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Are Over-the Counter (OTC) Desensitising toothpastes used for dentine hypersensitivity effective? An Overview

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Abstract

Introduction

Dentine hypersensitivity (DH) poses a significant challenge for both patients and clinicians, often overlooked despite its prevalence. Currently the hydrodynamic theory is widely accepted as the primary explanation for its pathophysiology. Although various management strategies exist, over the counter (OTC) toothpastes are commonly recommended by dental practitioners. This overview aims to assess the claims made on the claims of effectiveness on selected desensitising toothpaste packaging following a survey in a local UK supermarket. The collated information on the active ingredients of selected toothpastes was then compared with the available evidence from the published literature.

Introduction

Dentine hypersensitivity (DH) is a prevalent condition which may impact on a patient's quality of life (QoL) (Bekes & Hirsch, 2012, Gillam 2021); and is often underestimated by clinicians (Gillam 2013). According to a systematic review and meta-analysis, the average prevalence of DH in all published studies that were included was 33.5%, and the best overall estimate was 11.5%. (Zeola et al., 2019). According to Irwin & McCusker, the prevalence of sensitivity was 57.2%, and most common among individuals aged 30-39 (Irwin & McCusker, 1997) Most teeth in the oral cavity can be affected with the buccal or facial surfaces most affected.

Mainly in the maxillary teeth, specifically the premolars and canines (Splieth & Tachou, 2013), although the first and second molars are often affected in periodontally involved teeth (Chabanski et al 1997). The aim of this overview is to evaluate the effectiveness of selected over the counter desensitising products (e.g., packaging/labelling claims) and compare these claims with evidence from the available published literature.

Methodology

A study based on a previous study by Sadia & Gillam (2024) was conducted by one of the authors (MA) to identify a range of home or consumer (over the counter) desensitising toothpaste products for the treatment of DH in a local supermarket store in the UK. Information relating to the ingredients of the various selected toothpastes together with the claims made on the cartons (packaging/labelling) was collated and subsequently reinforced by data from the manufacturers' websites. The various claims made by the manufacturers on their products was then compared with the available evidence from peer reviewed journals (see Tables 1 and 2). Of the various desensitising products identified in the initial survey the following selected desensitising products with their specific active ingredients were evaluated 1) Stannous Fluoride, 2) Potassium salts, 3) Strontium containing toothpastes, 4) Calcium sodium phosphosilicate, 5) Nano-hydroxyapatite products and 6) Arginine products (see Tables 1 & 2):

How do Desensitising toothpastes work?

There are currently three main mechanisms of DH proposed to explain the underlying mechanism of DH:

1). The Direct Innervation theory, which proposed that mechanical stimuli directly transmit pain because the nerve endings go through the pulp-dentin complex and penetrate the dentino-enamel junction (DEJ). However, there is limited data to support this theory (Davari et al., 2013)

2) The odontoblast receptor theory. Odontoblasts act as pain receptor cell and send messages to the pulpal nerves. But this notion has been previously disproved due to the incapacity of the cell matrix of odontoblasts to generate neural impulses. Furthermore, there is insufficient data to establish a link between pulpal nerves and odontoblasts. (Davari et al., 2013; Mrinalini et al., 2021). However, increasing evidence suggests that the odontoblast might contribute to the initial phases of mechanical, thermal, and chemical DH. Solé-Magdalena proposed that odontoblasts may serve as sensory cells, releasing neurotransmitters upon odontoblast stimulation, which can then interact with the pulp sensory nerve fibres (Solé-Magdalen et al. 2018). If so, this may explain how potassium-containing toothpastes and mouth washes may alleviate DH.

3)The most widely recognised theory is the hydrodynamic theory. According to this view, dentinal tubules that are exposed between the pulp and the dentine surface are the source of DH. This implies that fluid displacement brought on by stimuli such as changes in temperature, physical properties, or the presence of osmotic stimuli close to the exposed dentine causes baroreceptors located on the nerves in the pulp trigger the pain associated with DH. Fluid can move in the direction of either the pulp's interior or the outer surface of the dentine. Dentinal fluid moves away from the dentine-pulp complex because of cooling, drying, evaporation, and exposure to hypertonic substances, which exacerbate pain. On the other hand, heating induces an inward flow towards the pulp. Cold stimuli provoke pain in about 75% of individuals with DH. Notably, sensitive dentine exhibits a significantly higher number of tubules, about eight times more than non-sensitive dentine, and these tubules are wider in sensitive dentine compared to their non-sensitive counterparts (Davari et al., 2013)

Most desensitising toothpastes are therefore designed

to (1) occlude dentine tubules or (2) to prevent conduction of pulpal nerve (Kanehira et al., 2015). One method of treating DH is through OTC desensitising agents which are easy to use, affordable and non-invasive. Most OTC desensitising toothpastes work by blocking dentinal tubules or by depolarising the dental nerve and contain many active components, including strontium chloride, stannous fluoride (SnF2), calcium sodium phosphosilicate (CSP) and arginine (Hu et al., 2018; Martins et al., 2020, 2022). One systematic review which compared desensitising toothpastes with different active ingredients reported that most toothpastes demonstrated superior efficacy in addressing DH compared to placebo or fluoride toothpastes (NaF, MFP). In addressing tactile stimulus, toothpastes containing strontium and potassium were beneficial and this is supported by another systematic review which also reported that there was insufficient evidence for toothpastes containing strontium alone as it was only effective when there was a combination of strontium and potassium (Hu et al., 2018; Martins et al., 2020, 2022). For the air stimulus, arginine demonstrated better efficacy. However, CSP was reported to be the most effective for all the studied stimuli. (Martins et al., 2020, 2022)

The efficacy of fluoridated toothpastes in addressing sensitive teeth is notably enhanced when combined with dentine fluid-obstructing agents such as various metal ions, potassium, and oxalates. Various toothpaste formulations incorporating potassium salts (nitrate, chloride, and citrate) with different fluoride concentrations and salts have undergone testing and reveal that such combinations effectively manage DH (Petersson, 2012) (see Table 1).

Active ingredient	Mechanism	Evidence
Stannous Fluoride	Generates soluble mineral ions that form an insoluble precipitate, blocking the dentinal tubules	Parkinson et al, 2015, Hines et al. 2019 Arshad et al. 2023
Potassium-containing	Prevents the conduction of the pulpal nerves	Orchardson & Gillam 2000, Poulsen et al. 2006, Pradeep & Sharma 2010, Karim and Gillam 2013
Strontium	Blocking exposed dentine tubules and depolarises the pulpal nerve	Uchida et al 1980, Minkoff and Axelrod (1987), West et al. 2015) Note Several reviews Have questioned the effectiveness Of Strontium based toothpastes (Karim and Gillam 2013, Bae et al. 2015, Levenson 2016)
Calcium sodium phosphosilicate	Forms a protective layer of hydroxyapatite to occlude the dentinal tubules	Pradeep & Sharma 2010, Jones et al. 2015, Zhu et al. 2015, Hall et al. 2017, Arantes et al. 2019,
Nano-hydroxyapatite	Blocks the open dentinal	Shetty et al. 2010, Vano et al. 2014,

	tubules	Amaechi et al. 2021
Arginine	Deposited on the surface of the exposed dentine to block the dentinal tubules.	Ayad et al. 2009, Hall et al. 2017, Arantes et al. 2019, Arshad et al. 2021

Table 1: Outlining the mechanism of different active ingredients (Hu et al., 2018; Martins et al., 2022, Sadia & Gillam 2024)

Is there any evidence to substantiate the claims made by the Manufacturers.

Clinical studies (Selected comparative studies)

Arginine based toothpastes

1) Arginine and calcium carbonate vs. potassium

One study undertaken for the clinical efficacy of Colgate Sensitive Pro-relief toothpaste, compared its contents of 8.0% arginine, calcium carbonate, and 1450ppm fluoride to a commercial toothpaste containing 2% potassium ions and 1450ppm fluoride to identify which ingredient helps DH. The results indicated that the toothpaste containing arginine in a calcium carbonate base reduced DH in response to both tactile and air blast stimuli more than the commercial toothpaste. The study included 80 individuals, with a significantly greater proportion of females (n=56) than males (n=24), potentially compromising the generalizability of the findings.

In addition, the specific characteristics of the sample were not defined and the lack of information on the participant recruiting procedures raises concerns about the study's transparency and potential biases. Without detailed information on recruitment procedures, it is unclear whether participants were recruited in a way that guaranteed representativeness and reduced selection bias. Random allocation of participants to either the test or control group mitigated some potential biases, increasing the study's internal validity. In addition, the selection criteria were based on the Yeaple probe and the Schiff Cold Air Sensitivity Scale, which focus on physical quantifiable measures rather than subjective interpretations, which improves diagnostic reliability and objectivity. (Docimo et al., 2009).

2) Arginine vs. strontium acetate vs fluorocalcium phosphosilicate

One study comparing Pro-argin™ in Colgate Sensitive Pro-relief™ and 8% strontium acetate in Sensodyne Rapid Action™, fluorocalcium phospholsilicate and a control using Colgate Total with sodium fluoride toothpaste. All toothpastes showed reduction in DH relative to baseline after one-minute of application with a better response from Pro-argin, followed by strontium acetate. In contrast, it was concluded that Fluorocalcium phosphosilicate was the best treatment option for long-term management of DH as there was a greater reduction relative to baseline after subsequent six weeks of application. The total sample size used in this study was 140 participants, each group having 35 subjects in number.

Although the sample size may be deemed adequate, it's noteworthy that the study was conducted in Karachi, Pakistan, with a mostly Asian population. This introduces

a potential limitation regarding the generalizability of the results to the UK population, which predominantly comprises individuals of mainly Caucasian descent. However, thorough selection criteria were used to exclude any participants that may affect the results due to confounding variables. The study's adherence to random allocation and use of objective measures enhanced its validity and mitigates against biases, increasing the reliability of the findings. (Arshad et al., 2021)

3) Arginine vs. CSPS

A study compared bioactive glass with arginine in reducing dentine permeability. The test products comprised (1) a fluoride toothpaste, (2) a CSPS containing toothpaste, (3) an Arginine containing toothpaste. These were applied to a dentine disc and subsequently checked for tubule occlusion following a single application of toothpaste and occlusion following acid challenge. After a single application of toothpaste and an acid challenge, there was no significant difference in the reduction of dentine permeability between the arginine and CSPS toothpaste formulations. Dentine discs treated with only a fluoride toothpaste did have fine debris but most of the tubule orifices remained open. After the acid challenge, the reduction in permeability achieved by both the arginine and CSPS toothpastes exhibited greater stability compared to the fluoride-based toothpaste.

The study did highlight that it only involved a single application of dentifrice and one acid challenge cycle, further studies employing repeated applications and additional erosive cycles are recommended to simulate the long-term conditions in the oral cavity. Although human teeth were used in the experiment, it is important to note that outcomes within the mouth cavity may differ due to a variety of factors, most notably saliva. This is especially important for CSPS, since its interaction with saliva promotes the development of hydroxycarbonate crystals by releasing calcium and phosphate ions, hence different results may occur when used in-vitro (Champaiboon et al., 2020). The evidence for the effectiveness of other desensitising toothpastes is highlighted in Table 2

Marketing of Toothpastes

An analysis of toothpastes specifically formulated for sensitivity in the consumer market (local supermarket) revealed a notable similarity in their ingredient lists, typically featuring a single active agent designed to combat DH. Table 2 provides details of various toothpaste brands, outlining their respective claims, ingredients, and literature to support the active agents.

The prevalent active ingredients observed in these formulations include potassium salts, CSP, arginine, and stannous fluoride. Numerous studies support the efficacy of these ingredients in reducing DH, so overall most of the toothpastes that contain these active ingredients will help DH. Despite these similarities, the market is heavily influenced by marketing and branding, leading consumers to gravitate towards well-established and recognized brands, often disregarding price differentials. Manufacturers use a variety of designs and packaging tactics to achieve a competitive advantage over similar products, with customers preferring certain toothpaste brands.

The rise in media marketing has a further impact on decision-making (Opeodu & Gbadebo, 2017). Consequently, the toothpaste market exemplifies how marketing strategies can significantly impact consumer choices, overshadowing the intrinsic similarities in product composition and function (Table 2).

Product	Ingredients	Claims on Package	Literature Support (Selected studies)
Sensodyne Repair and Protect	Glycerin, PEG-8, Hydrated Silica, Calcium Sodium Phosphosilicate (NOVAMIN), Cocamidopropyl Betaine, Sodium Methyl Cocoyl taurate, Aroma, Titanium Dioxide. Carbomer, Silica, Sodium Fluoride, Sodium Saccharin, Limonene.	'Clinically proven sensitivity relief + daily repair'	(Champaiboon et al., 2020)
Sensodyne Sensitivity and Gum	Glycerin, PEG-8, hydrated silica, pentasodium Triphosphate, Aroma, sodium lauryl sulfate, titanium dioxide, carbomer, Stannous Fluoride (0.454%), cocamidopropyl betaine sodium saccharin, Sodium Fluoride (1450ppm), limonene	'Clinically proven dual action for daily protection' 'Improves gum health'	(Hines et al., 2019)
Sensodyne Daily Care Original Mint	Aqua, Sorbitol, Hydrated Silica, Glycerin, Potassium Nitrate, Cocamidopropyl Betaine, Aroma, Xanthan Gum, Titanium Dioxide, Sodium Fluoride 0.315% W/w (1450 ppm Fluoride), Sodium Saccharin, Sodium Hydroxide, Sucralose, Limonene	'Daily care for sensitive teeth + strong teeth + healthy gums'	(West et al 2015)
Parla Pro Toothpaste Tabs with Hydroxyapatite	Sorbitol, calcium carbonate, potassium citrate, hydroxyapatite, sodium methyl cocoyl taurate, hydrated silica, xylitol, yeast, tocopherol succinate, acacia Senegal gum extract, mentha arvensis leaf oil, sodium monoflourophosphate (1450ppmF), magnesium, stearate, menthol, mica, stevioside, mentha piperita oil, methyl cobalamin, limonene, linalool	'Helps fight sensitivity'. 'Remineralises and strengthening enamel'. 'High gloss whitening' 'Contains Vit E and B12 supporting a healthy immune system'	There does not appear to be any clinical studies registered on the Manufacturers' website. (Low et al., 2015)
Corsodyl Gum + Breath and Sensitivity	Glycerin, PEG-8, Hydrated Silica, Penta sodium Triphosphate, Aroma, Sodium Lauryl Sulfate, Titanium Dioxide, Carbomer, Stannous Fluoride, Cocamidopropyl Betaine, Sodium Saccharin, Zine Chloride, Carrageenan, Sodium Fluoride, Limonene	Gum problems, sensitive teeth, and bad breath	(Hines et al., 2019)

Colgate Sensitive Instant Relief-Repair and Prevent	Arginine 8%, calcium carbonate, aqua, sorbitol, aroma, poloxamer 407, sodium monoflourophosphate (1450 ppm F-), cocamidopropyl betaine, zinc oxide, benzyl alcohol, cellulose gum, zinc citrate, sodium bicarbonate, tetrasodium pyrophosphate, xanthan gum, sodium saccharin, sucralose, limonene	'Clinically proven lasting relief for 8 weeks'	(Docimo et al., 2009)
Colgate Sensitive and Sensifoam	Aqua, Glycerin, Hydrated Silica, Sorbitol, Potassium Nitrate, PEG-12, Sodium Lauryl Sulfate, Aroma, Xanthan Gum, Cellulose Gum, Cocamidopropyl Betaine, Sodium Saccharin, Sodium Fluoride (1450ppm), Potassium Hydroxide, Eugenol	'Clinically proven for sensitive teeth'	(Sharma et al., 2012)
OralCare+ by Sainsbury's	Aqua, Sorbitol, Hydrated Silica, Potassium Nitrate, Sodium Lauryl Sulfate, Cellulose Gum, Aroma, Zinc Citrate, Sodium Fluoride, Sodium Saccharin, Sodium Hydroxide, Limonene, C1 77891	'Sensitive – targets multiple causes of sensitivity' 'Strengthens and remineralise teeth'	(Sharma et al., 2012)
Oral-B Sensitivity and Gum Calm Original	Aqua, Sorbitol, Hydrated Silica, Sodium Lauryl Sulfate, Sodium Gluconate, Carrageenan, Aroma, Kanthan Gum, Cocamidopropyl Betaine, Zinc Citrate, Stannous Fluoride, Sodium Hydroxide, Stannous Chloride, Sodium Saccharin, CI 77891, Sodium Chloride, Sodium Fluoride, Cinnamal, Benzyl Alcohol, Sucralose, Eugenol, Sodium Benzoate, Citric Acid, Sodium Citrate, Potassium Sorbate	'Immediately relieves sensitivity pain' 'soothes gums'	(Hines et al., 2019)

Table 2: Outlining the selected desensitising toothpastes together with their ingredients, claims and supporting literature.

Discussion

The present study was part of a series of undergraduate student projects designed to introduce students to the principles involved in dental research. The project involved 1) reviewing the published literature and writing a review, 2) involvement in a hands-on assignment (e.g., conducting a survey on the effectiveness of oral care projects and 3) designing a clinical study based on selected projects from the survey. The format following the format of previous studies assigned to evaluate the effectiveness of OTC oral care products) (Anand & Gillam 2024, Caresmel & Gillam 2024, Rathore & Gillam (2024, Sadia & Gillam 2024). In the present study the assignment was to evaluate the effectiveness of selected OTC and compare the claims of the products based on their packaging/labelling and compare the results with the available evidence from the published literature.

The results from the study indicated that most of the selected OTC products were effective in the published studies (see Tables 1 & 2), however it should be acknowledged that some of the formulations in the original studies may not necessarily be the same as in the final commercial product. Furthermore, some of the original ingredients in early studies are no longer available. One of the problems when evaluating the published studies particularly with the systematic reviews and meta-analysis is that the inclusion criteria for evaluating the various studies vary, for example, some studies will only include studies of six weeks or longer (Poulsen et al, 2006, Karim & Gillam 2013) whereas other studies such as Bae et al (2015) and Hu et al (2018) may include studies of varying duration, this could lead to different conclusions on the same products. One should also check whether the various claims such as immediate reduction in sensitivity or a long-lasting reduction can be validated in the study design. One final observation that may be relevant here, is that all the published studies are generally well supervised randomised clinical trials (RCTs) where the compliance is good and both non placebo (e.g., Hawthorne effect) and placebo effects may also influence the participants. The question of concern is whether the OTC desensitising products are as effective in the general consumer population. This is perhaps an area for future study.

Conclusion

OTC desensitizing toothpastes contain active components (such as stannous fluoride, arginine with calcium carbonate, calcium sodium phosphosilicate and potassium salts), each aiming to alleviate DH by either blocking the dentinal tubules or inhibiting pulpal nerve conduction. The published literature shows that all the selected active agents do have a positive effect to some degree. However, it is important to acknowledge that there is no one toothpaste or desensitising product that can resolve every patient's sensitivity. The condition should be managed and monitored by the clinician with the appropriate treatment and recommendations based on the patient's individual clinical needs.

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