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EFFECTS OF PIEZO - CATALYSIS FOR TOOTH WHITENING - A REVIEW

APURVA CHOUDHARY[1], BALAJI GANESH S[2*] AND SMILINE GIRIJA AS[3]

1: Research Associate, Saveetha Dental College, Saveetha Institute of Medical and Technical Science, Saveetha University, Chennai.

2: Scientist, White Lab- Materials Research Centre, Saveetha Dental College, Saveetha Institute of Medical and Technical Science, Saveetha University, Chennai 77

3: Associate Professor, Department of Microbiology, Saveetha Dental College, Saveetha Institute of Medical and Technical Science, Saveetha University, Chennai 77

***Corresponding Author: E Mail: Dr. Balaji Ganesh S: balajiganeshs.sdc@saveetha.com**

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ABSTRACT

The increasing demand for a whiter smile has resulted in an increased popularity for tooth whitening procedures. Fastest growing aesthetic dentistry procedure is tooth whitening. This review demonstrates that the piezo catalysis based on tooth whitening via BTO (Barium titanate) nanoparticles is non destructive to the tooth enamel and biocompatible without cytotoxicity as compared to other clinical whitening agents. This review demonstrates that the piezo -catalysis based tooth whitening via BTO nanoparticles is non destructive to the tooth enamel and biocompatible without cytotoxicity as compared to other clinical whitening agents. Piezo-catalysis tooth whitening has the ability to be widely adopted for home use, without requiring significant investment. It can also be used in clinical aspects. The review article concludes that piezo - catalysis effects based tooth whitening method can replace traditional abrasive in the toothpaste and to generate reactive oxygen species via piezo - catalysis to bleach tooth stains.

Keywords: Piezo catalysis; Tooth whitening; Nanoparticles

INTRODUCTION

People are eager to improve their appearance with a whiter smile with the development of the aesthetic standard. Fastest growing aesthetic dentistry procedure is tooth whitening **[1]**. Due to the various factors such as tobacco use, drug ingestion, eating dark fruits, consumption of vinegars causes discolouration and staining of teeth **[2]**. One study demonstrated that tooth stain can be whitened after root canal **[3]** and cleaning and shaping **[4]**. There are several common methods for tooth whitening, such as professional cleaning and polishing, coverage with crowns or veneers, daily tooth brushing with the help of abrasive toothpaste and bleaching **[5]**. These all techniques are expensive and time consuming **[6]**. Lightening tooth color can be done by a wide variety of bleaching methods, including in-office (professionally administered), at-home (professionally dispensed) and over-the-counter (self-administered) techniques. Home bleaching techniques require more procedural time and cannot be well controlled due to their mode of administration. The main advantages of in-office bleaching technique includes dentist control, avoidance of tissue exposure, reduced treatment time and enhanced patient satisfaction due to immediate results. Since 1910, Power bleaching has been performed using varying hydrogen peroxide activation techniques **[7]**. Serious concerns have been stated concerning the safety of conventional hydrogen peroxide- containing bleaching products, including enamel surface alterations including minute depressions, porosities and slight erosive defects following scanning electron microscopic evaluations. Considering the fact that pH of different brands of bleaching gels vary greatly, it is stated that in a laboratory setting hydrogen peroxide solution (pH=6.4) is able to remove mineral contents of enamel, although the critical pH for enamel demineralization has been considered to be between 5.2 and 5.8 **[8]**. Laser-assisted bleaching uses laser beams to accelerate release of free radicals within the bleaching gel to decrease time of whitening procedure. Lasing is also capable of minimizing post-bleaching hypersensitivity, loss of enamel microhardness and gingival irritation due to lack of hydrogen peroxide use. Decreased chair time can also be anticipated following laser use. Many authors have indicated that light energy does not have any clinical influence on tooth whitening **[9]**. Calcium phosphate with bioactive glass can be used in tooth bleaching **[10]** and GIC barrier in non

vital tooth bleaching **[11]**. Bleaching options are there for calcified canal **[12]**. Bleaching agents may increase the matrix metalloproteinases mediated collagen degradation in dentin **[13]**. Bleaching can have some effects in pulp vitality **[14]**. Veneers are one of the esthetics options available **[15]**. There are various different treatments in tooth whitening **[16]**. And dental practitioners are aware of that **[17]**.

One study demonstrated that the piezoelectric effect is the electric charge that accumulates in solid materials and responses to the mechanical stress **[18]**. Piezoelectric materials are ultra sensitive to mechanical vibration, water flow, muscle movement and can induce electric changes **[19]**. Since it has the ability to convert mechanical stimuli into electrical signals. Piezoelectric materials can be used as catalysers, which can be called piezo catalysis or melchano- catalysis **[20]**. Classical piezoelectric materials such as ZnO, $BaTiO_3$ and $BiFeO_3$ can be demonstrated as efficient piezo- catalysis **[21]**. The effects of piezo -catalysis is similar to photo catalysis, it is based on photo induced charges rather than mechanically induced charges. The aim of review is to analyse the effects of piezo -catalysis for tooth whitening.

Tooth whitening

Tooth whitening is a form of treatment and it is a part of a comprehensive treatment plan, tooth whitening methods are safe and effective **[22]**. Tooth whitening methods include the use of abrasive products to remove external stains. The mineral phase of human teeth consists of calcium phosphate in the form of hydroxyapatite **[23]**. The original colour of pure hydroxyapatite is colourless white. Naturally enamel has white colour with some translucency. Due to continuous chemical and mechanical factors, enamel will become thinner and translucent due to that dentin will become more visible and the overall tooth colour will become darker **[24]**. The most classic hydrogen peroxide- based whitening agents are effective, but this can lead to enamel demineralisation, cytotoxicity. Piezo- catalysis techniques are harmless and convenient tooth whitening strategy by replacement by abrasives traditionally used in toothpaste with piezoelectric particles. Since electrical charges can be induced by mechanical vibration, piezoelectric materials have also been employed as catalysers, termed as piezo-catalysis or mechano-catalysis.

The piezoelectric effect, discovered in 1880 by brothers Pierre Curie and Jacques Curie, is the electric charge that accumulates in

certain solid materials with non-centrosymmetric structure in response to mechanical stress. With the ability to convert mechanical stimuli into electrical signals, or vice versa, piezoelectric materials have been widely used for sensors, transducers, actuators, and energy harvesters for self-powered devices. Some piezoelectric materials such as ZnO, BaTiO3 are efficient piezo catalysts and can be used in daily toothbrush, a nondestructive and safe tooth whitening strategy based on the piezo-catalysis effect, easily realized by replacement of abrasives with piezoelectric nano-particles. One study demonstrated the chlorhexidine causes staining of teeth **[25, 26]** and natural extract can also be used in future and can be used to remove the tooth stain **[27]**. Discoloration of teeth is one of the problems in cases of avulsion **[28]**.

Working principle

When toothbrush and teeth come in contact during tooth brushing, there will be mechanical vibration between them as shown in **Figure (1a)**. The traditional abrasive-based toothpaste method, where tooth whitening is realized by the mechanical friction between teeth and abrasive **Figure (1b)**. There will be proposed piezo -catalysis effect based tooth whitening method wherein piezoelectric particles replace traditional abrasive in the toothpaste, to generate reactive oxygen species via piezo- catalysis to bleach tooth stains in **Figure (1c)**. There will be original electrostatic poled piezoelectric materials in **Figure (1d)**, the release of screening charges under compressive stress, which combine with water molecules and then produce reactive species in **Figure (1e)**. This will cause modified electrostatic balance states under maximum compressive stress in **Figure (1f)**. At last in **Figure (1g)**, there will be adsorption of charges from the surrounding electrolyte under reduced compressive stress **[29]**. The charges in the electrolyte with opposite popularity to the adsorbed charges will participate in the redox reaction to produce reactive species **[30]**. This will cause the removal of the removal of stain.

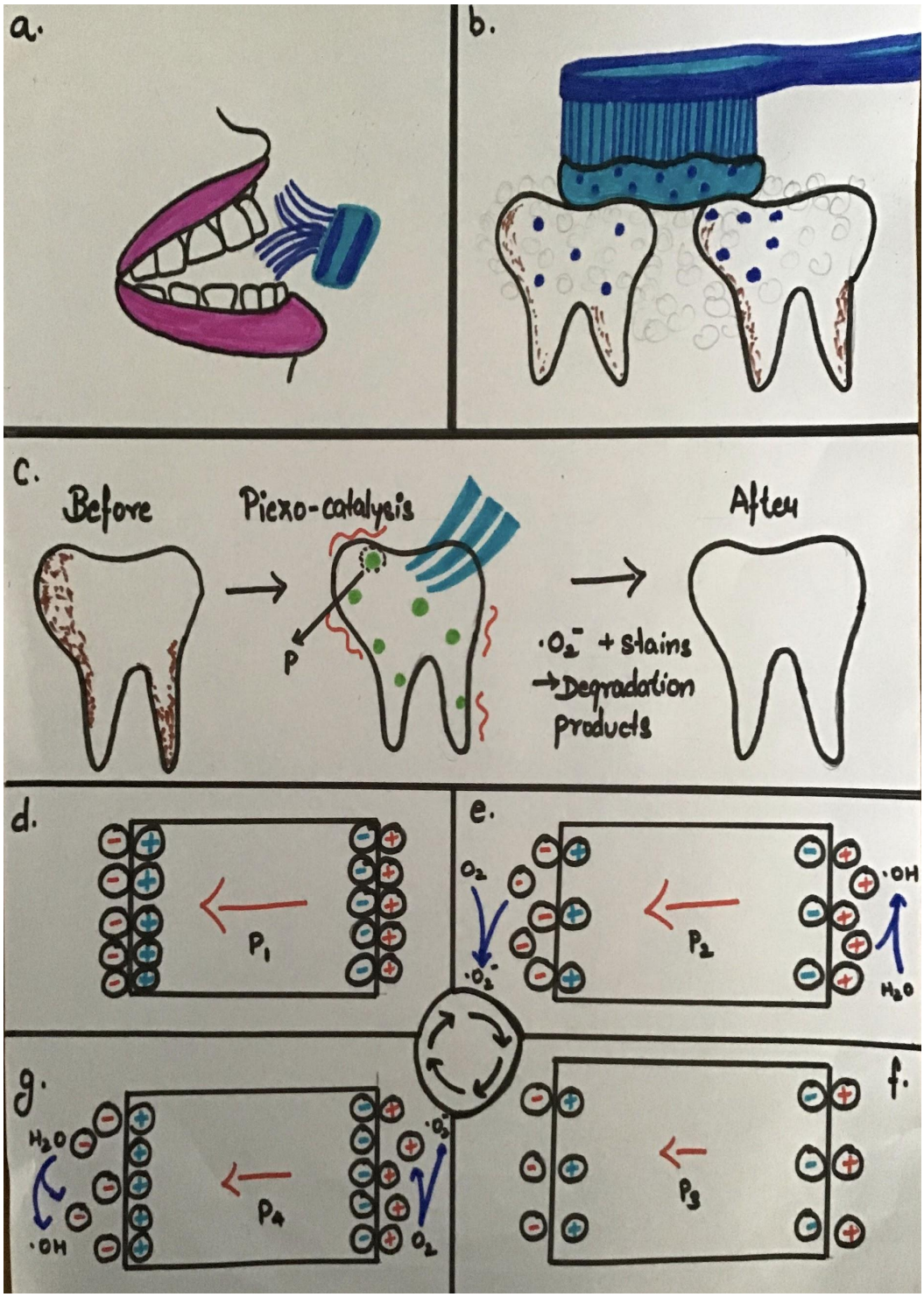

Figure 1: Working Principle of Tooth Whitening

Tooth whitening based on piezo - catalysis

Previous article described about tooth whitening using poled BTO nanoparticles **[31]**. It is noted that the tooth whitening effect under constant vibration was more than that under discontinuous vibration. The concentration of BTO nanoparticles will decrease in the discontinuous vibration process. Piezo- catalysis based tooth whitening has been demonstrated using both ultrasonic excitation and with more traditional, commercial electric toothbrush. As such, this technique can accelerate the tooth whitening relative to the traditional mechanical friction of abrasive based toothpastes alone.

The reactive species produced by BTO nanoparticles oxidise the multiple conjugated double bonding of large organic molecules and convert into smaller compounds that is tooth whitening **[32]**.

Degradation based on piezo -catalysis

Indigo carmine can be degraded by piezo - catalysis. Indigo Carmine is a common good colorant used in juice drinks, carbonated beverages, and plays a key role in tooth staining **[33]**. The ultrasonic vibration was used to stimulate the mechanical stimuli during regular tooth brushing. It is evaluated that the piezo- catalysis performance of BTO nanoparticles can degrade the Indigo Carmine in aqueous solutions. The degradation of Indigo carmine via pole and unpole nanoparticles can be identified by its wavelength, vibration time and magnetic field.

The structural stability of nano- sized BTO also serves as the degradation of organic dye. The piezoelectricity dependence of degradation of organic dyes can also be understood by a series of chemical reactions.

Piezo -particles + vibration -> Piezo- particles ($q^- + q^+$)

$$q^- + O_2 - .O_2^-$$

$$q^+ + H_2O - .OH$$

$$O_2^- + \text{Organic dye} - \text{Degradation products}$$

Non destructive and harmless nature of piezo - catalysis

Piezo catalysis based tooth whitening is non destructive to enamel. The biocompatibility of piezo catalysis was evaluated using the MTT method **[34]**. The BTO nanoparticles were confirmed as biocompatible, since the

cells showed no charges with time and there is no difference relative to the control.

The cytotoxicity demonstrates the BTO nanoparticles are biologically safe and piezo-catalytic tooth whitening procedure is harmless **[35]**. Additionally the possibility of leakage during vibration was also examined, and the results show no nanoparticle leakage during daily tooth brushing vibration levels.

It has been demonstrated that a nondestructive, biocompatible, cost-effective, and time efficient tooth whitening strategy based on piezo- catalysis effect due to piezoelectric nanoparticles. The tooth whitening system shows excellent chemical, structural and electrical stability using pole BTO nanoparticles **[36]**. The piezo- catalysis based tooth whitening effect was also demonstrated using a more practical electric toothbrush and BTO turbid liquid **[37, 38]**.

This review demonstrates that the piezo - catalysis based tooth whitening via BTO nanoparticles is non destructive to the tooth enamel and biocompatible without cytotoxicity as compared to other clinical whitening agents. Piezo- catalysis tooth whitening has the ability to be widely adopted for home use, without requiring significant investment. It can also be used in clinical aspects.

CONCLUSION

The review article concludes that piezo-catalysis effect based tooth whitening method can replace traditional abrasive in the toothpaste and to generate reactive oxygen species via piezo - catalysis to bleach tooth stains.

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