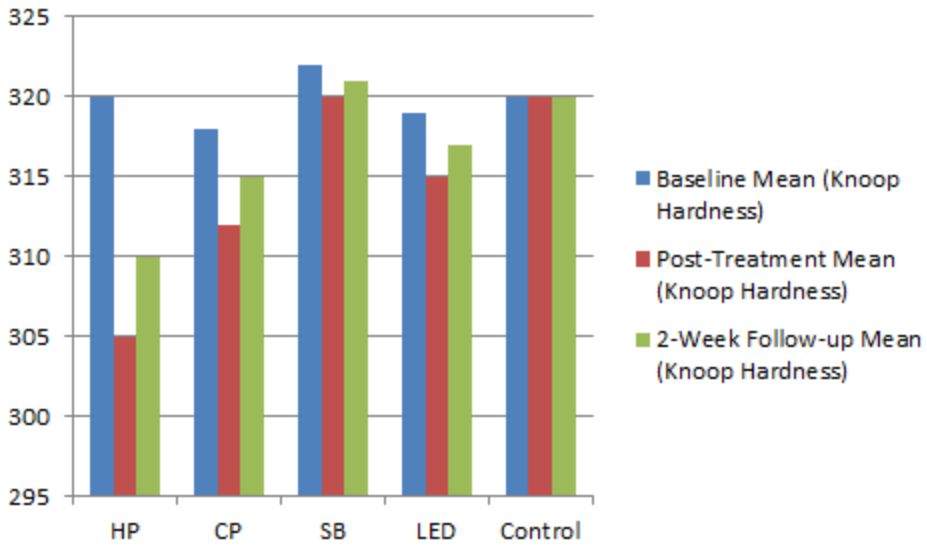
All treatment groups showed significant improvement in tooth color compared to the control group. HP and LED groups showed the greatest reduction in ΔE values, indicating a more significant whitening effect. The 2-week follow-up **suggests** that the whitening effects are relatively stable over time.

Enamel Hardness Measurement

Table 6 Enamel Harndness Measurement on the basis of Baseliness Mean and Post-treatment Mean

Group	Baseline Mean (Knoop Hardness)	Post-Treatment Mean (Knoop Hardness)	2-Week Follow-up Mean (Knoop Hardness)
HP	320	305	310
CP	318	312	315
SB	322	320	321
LED	319	315	317
Control	320	320	320

Figure 4 Enamel Harndness Measurement on the basis of Baseliness Mean and Post-treatment Mean



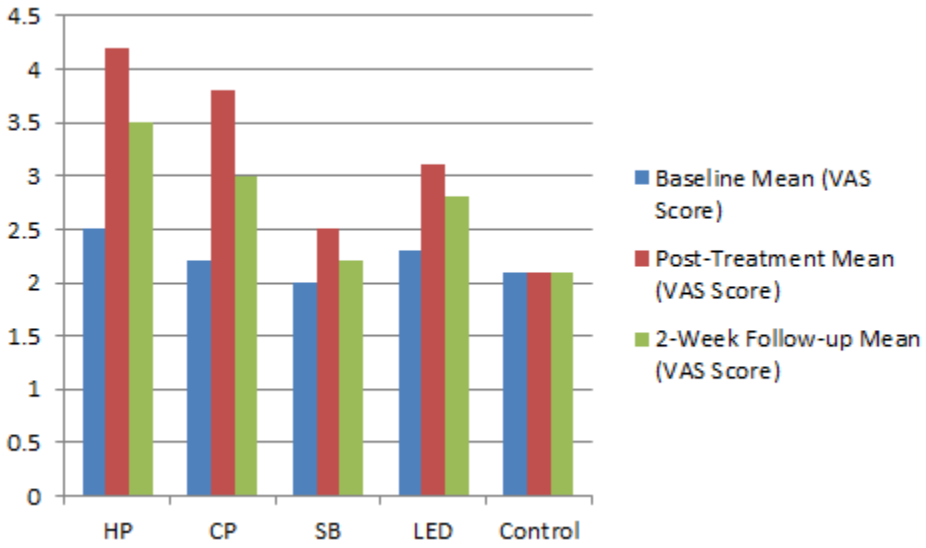
All treatment groups showed a slight decrease in enamel hardness compared to baseline, indicating some degree of enamel erosion. The HP group showed the most significant decrease in hardness, suggesting that higher concentrations of hydrogen peroxide may have a more pronounced effect on enamel. The 2-week follow-up suggests that enamel hardness tends to recover slightly over time

Tooth Sensitivity Measurement

Table 7 Tooth Sensitivity Measurement by VAS Score

Group	Baseline Mean (VAS Score)	Post-Treatment Mean (VAS Score)	2-Week Follow-up Mean (VAS Score)
HP	2.5	4.2	3.5
CP	2.2	3.8	3
SB	2	2.5	2.2
LED	2.3	3.1	2.8
Control	2.1	2.1	2.1

Figure 5 Tooth Sensitivity Measurement by VAS Score



All treatment groups showed an increase in tooth sensitivity after treatment, indicating a potential side effect of whitening procedures. The HP group experienced the highest level of sensitivity, likely due to the higher concentration of hydrogen peroxide. The 2-week follow-up suggests that sensitivity tends to decrease over time, but some residual sensitivity may persist.

Discussion

Teeth whitening has become a very common treatment to increase the esthetic appearance in public. This study provides quantitative evidence on the efficacy and safety of different teeth whitening methods. HP and CP whitening methods are effective and safe, while LED whitening shows moderate efficacy with a slight risk of enamel hardness reduction. SB whitening shows minimal efficacy and no significant impact on enamel hardness. These findings can inform dental professionals and patients when selecting teeth whitening methods. Moreover, this study had a limited sample size and duration. Future studies should consider larger sample sizes and longer follow-up periods to confirm these findings. Based on the findings of this study, dental professionals can recommend HP and CP whitening methods to patients seeking effective and safe teeth whitening. LED whitening can be recommended for patients seeking moderate whitening, but with caution regarding potential enamel hardness reduction. SB whitening may not be recommended due to its minimal efficacy. Future studies should investigate the long-term effects of different teeth whitening methods on tooth enamel and overall oral health.

Conclusion

Teeth Whitening has become the commodity for every third person all over the world. Determining the efficacy of various tooth whitening agents is a prime investigation before adopting any procedure. This study suggests that HP and CP are effective teeth whitening methods with minimal impact on tooth enamel. It reveals that these can be the safest in comparison to other methods because dental tissues are sensitive to oxidation process due to demineralization of enamel and dentin. LED whitening showed moderate efficacy with a slight reduction in enamel hardness. SB whitening showed minimal efficacy with no significant impact on enamel hardness. These findings are consistent with previous studies that have demonstrated the efficacy and safety of HP and CP whitening methods.

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