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External Tooth Bleaching – A Review

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Abstract: *The current knowledge of tooth whitening with respect to external bleaching methods is to be reviewed.There has been a dramatic increase in the number of products and procedures over current years with a concomitant rise in publications on this topic with regards to the importance of tooth whitening for patient and consumers. According to the Literature, mechanisms of tooth whitening by peroxide happen by the diffusion of peroxide over enamel to cause oxidation and therefore lightening of coloured species, particularly within the dentinal regions. Changes in tooth colour can be measured using a number of approaches. They arevisual measurements by skilled clinicians and instrumental measurements using spectrophotometry, chromameters and digital image analysis. The main factors that affect tooth whitening efficacy by peroxide comprising products are concentration and time. Generally, greater concentrations are faster than lesser concentrations. However, lesser concentrations can approach the efficacy of greater concentrations with prolonged treatment times. Other bleach systems to peroxide have received only slight attention. The effectiveness of light activated systems versus non-light activated controls in clinical studies is restricted and contradictory. Other factors which can influence tooth bleaching outcome contain type of stain, initial tooth colour and subject age.*

Keywords: *Tooth whitening, peroxide, bleaching*

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I. Introduction

Aesthetics of the teeth, including tooth colour is of great importance to the patient. For examples, in the UK and in USA it has been reported that 28% and 34% of adult population are dissatisfied with the appearance of their current tooth colour.In addition, in a survey of 3215 subjects from the UK, 50%perceived they had some kind of tooth discolouration[1]. Colour of the tooth is influenced by a combination of their inherent colour and the presence of any external stains that may form on the tooth surface. Inherent tooth colour is due to the light scattering and adsorption nature of the enamel and dentine. Dentine plays a main role in determining the general tooth colour. External stains have a tendency to form in areas of the teeth that are less reachable to tooth brushing and the coarse action of toothpasteand is often stimulated by smoking, dietary consumptionof tannin-rich foods (e.g. red wine) and the use of some fewcationic agents such as chlorhexidine, or the use of metal salts, for example tin and iron. Tooth colour can be improved by various methods like whitening toothpastes, expert cleaning by scaling and polishing to remove stain and plaque, internal and external bleaching of non-vital and vital teeth, respectively, microabrasion of enamel, crowns and veneers placement[2]. The current literature review's scope is restricted to the external bleaching of vital teeth and willemphasis on the following topics; mechanisms of tooth bleaching; in vivo and in vitro evaluation approaches, and factors influencing the effectiveness of the tooth bleaching process. A number of methods and approaches have been described in the literature for the bleaching of vitalteeth. For examples, methods using different bleach agents, concentrations, time of application, product format, application mode and light activation. There are three types of bleaching procedures namely, dentists administered nightguard bleaching, in-office or power bleaching and bulk market

bleaching products.A relatively low level of whitening agent is applied to the teeth via a custom fabricated mouth guard which has to be worn at night for at least 2weeks for Nightguard bleaching. In-office bleaching uses high amount of whitening agents, like 25–35% products that contain hydrogen peroxide, for shorter period of time. The whitening gel which has to be applied to the teeth after shielding the soft tissues and the peroxide may be additionally activated by heat or light. The in-office treatment can result in significant whitening after a single day treatment visitbut may require multiple treatment appointments for optimum whitening. Mass market products typically contain lesser levels of whitening agent (e.g. 3–6% hydrogen peroxide) that are applied by the individual themselves to the teeth using some shields for the gums or strips or paint-on product formats and typically need twice per day application for up to 2 weeks[3].

II. Mechanism Of Tooth Bleaching

Bleaching is the process of whitening that can occur in solution or on a surface. These materials or solutions are organic compounds that have extended conjugated chains of alternating single or double bonds and contain heteroatoms, carbonyl, and phenyl rings in the conjugated system and are known as a chromophore. Elimination of one or more of the double bonds in the conjugated chain may lead to bleaching and decolourisation of the chromophore by method of oxidation of other chemical moieties in the conjugated chain or in conditions where the conjugated chain is cleaved .A wide variety of organic and inorganic compounds get oxidises by hydrogen peroxide. These reactions mechanism are diverse and depends on the substrate, the reaction environment, and catalysis. In general, the bleaching mechanism by hydrogen peroxide is not well understood and it can form a number of different active oxygen species which depends on reaction conditions, like temperature, pH, light and presence of transition metals[4,5].

Hydrogen peroxide bleaching generally proceeds via the perhydroxyl anion under alkaline conditions. Free radical formation also arises due to other conditions like homolytic cleavage of either an O–H bond or the O–O bond in hydrogen peroxide which give H" + "OOH and2"OH (hydroxyl radical), respectively. Hydroxyl radicals formation from hydrogen peroxide increases under photo chemically initiated reactions using light or lasers. Teeth whitening mechanism by oxidising materials like hydrogen peroxide and carbamide peroxide are currently not fully understood[6]. The available literature and evidence point towards the early diffusion of peroxide into and through the enamel to reach the enamel dentine junction and dentine regions. Indeed, a number of authors have demonstrated via in vitro experiments that the lower level of peroxide penetration into the pulp chambers of extracted teeth after exposure times of 15–30 minutes from a variety of peroxide products and solutions. The peroxide level measured in these experiments is considerably much lower, as a result the peroxide level that is needed to produce pulpal enzyme inactivation is not achieved. Peroxide that diffuses into the tooth, reacts with organic coloured materials that are found within the tooth structures leads to a colourreduction[7]. This is obvious within dentine as demonstrated by McCaslin et al. He showed that there is change in the colour throughout the dentine when hemisectioned human teeth mounted on the glass slides undergoes external bleaching with carbamide peroxide. Dentine specimens treated with 10% carbamide peroxide,5.3% to 6% hydrogen peroxide is shown to give a significant reduction in yellowness and an increase in whiteness[8]. In addition, Sulieman et al showed that major bleaching occurred within the dentine, mostly on the buccal surface in which 35%hydrogen peroxide gel had been applied. This has been showed using sectioned extracted teeth that has been stained internally with black tea chromophores. Photo-oxidation of tetracycline molecules bound within the tooth structures leads to the colour so obtained in the tetracycline stained teeth. It is possible to bleach these teeth in some cases to give significant and long-term tooth whitening. The mechanism by which the tetracycline stain is affected by peroxide is due to the chemical degradation of the unsaturated quinone type structures that are found in tetracycline leads to less coloured molecules. However there appears to be a lack of information available in the literature concerning the nature and chemical composition of the coloured materials that are found naturally within the dental hard tissues and the mechanistic effects of peroxide on this kind of structures.To resolved the chemical mechanistic features of tooth bleaching further research is required in this area[9].

III. Clinical Measurement Of Tooth Whitening

The colour of teeth and the colour changes that occur during toothwhitening techniquescan be measured using numerous methods. Of all the methods the most commonly used method isto check the tooth with a standardshade guide.This method is the most commonly used one to find out the colour changes in tooth.A number of factors can influence this process of tooth whitening. For example,conditions of the light, familiarity, time of life, human eye fatique, cosmetics, room design and colour blindness as to mention few.Thus,to control all this factors proper care is needed.Differentiation of tooth colour can be improved through training as well as experience also counts and investigators undergo colourstandardisation exercisesand training using colourshade monitors in their studies[10]. Colorimeters are instruments intended to measure theobjects colour. The colour is usually expressed in relations to the Commission Internationale de l'E´clairage

(CIE) Lab colourspace. The CIE Lab colour space signifies aneven tone colourspace, with identical distances corresponding to identical perceiveddifferences of the colour. The three axes in this three-dimensional colourspace are L*, a* and b*. The L* value represents the measure of thelightness of an object and is quantified on a scale. L* value of aflawless black has a zero and a flawless reflectingdiffuser a 100. The a* value represents the measure of redness(positive a*) or greenness (negative a*). The b* value signifies themeasure of yellowness (positive b*) or blueness (negative b*). For neutral colours(white, greys) the a* and b* co-ordinates approach zero and for more saturated orintense colours the scale increases[11].Measurement of tooth colour by using colorimeter through in vivo requires the construction of a conventionsittingjig to make sure reproducible intra-oral positioning of theinstrument's aperture onto the tooth surface.Innumerous studies, this method has been utilised for measuringlongitudinal changes in tooth colour followed by tooth whiteningprocesses.Another method for measuring tooth colour is by the use of anon-contact camera-based digital imaging and analysis systems.Usually, the anterior teeth image iscaptured under precise lighting conditions by a digitalcamera along with proper calibration tiles or standardsand then analysed through computer software tofind out the individual tooth colour, that are often expressed in terms of CIE Lab values. For example, using a10% carbamide peroxide tray-based arrangement after 14 days, the meanchange from baseline in L* and b* were found to be 2.07 and -1.67 respectively[12].

IV. In Vitro Models For Tooth Whitening

In vitro models are important for earlyassessment of samples and optimising treatment protocols. Important data regarding product safety are also obtain by these models in relation to its effect on the hard tissues and offer mechanisticunderstanding of the bleaching process. To estimate the effectiveness of tooth whiteningproducts various in vitro models are described in the literature and these are summarised below. The bulk ofthese models use whole or cut human or bovine toothsamples and uses their previous colour. However, few in vitro models increased the levels of intrinsic toothcolour by staining them with black tea or blood components. Changes in tooth colour are measured by instrumental means[13,14].

V. Factors Influencing Tooth Whitening

1. TYPE OF BLEACH

The majority of current tooth whitening studies involvethe use of either hydrogen peroxide or carbamide peroxide. Carbamide peroxide is formed by urea and hydrogenperoxide as an additional reaction and when they contact with water dissociates into ureaand hydrogen peroxide. For example, carbamide peroxide gel in 10%(w/w) would produce a maximum of 3.6% (w/w) hydrogenperoxide. In general, the effectiveness of products containing hydrogen peroxide are approximately the same when compared with products containing carbamide peroxide with equal or similar hydrogen peroxide content and are deliveredusing similar format and formulations, which has been tested either in vitro or in vivo[16].For example, Nathoo et al. showed in aclinical study that a single application of either a 25%carbamide peroxide gel or a 8.7% hydrogen peroxide gel bothgave a significant tooth shade lightening after 2weeks use as compared to the baseline, but he did not find any statistically noteworthy variances between the products. [17]An alternative source of hydrogen peroxide is sodium per carbonate and this has been used in products that contain silicone polymer that is painted onto the teeth forming astrongand resilient film for overnight bleaching procedures. The peroxide gets released gradually for up to 4 hours and improves thetooth colour after 2 weeks of usage. However, the vitro efficacy of sodium percarbonate versus hydrogen peroxide that are tested in the identicalproduct setup and conditions has not been reported. A tooth bleaching system that is based on sodium chloriteis applied to the tooth surface and triggered under acidicconditions has been described in the literature however no useful informations has been reported to date. Similarly, other vital tooth bleaching systems have also been mentioned inthe literature with restricted evidence that supports theirefficacy. These include sodium perborate,peroxymonosulphate,peroxide plus metal catalysts and oxireductase enzymes.The long term acceptability and relativeeffectiveness of these alternative tooth bleaching systems requires more research[18,19].

1. CONCENTRATION AND TIME

Two of the main factors which determine the overall tooth whiteningefficacy from peroxide containing products are the concentrationof the peroxide and period of application. For example, Sulieman et al found that when the concentration of gel is high, the application should be lower to obtain a uniform and even bleaching. He made this finding bycomparing the in vitro tooth bleaching effectiveness of gels that contain 5–35% hydrogen peroxide. Leonard et al compared the in vitro tooth bleaching efficacy of 5%, 10% and 16% carbamide peroxide gels and found that initially the whitening process was faster for the 16% and 10% than the 5% concentration[20].However, the effectiveness of the 5% come close to the higherconcentrations when the treatment time was extended. Kihn et al. in a clinical study showed that a 15% carbamide peroxide gel gave significantly more tooth whitening as compared to a 10% carbamide gel after 2 weeks of usage[21]. This result

was confirmed in another clinical study reported by Matis et al. However, in this latter study, when 6 weeks of the treatment time is extended, the differences in tooth whiteness were no longer of significant statistically. For higher concentrations of carbamide peroxide the initial rate of bleaching was faster and this has been observed whentetracycline stained teeth is bleached in vivo over a 6 months period In the first month, the most rapid whitening occurred with 20% carbamide peroxide compared to 15% and10% carbamide peroxide in this case. In addition, clinical studies withhydrogen peroxide based products like the strip showssimilar concentration and time effects for whitening of tooth. [22]

2. HEAT AND LIGHT

Rise in temperature increases the rate of chemical reactions. 108C rise can double the rate of reactions. Abbot reported in 1918 that the use of a high intensity light to raise the temperature of hydrogen peroxide and accelerate the rate of chemical bleaching of teeth. Other methods for heating the peroxide havealso been described to accelerate tooth bleaching, like the use of a heated dental instruments[23]. However, dental pulp can be damaged if excessive heating is done.In current approaches, the peroxide bleaching is accelerated with simultaneous lighting ofthe anterior teeth with various sources that have a range ofwavelengths and spectral power, for examples, curinglights of halogen, plasma arc lamps, lasers and light-emitting diodes. Rise in pulpaltemperatures have been measured using in vitro modelsduring tooth bleaching in case of some light sources. The chemical redox reactions of the bleaching process can be accelerated by peroxide which gets activated by the light source. In addition, the overall acceleration of the bleaching process is speculated by the light source that energises the tooth stain.Some of the stuffs thatare used in light activated bleaching processes containelements that claim to help the transfer of energy from lightto the gel of peroxide and this are often coloured materials, for example, carotene and manganese sulphate.Theefficacy of light activated peroxide tooth bleaching system have been demonstrated in case studies. However, the actual effect of light on tooth bleaching versus appropriate non-light device is restricted and provocative as stated in the literature evidence from in vitro and clinical studies[24]. An invitro study using naturally coloured extracted human teethshowed that when various light sources are applied it significantlyimproved the whitening efficacy of some bleach materials.Additionally some other in vitro studies haveclearly shown significant tooth whitening benefits for peroxide as well as light versus appropriate control situations.On the other hand, these studies artificially stained the tooth specimenswith materials such as, black tea, caffeine, tobacco and redwine, i.e. ingredients commonly found to promote extrinsicstains. Thesechromophore seems to be different to thatwhich may be found naturally inside the tooth. Tavares et al conducted a tooth whitening clinical studyto compare gel of 15% hydrogen peroxide illuminated with a plasma light gas source against 15% peroxide alone versus placebogel with light, all treatments lasting 1 hour. The change in Vitashade from baseline for peroxide with light, only peroxide and placebo with light were 8.35, 5.88 and 4.93, respectively with peroxide with light being considerably different to theother groups. In contrast, Hein et al demonstrated that noextra effect in any of the three light sources tested overthe bleaching gel alone for three marketable products in a fragmented mouth clinical design. Therefore, more work is clearlyneeded in order to clearly demonstrate the additional useful advantage of light activated tooth whitening systemsagainst their non-light activated controls [25,26].

VI. Other Factors

The initial tooth colour and type of intrinsic stain can playan important role in the final outcome of tooth bleaching. Tetracycline staining that are mild to moderate tends to respond toprolonged bleaching regimes of 2–6 months. However, itis documented that tetracycline staining that are severe are moredifficult to bleachwith the darker the teeth at baseline,the longer it can take to lighten the teeth.In addition, it isstated that when the tetracycline discolouration is locatedin the neck of the tooth, the prediction for bleaching is thepoorest; when it is dark grey or blue, the prognosis also ispoor.For non-tetracycline stained teeth, a metaexamination ofsample controlled, patient applied tooth whitening. Clinical studies using carbamide peroxide in 10% found that 93% ofpeople who used the peroxide product and 20% who used theplacebo exhibited a variation of two shade guide unit. Additionally, 20% of subjects who used the peroxide productachieved a mean change of five shade guide unit[27]. The tooth colour change of 80 subjects after using 10% carbamide peroxide in a gumarmour for 14 days was evaluated by Ishikawa-Nagai et al and found a solid correlation betweentotal colour change and b* values, demonstrating thatbleaching works capably for teeth with a yellow hue.Further, an analysis of the clinical results with subjects who are undergoing tooth bleaching, indicate that when more the teeth are yellower at baseline, the magnitude of the whitening response will be higher.This study shows asignificant relationship between subject age and the extentof whitening response, with younger subjects experiencingbetter tooth whitening.Further, there was aconnection between subject age and the initial colour andthe extent of whitening response. Older subjects with lessyellow initial tooth colour revealed the least mean colourchange after bleaching, whereas younger subjects with extrayellow initial tooth colour showed the highest mean colourchange after bleaching.In addition, neither gender nor consumption of caffeine had any major effect on

the tooth whitening response. The presence of pellicle and plaque on the tooth surfacehas the hypothetical potential to decrease the peroxide activityby acting as a substrate for bleaching by peroxide and/or degrading peroxide[28]. Wattanapayungkul et al demonstrated that the rate of peroxide degradation did not rise with thecompany of pellicle on tooth surfaces in vivo over 1 hoursignifying that pellicle does not have a major effect onthe constancy of peroxide. A clinical study by Gerlachet al, comparing the effect of immediate brushing with atoothpaste before the bleaching procedure versus no brushing before tooth bleachingwith 6.5% hydrogen peroxide over a 14-day period, advisedthat tooth brushing immediately prior to bleaching has only amodest positive impact on overall efficacy. Therefore, the adjustingrole of pellicle on peroxide transfer and whitening efficacyappears to be small overall[29].

VII. Concluding Remarks

Nowadays patients and consumers have known the importance of tooth whitening, as a result there has been a dramatic growth in the figure of tooth whitening products and procedures. Alongside, there has been a rapid increase of published in vivo and in vitro tooth whitening studies. Extensive literature describing their efficacy and safety is clearly evident. However, some of this literature is conflicting, and these topics warrant further careful evaluation as they were outthe scope of the current review. Numerous approaches to measure tooth colour changes following tooth whitening exist, each with their own pros and cons, and this topic is likely to be an area commanding further studyin the future. With the constant interest in tooth whiteningamongst basic and clinical researchers, the further systematicunderstanding and optimisation of the aspects controlling the tooth whitening process will continue to expand. This will further improve the products of tooth whiteningand itsprocesses, and give significant aids to the field of aesthetic dentistry. This will ultimately lead to the enhancement of patient agreement and satisfaction with the whitening outcome [30].

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