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Review

Whitening toothpastes: A review of the literature

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ABSTRACT

Objectives: To review and summarise the whitening agents contained within tooth whitening toothpaste formulations, their mode of action in tooth whitening, and the *in vitro* and clinical methods used to evaluate and demonstrate their efficacy.
Methods: Original scientific full papers or reviews listed in ISI Web of Science and Medline were included in this review using the search terms white*, toothpaste and dentifrice.
Conclusions: Due to the reported consumer and patient dissatisfaction with their perceived tooth color, toothpaste manufacturers have responded by developing a vast array of contemporary whitening toothpastes. One of the key functional ingredients in whitening toothpastes is the abrasive system. In general, these have been designed to give effective removal of extrinsic stains and help prevent tooth stains from reforming without undue abrasivity towards the dental hard tissues. Whitening toothpastes may contain additional agents that augment the abrasive cleaning by aiding the removal and/or prevention of extrinsic stains, for examples, peroxide, enzymes, citrate, pyrophosphate and hexametaphosphate, or optical agents such as blue covarine which can improve tooth whiteness following tooth brushing. *In vitro* methods used to evaluate tooth whitening efficacy typically determine the ability of a toothpaste formulation to remove/prevent model extrinsic stains on substrates such as enamel or hydroxyapatite or changes in the intrinsic color of tooth specimens. Clinical protocols for evaluating the efficacy of whitening toothpastes typically determine either stain removal or prevention, where changes in natural stain or chlorhexidine/tea induced stain are measured typically over 2–6 weeks. In some clinical studies the overall tooth color change was measured using techniques such as Vita shade guides, colorimeters and image analysis of digital photographs of teeth.

1. Introduction

The color of the teeth is influenced by a combination of their intrinsic color and the presence of any extrinsic stains that may form on the tooth surface.[1,2] Intrinsic tooth color is greatly influenced by the light absorption and scattering properties of the enamel and dentine, with dentine playing a significant role in determining the overall tooth color.[3,4] Extrinsic color is linked with the adsorption of materials into the acquired pellicle on the surface of enamel, which ultimately cause staining.[5] Factors that influence extrinsic stain formation include poor tooth brushing technique, smoking, dietary intake of colored foods (e.g. red wine), subject age and the use of certain cationic agents such as chlorhexidine or metal salts like tin and iron.[1,5–8]

Consumers and patients alike have always had a strong desire for white teeth and many individuals are dissatisfied with their current tooth color as indicated in a number of recent studies.[9–11] Depending on the population examined, these studies have shown that personal dissatisfaction with

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tooth color ranges from 17.9 to 52.6%. This desire for whiter teeth has given rise to a growing trend in the increased use of tooth whitening products.[12,13] Manufacturers of oral care products are constantly developing improvements and new approaches for tooth whitening in order to meet the demanding expectations of patients and consumers. Thus, today there is a huge range of product types and technologies addressing the problem of tooth discoloration available on the market. The majority of these products work in one of two ways, either by bleaching of the teeth, or by the removal and control of extrinsic stain. Tooth bleaching typically involves the application of hydrogen peroxide or carbamide peroxide containing gels to the teeth through various formats, including a mouth guard or strip or even painting directly on. The peroxide causes decolorisation or bleaching of the colored materials found within the tooth giving rise to whiter teeth.[14] In order to optimise the removal and control of extrinsic stain, specific abrasives and/or chemical agents can be added to toothpaste. These improved stain removal/prevention products are termed whitening toothpastes.

The purpose of the current review is to summarise the available literature concerning the technology contained in tooth whitening toothpaste formulations, their role in tooth whitening, and *in vitro* and clinical methods used to evaluate and demonstrate their efficacy. Only original scientific full papers or reviews listed in ISI Web of Science and Medline were included in this review using the search terms white*, toothpaste and dentifrice. The total number of studies identified which described the technology behind whitening toothpastes and their efficacy was 57, of which 22 were *in vitro* studies and 35 were clinical studies. The majority of studies (89%) were published from 1998 onwards. Most of the clinical studies investigated natural extrinsic stain removal and/or prevention (69%), with clinical sample sizes in the range 22–219 subjects, although typically of the order 30–60 subjects and durations typically of 2–6 weeks, but sometimes prolonged for 12 weeks or more. Other clinical studies investigated the impact of whitening toothpastes on chlorhexidine induced stain (20%) or to a lesser extent on intrinsic tooth color (11%).

2. Whitening toothpastes

Oral care product manufacturers are well aware of the consumer dissatisfaction with their perceived tooth color and, in response, have developed a vast choice of contemporary toothpastes to address the problem. Most contain the same basic functional ingredients, all of which have a specific role to play within the formulation. These include: solid cleansing abrasive materials, humectant for solubilisation of other ingredients and to prevent the formulation from drying out; thickening agent to define the rheological properties of the formulation; surfactant to generate foam and impart desirable sensorial properties during use, active agents such as fluoride to provide health benefits, flavour, sweetener, opacifying agents; colors for characteristic taste and appearance; and buffering agents and preservative to maintain formulation stability.[15]

In general, toothpastes that are specifically formulated for tooth whitening provide this benefit by removing and preventing the formation of extrinsic stain. It is well documented that if a very low abrasive toothpaste is used, stained pellicle usually accumulates on the surfaces of teeth[16] and it is now widely accepted that toothpastes require a certain amount of abrasivity to remove or prevent extrinsic stains from forming.[16–18] Other toothpaste ingredients have been described in the literature for removing and preventing extrinsic stain including surfactants, polyphosphates and enzymes (Table 1). However, the evidence to date still suggests that the primary stain removal ingredient in toothpaste is the abrasive.[15]

Table 1 – Tooth whitening agents.

Abrasives	Hydrated silica Calcium carbonate Dicalcium phosphate dihydrate Calcium pyrophosphate Alumina Perlite Sodium bicarbonate
Chemical	Hydrogen peroxide Calcium peroxide Sodium citrate Sodium pyrophosphate Sodium tripolyphosphate Sodium hexametaphosphate Papain
Optical	Blue covarine

3. Evaluation of whitening toothpastes *in vitro*

The evaluation of tooth whitening using *in vitro* models is important as it allows the initial testing of scientific hypotheses and the rapid screening of many different types of materials and prototype formulations. This can lead to the optimisation and ultimately the identification of efficacious whitening toothpaste formulations. In addition, *in vitro* models have proven useful as they can be used to develop mechanistic insights and to gain important information on the safety of products, for example, in terms of their effects on the dental hard tissues.

A number of tooth whitening *in vitro* models evaluating the effects of toothpaste have been reported in the literature. These typically determine the ability of a toothpaste formulation to remove a model extrinsic stain from a substrate such as enamel or hydroxyapatite, although other methods have been described which evaluate stain prevention approaches or changes in the intrinsic color of tooth specimens following extensive brushing times.

One of the most commonly used methods for assessing the stain removal by toothpaste *in vitro* is the method developed by Stookey et al.[16] This model uses square bovine enamel blocks mounted in polymethylmethacrylate blocks. The specimens are polished and lightly acid etched in order to facilitate stain accumulation and adherence. They are attached to a staining apparatus which provides alternate immersion into a staining media and air drying at 37 °C. The staining media consists of tea, coffee, gastric mucin, sterilised trypticase soy broth and *Sarcina Lutea* bacterial culture. After a number of days, the stained specimens are assessed by visual means using a five-point scale