Treatment Approaches for Dentin Hypersensitivity

5

David G. Gillam

Abstract

The aim of this chapter is to review the various treatment approaches used by clinicians to treat dentin hypersensitivity and evaluate their efficacy in reducing dentin hypersensitivity. Evidence from both in vitro and in vivo studies will be assessed to determine whether there is any support for these treatment products and procedures based on their proposed underlying mechanism of action.

5.1 Introduction

The hydrodynamic theory promotes two basic approaches based on in vitro, in situ, animal and human studies for treating dentin hypersensitivity (DH) (Ling and Gillam 1996; Orchardson and Gillam 2006) (Fig. 5.1):

1. Dentin blocking agents that occlude patent (open) tubules (fluoride, strontium salts, oxalate, calcium phosphate, restorative materials, etc.) and as a consequence reduce any stimulus-evoked fluid movements within the dentin tubule
2. Nerve desensitisation agents that reduce intradental nerve excitability (e.g. potassium ions, guanethidine) in order to prevent a response from intradental nerves to the stimulus-evoked fluid movements within the dentin tubules

It should be acknowledged that in vitro results demonstrating superiority of the various products under examination should not be extrapolated into making claims on the efficacy of these products without first undergoing extensive clinical evaluation. There are however a vast array of products currently out on the commercial market with various claims of clinical efficacy in reducing DH, although currently there does not appear to be a gold standard product or therapy universally accepted by clinicians to treat the condition (see Chap. 6).

Application of these successfully tested products may either involve 'in-office' procedures by a clinician using a restorative approach (for example, restorative materials in the form of dentin bonding agents, glass ionomer cements (GIC), and periodontal surgical techniques) or by a clinician recommending an over-the-counter (OTC) approach (involving toothpastes, gels, mouthwashes).

5.2 Dentin Blocking Agents

Currently the hydrodynamic theory (Brännström 1963) is generally considered to be the mechanism of choice although other alternative mechanisms of stimulus transmission cannot be ruled

D.G. Gillam
Centre for Adult Oral Health, Institute of Dentistry, Barts and the London School of Medicine and Dentistry QMUL, Turner Street, London E1 2AD, UK
e-mail: d.g.gillam@qmul.ac.uk

S. Taha, B.H. Clarkson (eds.), *Clinician's Guide to the Diagnosis and Management of Tooth Sensitivity*,
DOI 10.1007/978-3-642-45164-5_5, © Springer-Verlag Berlin Heidelberg 2014

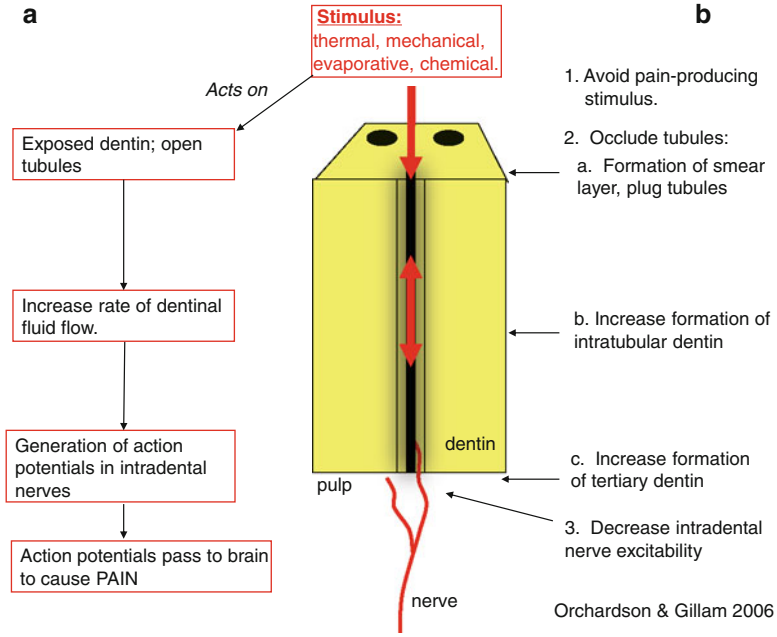

Fig. 5.1 Outline of the hydrodynamic mechanism by which (**a**) stimuli activate intradental nerves to cause pain and (**b**) subsequent resolution following natural desensitisation and treatment (Acknowledgement Orchardson and Gillam 2006)

out, since some clinical phenomena cannot be explained solely by this theory (Gillam 1992; Orchardson and Gillam 2006) (Fig. 5.1).

There are a number of products commercially available for the treatment of DH these include both in-office applied and over-the-counter products. The proposed mode of action for most of these products has been established using in vitro, animal, in situ and in vivo studies (Orchardson and Gillam 2006 Tables 5.1a and 5.1b).

5.2.1 Strontium-Containing Toothpastes

Strontium chloride has been claimed to act as both a protein precipitant and a tubule-occluding agent (Cohen 1961; Skurnik 1963; Blitzer 1967; Gedalia et al. 1978; Uchida et al. 1980). Gutentag (1965) however also demonstrated that strontium may stabilise excitable neural membranes by modifying their permeability to sodium and potassium. Several investigators have shown that strontium ions may be deposited as an insoluble barrier, possibly a calcium strontium–hydroxyapatite complex, at the dentin tubule openings (Pawlowska 1956; Ross 1961; Blitzer 1967; Gedalia et al. 1978). Kun (1976) however demonstrated in vitro that a topical application of concentrated strontium chloride solution produced a continuous deposit on the dentin surface as well as a degree of penetration into the dentin tubules. Furthermore he proposed as a result of evidence from the electron probe microanalysis and X-ray diffraction studies that the fundamental mechanism of the formation of strontium deposits was an exchange with the calcium of the dentin, resulting in recrystallisation in the form of strontium apatite. Evidence from other in vitro studies (Greenhill and Pashley 1981; Mostafa et al. 1983; Pashley et al. 1984; Addy et al. 1991), however, would appear to suggest that these results were attributable not to active ingredient per se but to the abrasive component(s) of a toothpaste which may contribute to the formation of a smear layer and to some degree occlude or block the exposed dentin tubule opening (Mordan et al. 2002) (Fig. 5.2a, b).

5.2.2 Selected Calcium Compounds

5.2.2.1 Casein Phosphopeptide–Amorphous Calcium Phosphate (CPP–ACP)

Toothpastes containing Casein Phosphopeptide–Amorphous Calcium Phosphate (CPP–ACP) were primarily developed for anticaries and

Table 5.1a Characteristics of selected occluding toothpastes

Product	Composition	Proposed mode of action
SensiStat®	Contains arginine in combination with calcium and bicarbonate/ carbonate	The arginine complex binds to the tooth surface and allows the calcium carbonate to slowly dissolve and release calcium. Limited in vitro and in vivo studies have been published in support of both laboratory and clinical claims for the product. Tubular occlusion
Colgate Pro-Argin™	Hydroxyapatite, sodium monofluorophosphate (MFP)	Recent in vitro and in vivo studies have been published in support of both laboratory and clinical claims for the product. Tubule occlusion
SensiShield® (NovaMin®)	Composed of calcium phosphorus, sodium and silica (calcium sodium phosphosilicate)	NovaMin® in contact with saliva and water reacts and releases Ca and PO4 ions. Sodium ions in the NovaMin particles exchange with hydrogen cations which in turn allows the calcium and phosphate ions to be released. A calcium phosphate layer is formed and subsequently crystallises into hydroxycarbonate apatite. The exposed dentin surface appears to act as a nucleation site for these ions to form hydroxycarbonate apatite and bypasses the intermediate phase of ACP formation. Mainly in vitro support for occlusion of dentine tubules, limited published clinical data supporting clinical efficacy of the product. Tubular occlusion
Amorphous calcium phosphate (ACP)	ACP is inorganic in nature and is made by combining soluble salts of calcium and phosphate through a two-phase system containing Ca in one part and PO4 in another. When mixed together they react to form an amorphous phosphate material that precipitates on to the tooth surface	ACP is highly soluble and susceptible to acid attack, and as such the ACP is not protected and as it has no delivery system, it has lower substantivity. It has lower substantivity. ACP is not bioavailable after the product is rinsed away. Previously incorporated in Enamelon toothpaste (no longer available) which relied on a dual-chamber system in the toothpaste tube. The product is now available in Enamel Care toothpaste (Church and Dwight). Limited and equivocal published data for effectiveness of ACP in the treatment of dentin hypersensitivity
Recaldent (CPP–ACP)	Casein phosphates (CPP) are peptides derived from milk protein casein that are complexed with calcium (Ca) and phosphate (PO4). In this complex the CPP maintains the Ca and PO4 ions in an amorphous form (ACP). The milk-derived peptide containing amorphous Ca and PO4 is the driving mechanism that binds to plaque, bacteria and the tooth surface	CPP–ACP uses peptides derived from the milk protein casein to maintain Ca and PO_4 in an amorphous calcium phosphate. The CPP binds to surfaces such as plaque, bacteria and soft tissue providing a bioavailable Ca and PO_4 at the surface of the tooth without precipitation. The ACP is released during acidic challenges. Stabilisation of ACP by the CPP ensures the delivery of Ca and PO_4 ions into the tooth structure before the ions crystallise. Most in vitro and in vivo studies support the product's anticaries benefit, however there does not appear to be any published clinical support on its effect in reducing dentin hypersensitivity
Nanit®active (Henkel)	Hydroxyapatite, sodium monofluorophosphate (MFP)	According to Henkel's product literature Nanit®active induces a process referred to as neomineralisation. The Nanit®active nanoparticles react with the calcium and phosphate ions in saliva, and a new protective layer is formed on the tooth surface (1–2 μm). Limited data available at present. Tubular occlusion

Acknowledgement from Mason et al. (2010) modified

remineralisation strategies rather than for the treatment of DH per se. According to Reynolds (1998), the CPP component binds to surfaces in the oral environment such as plaque, bacteria and soft tissue providing a bioavailable Ca and PO_4 at the surface of the tooth (e.g. enamel) without any precipitation. The ACP is subsequently released from the dental plaque during acidic challenges. The stabilisation of ACP component by the CPP ensures the delivery of both Ca and PO_4 ions onto the enamel surface for remineralisation. Both in vitro and in vivo studies have demonstrated that

Table 5.1b Characteristics of selected dentin blocking toothpastes

Product	Composition	Proposed mode of action
Blanx® Biorepair®	Hydroxyapatite, sodium monofluorophosphate (MFP)	Limited published data available at present. Tubular occlusion
Strontium salts (Sensodyne)	Strontium chloride (original), no fluoride	Hydrated technology. Published in vitro and in vivo studies supporting both the proposed mode of action and clinical effectiveness of both the acetate and chloride variants of the product. Tubular occlusion
	Strontium actate, sodium monofluorophosphate (MFP)	
Stannous fluoride	Stannous fluoride	Anhydrous technology. Uses hexametaphosphate to limit stains associated with the use of stannous ions. Two clinical studies in support of claims. Tubular occlusion
Crest® ProHealth™		
Colgate SnF_2	Stannous fluoride, potassium nitrate (5 %)	Dual-chamber delivery system. Published in vitro and in vivo studies supporting both the proposed mode of action and clinical effectiveness of the product. Presence of potassium would indicate its use as a nerve desensitiser; however in vitro studies tubule occlusion is in evidence. According to Mason et al. (2010) this product is no longer commercially available
Amine fluoride (elmex SENSITIVE)	Amine fluoride (olaflur)	Amine fluoride leads to the formation of a protective layer on the dentin containing calcium fluoride, which helps promote remineralisation and tubular occlusion. Limited published data available. Tubular occlusion

Acknowledgement from Mason et al. (2010) modified

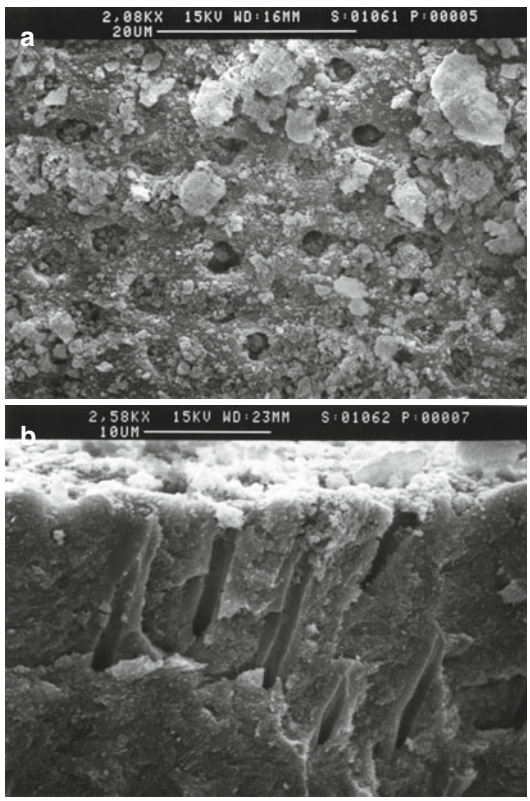

Fig. 5.2 (**a**) Coverage of the exposed dentin following a 2 min application of a fluoride toothpaste (Mordan et al. 2002). (**b**) Evidence of tubular occlusion of dentin tubules by toothpaste ingredients (e.g., silica) following a 2 min application of a fluoride toothpaste (Mordan et al. 2002)

calcium phosphate preparations deposit a mineral precipitate on to the dentin surface, block dentin tubules and reduce dentin permeability in the dentin disc model and DH in patients (Ebisu 2002; Suge et al. 2002; Cherng et al. 2004; Geiger et al. 2003; Azarpazhooh and Limeback 2008; Charig et al. 2009; Gandolfi et al. 2010; Walsh 2010) (Table 5.1a).

5.2.2.2 Calcium Carbonate and Arginine (Colgate Pro-Argin™)

Kleinberg (2002) suggested at physiological pH the positively charged arginine in the arginine/insoluble calcium carbonate compound combination binds to the negatively charged dentin surface enabling a calcium-rich mineral layer into the open (exposed) dentin tubule to act as an effective plug or tubular occludent. Initial laboratory (in vitro) evidence appears to support this in that the product does occlude the dentin tubules and effectively block fluid flow and is resistant to an acid challenge (Petrou et al. 2009), and subsequent clinical studies evidence appears to support its efficacy as a desensitiser (Ayad et al. 2009; Docimo et al. 2009; Hamlin et al. 2009; Nathoo et al. 2009; Schiff et al. 2009a, b, 2011; Que et al. 2010; Cummins 2011) (Table 5.1a). Recent systematic reviews by Sharif et al. (2013) and Yan et al. (2013) have also indicated that there are clin-

ical benefits for using Pro-Argin™ toothpastes in reducing DH; however both these investigators raised concerns regarding the quality of the conducted studies and recommended that further well-designed studies should be conducted to determine the efficacy of the product in reducing DH.

5.2.2.3 Bioactive Glasses

Bioactive glasses (calcium sodium phosphosilicate), for example, NovaMin® (developed by NovaMin Technology Inc., Alachua, FL, USA) based on the original 45S5 Bioglass® formulation by Larry Hench (US Biomaterials Corp., Jacksonville, FL, USA, now GSK) (Hench 2006), have been incorporated into toothpastes for the treatment of DH. The proposed mode of action is by the precipitating of hydroxycarbonate apatite (HCA) onto the dentin surface and subsequently occluding the dentin tubules (Litkowski et al. 1998; Gillam et al. 2002; Tai et al. 2006; Vollenweider et al. 2007; Burwell 2006; Burwell et al. 2009; Wang et al. 2010; Pradeep and Sharma 2010; Mneimne et al. 2011) (Table 5.1a).

One advantage of the precipitated HCA layer is that it is chemically and structurally similar to natural enamel and dentin (Burwell 2006). A recent randomised double-blind controlled trial, by Orsini et al. (2010), compared the clinical efficacy of a new toothpaste containing (HCA) nanocrystals and a sodium fluoride/potassium nitrate toothpaste and concluded that a new novel toothpaste formulation containing zinc-HCA nanocrystals significantly reduced DH after 4 and 8 weeks. There have however been concerns over the long-term durability of HCA in the oral environment, and it has been postulated that the formation of fluorapatite (FAp) rather than HCA is preferable, since this layer may be more resistant to acid attack and would therefore dissolve less readily when teeth are exposed to acidic conditions (e.g. during consumption of fruit juice and carbonated beverages). It has been recently demonstrated that fluoride-containing bioactive glasses form FAp rather than HCA in physiological solutions (Brauer et al. 2010).

5.2.2.4 Hydroxyapatite-Based Toothpastes

According to Hill et al. (2012), hydroxyapatite-based toothpastes have been widely used in China and the Far East (Park et al. 2005; Kang et al. 2009; Kim et al. 2009; Yuan et al. 2012). The published literature on hydroxyapatite toothpastes however is mainly in non-English journals and may, therefore, not be readily available in an English translation format (Park et al. 2005; Kang et al. 2009; Kim et al. 2009; Yuan et al. 2012). More recently, the commercial emphasis has focused on the use of nanocrystalline hydroxyapatite in toothpastes for desensitising and remineralising strategies (Rimondini et al. 2007; Orsini et al. 2010; Tschoppe et al. 2011). The proposed mechanism of action for hydroxyapatite-containing toothpastes is blocking the dentin tubules (Rimondini et al. 2007; Hill et al. 2012; Yuan et al. 2012) (Table 5.1a).

5.2.3 Selected Fluoride Formulations

Fluoride was first proposed as a desensitising agent in 1941 by Lukomsky (1941) and has subsequently used in toothpastes, gels, mouth rinses and varnishes (Orchardson and Gillam 2006). Sodium fluoride and stannous fluoride have been shown to reduce DH (Morris et al. 1999), and amine fluoride has also been incorporated into dentifrices although there is currently limited published data to support its use. Stannous fluoride (SnF_2) in a 0.4 % glycerin gel has also been reported to be effective in reducing DH (Miller et al. 1969) although this formulation and the use of SnF_2 may be problematic for a number of reasons, for example, (1) when placed in an aqueous environment, it appears to undergo hydrolysis and precipitates out of solution (Miller et al. 1969) hence the incorporation into a gel and (2) poor taste and staining characteristics. More recently investigators have demonstrated that a reformulated toothpaste containing stannous fluoride with a novel 0.454 % stabilised stannous fluoride formulation containing sodium hexametaphosphate (SHMP) was effective in reducing DH during an 8-week treatment compared to a sodium fluoride toothpaste as a control (Schiff et al. 2005, 2006; Day et al. 2010; Einwag et al. 2010; cited by Ni et al. 2010). According to Greenhill and Pashley (1981), fluorides decrease the permeability of dentine in vitro possibly by the precipitation of

insoluble calcium fluoride within the tubules. However the exact mechanism whereby fluoride reduces DH is unknown. Fluoride incorporation increases the resistance of dentin to decalcification (Furseth 1970) and reduces its solubility (Sandoval and Shannon 1969) as fluorapatite is more resistant to acid attack(s) than hydroxyapatite. Sodium monofluorophosphate has also been previously investigated as a toothpaste ingredient with desensitising effects by Hazen et al. (1968) and by Addy et al. (1987) who reported on its clinical effectiveness in combination with strontium acetate. Recently several investigators have reported on the clinical efficacy of a combined sodium monofluorophosphate/strontium acetate formulation for the treatment of DH (Mason et al. 2010; Hughes et al. 2010) (Table 5.1b). Higher fluoride concentration toothpastes containing 2,800/5,000 ppm sodium fluoride (Colgate Duraphat) have also been advocated for prevention of dental caries and as such may be of potential benefit in the treatment of root caries and DH.

One however should not ignore that natural desensitisation of dentin (both internally and externally) may occur irrespective of whatever treatment is provided by the clinician to the patient. For example, Orchardson and Gillam (2006) have suggested that there may be natural desensitising of dentin through precipitation of salivary proteins, toothpaste ingredients, etc., forming a smear layer which may occlude the dentin tubules or remineralisation (Pashley 1992a; Kawasaki et al. 2001) as well as the formation of both intra-tubular dentin and secondary/tertiary dentin over time (Addy and Dowell 1983) (Fig. 5.1).

5.3 Nerve Desensitisation and Noci0ception

As indicated earlier, the hydrodynamic theory (Brännström 1963) is generally considered to be the mechanism of choice, and as with dentin blocking agents, this theory appears to explain how nerve desensitisation may occur following the application of potassium-containing products (e.g. toothpastes gels, mouth rinses).

Several investigators (Greenhill and Pashley 1981; Pashley et al. 1984) however failed to observe any effect of potassium nitrate (either as a 30 % solution or 5 % toothpaste) in terms of a reduction in dentin fluid flow (dentin permeability) in the in vitro dentin disc model. In other words, these investigators were unable to demonstrate whether potassium nitrate reduced DH by blocking the dentin tubules and were therefore unable to determine the exact mechanism of action of potassium-containing toothpastes which were reported to be clinically effective when treating DH. These investigators however did not rule out the possibility that these agents may desensitise dentin via neural effects unrelated to hydrodynamic mechanisms.

In order to ascertain the precise mechanism for action for potassium, several investigators utilised a neurophysiological animal (cat) model which involved deep-cut cavity preparations with a very thin slice of dentin between the exposed dentin surface and the pulp (Kim 1986; Markowitz and Kim 1985, 1990; Markowitz et al. 1991). These investigators subsequently demonstrated that when using large molar concentrations of various divalent cation solutions (including potassium) applied to the dentin surface, both intradental nerve activity and sensory nerve activity were reduced. It was also evident from these studies that the important chemical moiety of potassium nitrate was the potassium salt and not the nitrate anion as previously believed. Furthermore potassium appeared to be the more effective desensitising agent compared to the other solutions tested irrespective of which combination of anion was used. On the basis of these observations, these investigators proposed that the mode of potassium desensitisation was through raising the intra-tubular potassium (K^+)

Table 5.2 Characteristics of selected nerve depolarising toothpastes

Product	Composition	Proposed mode of action
Sensodyne	Potassium nitrate, sodium fluoride (NaF)	Hydrated toothpaste technology. Evidence of a desensitising action based on historical animal studies. No evidence of tubular occlusion when potassium ions were tested in vitro. Evidence from the published literature suggests that potassium-containing toothpastes are effective in reducing dentin hypersensitivity although there is no evidence to suggest that it is by nerve depolarisation. Recent clinical study has reported that there is a transient depolarising effect when potassium ions are applied on exposed dentin
Colgate	Potassium nitrate, sodium monofluorophosphate (MFP)	
Crest	Potassium sodium fluoride (NaF)	
Sensodyne	Potassium chloride sodium fluoride (NaF)	
Colgate	Potassium citrate sodium monofluorophosphate (MFP)	

Acknowledgement from Mason et al. (2010)

concentration which would render the intradental nerves less excitable to any further stimulation by depolarisation of the nerve fibre membrane. Initially this increase in the potassium ion content elicits an increased number of action potentials, after the initial depolarisation; however the nerve fibre(s) cannot depolarise due to the maintained high levels of extracellular potassium ion content and as a consequence a sustained depolarised state occurs (axonal accommodation).

The interpretation based on the investigation by Kim and co-workers (1985, 1986, 1990, 1991 see above) has however been criticised by Sena (1990) who suggested that as a result of the deep-cut cavity preparations in the cat, the applied potassium ion only had a short distance to traverse the length of the dentin tubule to exert its effect to desensitise the nerve. In the normal clinical situation (in intact human teeth), however, the incoming potassium ion (e.g. if applied in a toothpaste product on the exposed cervical dentin) would have to overcome the opposing pulpal pressure that produces an outward flow of dentin fluid. Such an outward flow may therefore prevent the inward diffusion of substances from the oral cavity. Currently it is important to note that this proposed mechanism was based on animals and has not been confirmed for human dentin (Orchardson and Gillam 2000) (Table 5.2). For example if the desensitising effects of potassium are due to action potential inactivation, one might expect as Orchardson and Gillam (2000) suggested that the patient would experience a transient pain when a potassium-containing toothpaste is applied to the exposed dentin surface. This phenomenon has not been reported for toothpastes in humans. It may also be of note in this context, however, to reconsider the work by Anderson and co-workers (1958, 1962a, b) who postulated that if dentin was directly innervated, then chemical stimuli to the exposed dentin surface should cause a patient discomfort. Application

of algogenic (pain-inducing) substances such as potassium chloride, acetylcholine and histamine, however, failed to elicit a response. By way of contrast when these substances were applied directly to exposed pulpal tissue, an immediate response was elicited (Anderson and Naylor 1962; Anderson 1968, 1972). This observation may therefore be of interest when ascertaining the precise mode of action of potassium-containing preparations.

Several investigators have however attempted to explain the role of potassium diffusion across dentin (Stead et al. 1996; McCormack and Davies 1996).

(a) *Mathematical Model of Potassium Ion Diffusion*

In order to ascertain whether the potassium ion could diffuse down the dentin tubule, Stead et al. (1996) proposed a mathematical model of potassium ion diffusion which incorporated a number of variables, for example, dentin thickness, tubule diameter, time, diffusion gradient, outward fluid flow, the constituents of dentin fluid (molecule size), permeability of the odontoblast layer and the concentration of potassium (based on 5 % potassium in toothpastes).

According to these investigators, the application of potassium-containing preparations to the exposed dentin may increase potassium ions at the inner ends of the dentinal tubules to levels sufficient to inactivate intradental nerves; however, the localised increase in potassium ions may only be transient, and the concentration change will also be reduced by conditions that increase the tubular fluid flow velocity or the permeability of the barrier between the tubule and the pulp. The prediction from this model regarding nature of the transient effect of the potassium ion on nerve inactivation may be of interest particularly in the light of the results from the clinical studies by Ajcharanukul et al. (2007, 2011, 2012). These investigators utilised a cut cavity preparation approach based on the animal model in human subjects and demonstrated that potassium salts had a transient desensitising effect as predicted by Stead et al. (1996). However one of the conclusions from these studies was that the hydrodynamic mechanism responsible for responses to stimulation of dentin in humans has different properties from those demonstrated in the cat and may not necessarily be mediated by a hydrodynamic mechanism.

(b) *The Role of Nitric Oxide as a Secondary Messenger*

One of the problems with the mathematical model of potassium diffusion as proposed by Stead et al. (1996) was the various constraints to the diffusion of the potassium ion along the entire length of the dentin tubule (Orchardson and Gillam 2000). An alternative mechanism for potassium ion-mediated desensitisation was proposed by McCormack and Davies (1996). These investigators suggested that the potassium ion could evoke a novel synthesis of a mobile secondary messenger (nitric oxide) within dentin and the dental pulp. The proposed hypothesis is that the potassium ion may act on the odontoblast process to release nitric oxide (in the dental pulp) which in turn produces an analgesic effect by modulating nociceptive input through downregulation of sensitised nociceptors. Although this hypothesis may provide a plausible explanation for the role of the potassium ion in the treatment of DH there does not appear to be any supporting evidence from the published literature (Orchardson and Gillam 2000; Jackson 2000).

According to Orchardson and Gillam (2000), there appears to be no convincing evidence that desensitising preparations based on potassium chloride, nitrate and citrate act in the manner proposed. It is possible that any desensitising effects may be due to constituents other than the potassium salts. Although there is some evidence that toothpastes containing potassium ions are more effective than minus-active preparations in reducing dentin hypersensitivity, the potassium-containing

preparations are not always superior to controls such as sodium monofluorophosphate. Furthermore while a number of studies included in the Orchardson and Gillam (2000) review reported that potassium-containing salts were significantly better than the inactive (placebo) controls, a number of these studies did report an appreciable reduction in dentin hypersensitivity with the supposedly 'inactive' controls. One of the problems, in evaluating the various studies was the reported variation(s) in the extent of the 'control/placebo' response which may have accounted for most of the disparities between trial outcomes (Jackson 2000; Cummins 2009, 2010). A previous published systematic review by Poulsen et al. (2006) included six studies in the meta-analysis and concluded that there was no clear evidence available in the published literature for the support of potassium-containing toothpastes for the relief of DH. More recent reviews by Pol et al. (2010) and Karim and Gillam (2013) also highlighted the lack of data on the efficacy of potassium salts in reducing dentin hypersensitivity.

The use of topical guanethidine (1 % guanethidine solution (Ismelin, Ciba-Geigy, UK)) as a desensitiser has also been advocated although there are only two published studies by Hannington-Kiff and Dunne (1993) and Dunne and Hannington-Kiff (1993). These investigators proposed that topically applied guanethidine affects the anti-noradrenergic mechanisms in the teeth.

5.4 Placebo Effect

Both placebo and nocebo effects have been documented in the published literature and may impact on the results from studies evaluating the efficacy of a drug. The term 'nocebo' comes from the Latin 'noceo', to harm, and means 'I shall harm', whereas the term 'placebo' means 'I shall please' (Definition of placebo 2013: http://www.medterms.com). A negative placebo effect may occur during a clinical study where patients participating in the study experience adverse side effects unrelated to the specific pharmacological action of the drug that they are taking. The nocebo effect may be associated with a subject's prior expectations of adverse effects from treatment as well as with conditioning in which the subject learns from prior experiences to associate a medication with certain somatic symptoms (Definition of nocebo effect 2013: http://www.medterms.com). The placebo or placebo effect has been defined in the following manner:

(a) A substance containing no medication and prescribed or given to reinforce a patient's expectation to get well.
(b) An inactive substance or preparation used as a control in an experiment or test to determine the effectiveness of a medicinal drug.
(c) An active placebo – a placebo used in experimental tests of a drug that has noticeable side effects; 'an active placebo mimics the side effects of the experimental drug' (Definition of active placebo 2013: www.thefreedictionary.com).

According to Oken (2008), the interaction between the clinician and the subject during a clinical study may have an impact on outcomes independent of any specific treatment. For example, 'expectancy' may be affected by the personal history of subject–clinician interactions and shared experiences of the subject and clinician. Several investigators have also suggested that any placebo effects during a study may also be influenced by the number of subject–clinician interactions (Ilnyckyj et al. 1997; Paternak and Zimmerman 2007 cited by Oken 2008). There may also be other non-specific benefits from this interaction during a clinical study, for example, stress reduction, decreased anxiety or improvement of mood of the subject. According to Oken (2008), some clinicians are perceived to be better clinicians than others as a result of their personality or interaction style. These factors may therefore have profound effects in clinical studies, in particular pain-type studies, for example, a dentin hypersensitivity study, designed to evaluate the efficacy of various desensitising agents.

For example, a number of published studies evaluating desensitising toothpastes have demonstrated improvement in symptoms ranging from 30 to 80 % reduction in sensitivity when comparing test toothpastes to other toothpastes and placebo controls (Clark and Troullos 1990). The results from these studies are however somewhat conflicting and difficult to interpret, due in part to different methodologies and patient selection criteria. One of the main inherent problems in conducting clinical studies designed to assess the efficacy of desensitising products is the interference of placebo and/or Hawthorne effects that may introduce a degree of bias into the study (Gillam 1997, 2011; Addy et al. 2007). Several investigators have suggested that the utilisation of a double-blind placebo-controlled study is one possible way of resolving this particular bias, although such effects cannot be completely eliminated (Jeffcoat 1993; Holland et al. 1997; ADA Acceptance Program Guidelines 2012). For example, several investigators have reported that this effect can be as high as 40 % (Curro et al. 2000; West et al. 1997). Other investigators have also alluded to this effect in their published studies (Gillam et al. 1996, 1997a; Pearce et al. 1994; Chesters et al. 1992), but to what extent the placebo effect complicates the interpretation of the results of the study is difficult to predict. It should however be noted that according to Curro et al. (2000) the placebo effect observed in dentin hypersensitivity studies is not too dissimilar to those reported in other medical and dental therapeutic studies. For example, a review of 15 postoperative pain studies by Beecher (1955) cited by Curro et al. (2000) concluded that on average symptoms were satisfactorily relieved by the placebo medication in 35 % of the patients (the placebo response range of 15–58 %). According to Hróbjartsson and Gøtzsche (2001) in a systematic review detailing 27 trials involving the treatment of pain, the placebo had a beneficial effect, as indicated by a reduction in the intensity of pain of 6.5 mm on a 100-mm visual-analogue scale. If the magnitude of the placebo effect is reproduced in a clinical study, this may well confound any effects of efficacy of the active product. These and other confounding factors, for example, a random variation in patient symptoms over time (regression to the mean/mode, conditioning effects during the study, small sample size) affecting dentin hypersensitivity studies may also be complicated by the lack of universally acceptable positive and negative controls used in equivalence and superiority studies (Gillam 2011). A further problem that may confound determining the efficacy of these desensitising products is that the clinical efficacy of these products may be at the lower end of the therapeutic range (Addy et al. 2007). Curro et al. (2000) also suggested that subjects with chronic conditions such as dentin hypersensitivity typically have episodic or fluctuating symptoms and any potential change in these symptoms over time in a clinical study may be one of improvement (the so-called expectancy effect). A patient's expectancy of improvement may therefore influence outcomes as much as some active interventions, and this effect may be greater for novel interventions and for procedures (Oken 2008). It may therefore be suggested that the clinical study duration should be of a suitable duration (e.g. at least 6 weeks) as to minimise any 'placebo effects'.

It is important however to acknowledge that the amount of time required for a particular desensitising agent to achieve clinical effectiveness may be affected by several factors, including (a) variations in the motivation of individual patients and their ability to apply the product as intended and (b) the nature of the test agents and their likely mode of action. These factors may therefore dictate the design, nature and duration of any proposed clinical study.

5.5 Restorative Approaches

There are a number of restorative approaches for the treatment of DH that are provided for patients with localised moderate to severe DH which require immediate palliative alleviation (Orchardson and Gillam 2006). As indicated in Chap. 6, these desensitising agents may be classified on the basis of (1) whether products do not polymerise (varnishes/precipitants/primers containing HEMA), (2) whether they undergo setting

or polymerisation reactions (conventional glass ionomer cements, or resin-reinforced glass [ionomers/compomers; adhesive resin primers; adhesive resin bonding systems), (3) the use of mouthguards, (4) iontophoresis combined with fluoride pastes or solutions and (5) lasers (Pashley 2000). Examples of these products are resins, varnishes, primers, dentine bonding agents and glass ionomer cements which contain fluoride, aluminium, potassium or ferric oxalates; silica or calcium-containing materials; and protein precipitants to decrease dentin permeability or block the fluid movement through dentin (Tables 5.3 and 5.4). Other miscellaneous treatment approaches have also been recommended, for example, occlusal adjustment associated with cervical abfraction lesion (Coleman et al. 2003), crown restorations, root coverage surgery, pulp extirpation, extraction (Ong and Strahan 1989), homoeopathic remedies (Plantago) (www.hpathy.com), propolis (Mahmound et al. 1999) and hypnosis (Starr et al. 1989; Eitner et al. 2010). It should however be acknowledged that some of these restorative procedures may also initiate post-operative sensitivity, for example, crown preparations, restorations, restorative materials, nonsurgical (scaling) and surgical procedures and sensitivity from bleaching or whitening procedures. One of the problems, however, when recommending or evaluating these restorative approaches for the treatment of dentin hypersensitivity is that dental professionals not only appear to be uncertain as to the most successful way in which to manage dentin hypersensitivity but also express a level of dissatisfaction with the various products and techniques available (Cunha-Cruz et al. 2010).

Table 5.3 Selected dentin desensitising solutions and products tested in clinical trials

Type, chemical/ concentration	Product and clinical support
Fluorides	
Sodium fluoride, stannous fluoride, hydrogen fluoride	Dentinbloc, Colgate Oral Pharmaceuticals, Canton MA, USA (Thrash et al. 1992; Morris et al. 1999)
Potassium nitrate	
1–15 % solutions	Hodash (1974)
5, 10 % in gel	Frechosa et al. (2003)
Oxalate	
3 % potassium oxalate	Protect, Sunstar Butler, Chicago, IL, USA Camps and Pashley (2003)
3 % potassium oxalate	Oxa-gel, Art-dent Ltda, Araraquara, SP, Brazil Pillon et al. (2004)
6.8 % ferric oxalate	Sensodyne Sealant, GSK, Jersey City NJ, USA Gillam et al. (2004)
Calcium phosphates	
1.5M calcium chloride + 1.0M potassium oxalate	Geiger et al. (2003)
D/Sense 2 (Centrix Direct)	Kolker et al. (2002) (in vitro)
Quell Desensitizer (Pentron Clinical Technologies)	

From Orchardson and Gillam (2006), Pashley et al. (2008) modified

1. *Selected Non-polymerising Products*

   These products include varnishes/precipitants/primers containing HEMA.

   Historically varnishes and cavity liners such as Copalite have been recommended for the treatment of dentin hypersensitivity (Wycoff 1982), although most of these varnishes appear to provide inadequate insulation against thermal conduction under restorative materials (Voth et al. 1966). Varnishes such as copal varnishes (copal resin in an ether solution) were shown to be incompatible with the resin-based restorations due to their effect on the polymerisation process (Tjan and Chan 1987). As a result, a number of resin-compatible cavity varnishes, for example, Univar/Uniseal/Microjoin (Sci Pharm Duarte, Ca, USA) were introduced and evaluated on their ability to block dentin tubules (Tjan and Chan 1987; Tjan et al. 1987). Fluoride varnishes such as Duraphat® (Colgate Oral Pharmaceuticals), Dentinbloc (Colgate Oral Pharmaceuticals), Bifluorid 12 (VOCO GmbH), Isodan® (Septodont), Shellac F Cervitec® or Fluor Protector (Ivoclar Vivadent) have also been previously evaluated for the treatment of dentin hypersensitivity (Collaert et al. 1991; Thrash et al. 1992; Kielbassa et al. 1997; Gaffar 1999; Morris et al. 1999;

Table 5.4 Selected professionally applied dentin desensitisers tested in clinical trials

Type	Product and clinical support
Fluoride varnish	Duraphat, Colgate Oral Pharmaceuticals, Canton, MA, USA (Gaffar 1999; Corona et al. 2003)
	Fluoline, PD Dental, Altenwalde, Germany (Duran and Sengun 2004)
	Duraflor (Pharmascience) (Merika et al. 2006)
	Fluor Protector (Ivoclar Vivadent)/AllSolutions Fluoride Varnish (Dentsply) (Ritter et al. 2006)
Oxalic acid + resin	MS Coat, Sun Medical Co, Shiga, Japan (Prati et al. 2001)
	Pain-Free, Parkell Co, Farmingdale, NY, USA (Morris et al. 1999)
Sealants, primers	Seal and Protect, Dentsply, Konstanz, Germany (Baysan and Lynch 2003; Aranha et al. 2009)
	Dentin Protector, Vivadent, Germany (Schwarz et al. 2002)
	Gluma Desensitizer, Heraeus Kulzer, Dormagen, Germany (Duran and Sengun 2004; Dondi dall' Orologio and Malferrari 1993, Dondi dall' Orologio et al. 1999, 2002; Polderman and Frencken 2007; Aranha et al. 2009; Mehmood et al. 2011)
	Gluma Alternate, Heraeus Kulzer, Wehrheim, Germany (Dondi dall'Orologio et al. 1999)
	Health-Dent Desensitizer, Healthdent Inc, Oswego, NY, USA (Duran and Sengun 2004; Dondi dall'Orologio et al. 1999)
	Hemaseal and Cide (Germiphene)/HurriSeal Dentin Desensitizer (Beutlich Pharm.) (Kolker et al. 2002)
	One-Step (Bisco, USA) (Kakaboura et al. 2005)
	Prime and Bond 2.1, Dentsply Caulk, Milford, DE, USA (Swift et al. 2001)
	Scotchbond (Single Bond), 3M Dental Products, St Paul, MN, USA (Duran and Sengun 2004; Prati et al. 2001; Ferrari et al. 1999)
Etch + primer	Scotchbond, 3M Dental Products, St Paul, MN, USA (Ferrari et al. 1999)
	Systemp.desensitizer, Ivoclar Vivadent, Schaan, Liechtenstein (Stewardson et al. 2004)
Etch + primer + adhesive	Scotchbond Multi-Purpose Adhesive, 3M Dental Products, St Paul, MN, USA (Dondi dall'Orologio et al. 1999)
Primer + adhesive	SE Bond, Kuraray, Okayama, Japan (Duran and Sengun 2004)
Glass ionomer cements	Resin-modified glass ionomer liner (Vitrebond 3M ESPE) (Hansen 1992; Tantbirojn et al. 2006)
	Fuji VII (GC) (Polderman et al. 2007)

From Orchardson and Gillam (2006), Pashley et al. (2008) modified

Panduric et al. 2001; Merika et al. 2006; Ritter et al. 2006; Hoang-Dao et al. 2009; Bhandary and Hegde 2012). According to Ritter et al. (2006), the topical application of fluoride varnishes was thought to create a barrier by the precipitation of CaF_2 onto the exposed dentin surface which, in turn may occlude the dentin tubules thereby reducing dentin permeability and, as a consequence, DH. From a practical viewpoint, the application of a fluoride varnish may be useful in identifying whether a patient has DH during the diagnosis examination in order to rule out any other dental cause. The application of fluoride varnishes may also be incorporated in a stepwise management programme where non-invasive procedures are undertaken, and depending on whether the problem has been resolved or not, the clinician may either proceed to provide additional applications of the varnish or opt to provide a more invasive procedure (Orchardson and Gillam 2006). Other treatment approaches include the application of Hema-containing primers, for example, Gluma (5 % glutaraldehyde primer and 35 % hydroxyethyl methacrylate), calcium hydroxide and oxalate varnishes (Pashley 2000; Orchardson and Gillam 2006) (Tables 5.3 and 5.4). The efficacy of Hema-containing primers in treating DH has been evaluated in a number of clinical studies. For example, Felton et al. (1991) applied the primer to the facial surfaces of crown preparations in 20 patients and reported that in response to air, tactile and osmotic stimuli, DH was significantly reduced after 14 days compared to the control group. Other

investigators (Dondi dall' Orologio and Malferrari 1993, Dondi dall' Orologio et al. 1999, 2002; Duran and Sengun 2004) reported similar successful results when using the primer on exposed dentin. However a study by de Assis et al. (2006) in periodontal patients with hypersensitive teeth failed to demonstrate any efficacy with Gluma Desensitizer® compared to the control group. A more recent study by Mehmood et al. (2011) compared Gluma Desensitizer® with Duraphat® in 196 patients with non-carious cervical lesions. They conclude that Gluma Desensitizer® significantly reduced DH compared to the Duraphat® varnish. A 6-month study by Aranha et al. (2009) evaluated Gluma Desensitizer® with four other products or therapies (Seal and Protect, OXA GEL, fluoride and low-intensity laser treatment). They concluded that although both Gluma Desensitizer® and Seal and Protect had an immediate effect in reducing DH, all therapies demonstrated lower sensitivity scores at the 6-month evaluation point. The proposed mechanism of blocking the tubules with HEMA-containing primers may be a result of the glutaraldehyde component reacting with the albumin within the dentin fluid by protein precipitation; this in turn may reduce the outward fluid flow and as a consequence reduce DH (Pashley 2000).

The application of oxalate-containing solutions has also been evaluated for treating DH (Muzzin and Johnson 1989; Salvato et al. 1990; Kerns et al. 1991; Morris et al. 1999; Gillam et al. 1997, 2004; Pashley et al. 2001; Camps and Pashley 2003; Tay et al. 2003; Pillon et al. 2004; Pamir et al. 2007) although according to Pashley (2000) and Orchardson and Gillam (2000), the clinical evidence is somewhat inconclusive. In this context it is of interest that despite this reservation on the efficacy of these products, 40 % of practising dentists in the USA reported using oxalate preparations in order to treat DH (Cunha-Cruz et al. 2010). A systematic review by Cunha-Cruz et al. (2011) concluded that many of the oxalate products that were included for evaluation in the review were no better than the placebo controls with the possible exception of a 3 % monohydrogen monopotassium oxalate solution. These investigators concluded that the current evidence did not support recommending using oxalates for the treatment of DH. The mechanism by which oxalate products block the dentin tubules has been demonstrated by a number of investigators (Greenhill and Pashley 1981; Gillam et al. 2001; Yiu et al. 2005). According to Yiu et al. (2005) following the application of the oxalate solution on the depletion of calcium ions from the surface dentin forces the oxalate ions to diffuse further down into the dentin tubule and react to form insoluble calcium oxalate crystals. This reaction results in a subsurface tubular occlusion which will reduce fluid flow (dentin permeability) within the dentin tubules.

According to Pashley (2000), the use of calcium hydroxide paste has been applied for the treatment of DH. For example, Green et al. (1997) applied a 5-min treatment of calcium hydroxide on hypersensitive root surfaces and reported that in response to thermal and mechanical stimuli, DH was reduced for the duration of the 3-month study. Wolfart et al. (2004) also compared a calcium hydroxide solution with a glutaraldehyde-based dentin primer in 36 patients undergoing crown preparations and evaluated over a 30-month period. Although the investigators reported that a calcium hydroxide solution may be useful in treating DH, there were no reported differences between the two products. According to Ling and Gillam (1996) citing McFall (1986), calcium hydroxide blocks the dentin tubules by a deposition of calcium ions that bind to free protein radicals and increasing the remineralisation of the exposed dentin. It was claimed that the initial application was successful for 80–90 % of the time, but this effect rapidly diminished and frequent reapplication was required. Pashley et al. (1986) applied a calcium hydroxide paste to human dentin in vitro in order to determine its effects on dentin permeability. The results indicated that although the paste reduced dentin permeability

in both smear layer and non-smear layer samples, calcium hydroxide provides little protection to an acid challenge. On the basis of these studies, it would appear that the use of calcium hydroxide on exposed root surfaces may be of limited value.

2. *Selected Products That Undergo Setting or Polymerisation Reactions*

These products include conventional glass ionomer cements, or resin-reinforced glass ionomers/compomers; adhesive resin primers; and adhesive resin bonding systems.

The use of conventional glass ionomer cements (GIC) or resin-reinforced glass ionomers/compomers has been recommended for a number of clinical conditions in the oral cavity, for example, as a liner in prepared cavities (Hansen 1992; Tantbirojn et al. 2006; Burrow et al. 2009), fissure sealing (Pardi et al. 2003), cementing orthodontic brackets (Charles 1998), treatment of dentin hypersensitivity (Wycoff 1982), non-carious cervical lesions (Francisconi et al. 2009) and a combined surgical/restorative intervention of gingival recession with associated non-carious cervical lesions (Santamaria et al. 2007). It should however be acknowledged that the term 'glass ionomer cement' is loosely applied in the published literature and therefore may be somewhat misleading as there are differences between the original GIC product and the various resin-modified and composite resin materials that have been developed over the last 20–30 years. From a clinical point of view, it is important to note that they may bind differently to the tooth surface depending on whether they are a conventional GIC or a resin-modified GIC (Tyas and Burrows 2004). According to Mount et al. (2009), with the conventional GIC or a resin-modified GIC, there is an ion exchange adhesion with the tooth surface via a polyacid interaction even though the initiation may be different (acid–base setting/acid–base setting plus photoinitiation). There is also a sustained fluoride release from the material as well as a subsequent fluoride recharging from the oral environment over time has also been demonstrated. With both the conventional and polyacid-modified composite resin systems there does not appear to be any particular benefit apart from a minimal benefit via a polyacid reaction of the polyacid-modified composite resin system (Mount et al. 2009). Several investigators have used various GIC products to treat DH, for example, Low (1981) reported a reduction in sensitivity following the placement of the material in cervical abrasion lesions. Polderman and Frencken (2007) also reported that a low-viscosity glass ionomer (Fuji VII) was more effective in treating DH than Gluma Desensitizer after 3 months and after 24 months.

The rationale of using adhesive restorative materials (dentin bonding agents, resins and adhesives) for the treatment of DH was based on the possibility of blocking the dentin tubules (Brännström et al. 1979; Pashley 1992b). Results from the initial studies using these materials indicated that there was an immediate and long-lasting effect in reducing DH except when the adhesive sheared off the dentin surface resulting in a return to the previous baseline values (Ling and Gillam 1996). According to Tyas and Burrows (2004), the mechanism by which these materials bond to the dentin is via a hybrid layer or resin-impregnated layer. Basically this is a micromechanical interlocking of resin around the collagen fibrils exposed by the demineralisation process during the pretreatment phase when placing the material onto the dentin surface. From a clinical viewpoint, these materials offer a challenge to the dental practitioner as they are very technique sensitive and require careful handling and manipulation. It is essential that the dental professional follow the instructions from the manufacturer very carefully when placing the material in the oral environment. Furthermore it is also important that the dental professional has an understanding of the characteristics associated with both conventional glass ionomer cements, or resin-reinforced glass ionomers/compomers, and adhesive restorative materials in order to

maximise the usefulness of these materials in the oral environment.

According to Orchardson and Gillam (2006), the dental professional should be aware of the pragmatic nature of the published clinical studies of adhesive desensitising materials. For example, many of the reported studies are single-blind studies because true double-blind conditions are difficult to achieve. A further problem when analysing results from the published literature is that there has been a major change in the available products since the original introduction of dentin bonding agents, resins and adhesives. A selection of published studies that claim to relieve DH by blocking the dentin are presented in Table 5.4 (based on Orchardson and Gillam 2006 and Pashley et al. 2008 published reviews). A recent 6-month study by Veitz-Keenan et al. (2013) reported on the use of a potassium nitrate toothpaste, sealant (one-step self-etch dentin bonding agent [Clearfil S3 Bond, Kuraray, Okayama, Japan]/Clearfil Liner Bond 2 Protect Liner F, Kuraray) or restoration (dentin bonding agent [Clearfil S3 Bond]/flowable composite resin [Premise Flowable, Kerr]) for the treatment of hypersensitive non-carious cervical lesions. The results indicated that both the sealant and the restoration treatment proved equally effective for most participants in reducing dentin hypersensitivity in non-carious cervical lesions.

The application of both adhesive restorative materials (dentin, bonding agents, resins and adhesives) would therefore appear best suited to localised rather than generalised areas of dentin hypersensitivity and would appear to be ideal for using within the stepwise minimal intervention approach as suggested by Orchardson and Gillam (2006).

3. *Use of Mouthguards*

According to Haywood (2000) and Tredwin et al. (2006), tooth sensitivity is a common adverse reaction of external bleaching procedures. It has also been reported in the literature that patients who have a pre-existing history of DH or with gingival recession and associated DH may be more likely to experience DH during the bleaching process (Leonard et al. 2004). For patients with pre-existing dentin hypersensitivity, the use of a desensitising product, for example, 5 % potassium nitrate (toothpaste or in a bleaching tray), prior to bleaching the teeth may alleviate further discomfort during the bleaching phase of the treatment (Haywood et al. 2001, 2005). Other products such as amorphous calcium phosphate (ACP) have also been recommended for the prevention of DH/bleaching sensitivity either as a toothpaste or as a professionally applied product (Giniger et al. 2005). According to Haywood (2002), the incidence of DH/bleaching sensitivity ranges between 55 and 75 % of subjects undergoing bleaching procedures in randomised clinical trials.

Several investigators have suggested that bleaching sensitivity is mediated by a hydrodynamic mechanism (Croll 2003; Swift 2005; Markowitz 2010). Croll (2003) described a mechanism where oxygen bubbles from the carbamide or hydrogen peroxide form in the dentin tubules during the bleaching process and initiate dentin fluid movements that in turn may activate the intradental nerves. No evidence however has been advanced to support this interesting hypothesis although the hydrodynamic hypothesis does not appear to fully explain the mechanism of pain associated with the bleaching process.

4. *Iontophoresis Combined with Fluoride Pastes or Solutions*

Several investigators have recommended the use and application of fluoride with or without iontophoresis (Gangarosa and Park 1978; Brough et al. 1985; Gupta et al. 2010; Aparna et al. 2010) although the clinical efficacy of this technique has been questioned (Gillam and Newman 1990; Pashley 2000).

5. *Lasers*

The use of laser technology has been advocated by several investigators for the treatment of DH (Renton-Harper and Midda 1992; Kimura et al. 2000; Yilmaz et al. 2011a, b; Umberto et al. 2012). The evidence for the efficacy of this therapy is, however, somewhat equivocal (West 2007; He et al. 2011)

(see Chap. 6). According to Kimura et al. (2000), the rationale and mechanism of how laser therapy is effective in treating DH is inadequately explained. A number of investigators have proposed that lasers may work either through a process which involves the coagulation and precipitation of plasma proteins in the dentin fluid (Pashley 2000) or by the effect of the emitted thermal energy from the laser altering intradental nerve activity (Orchardson et al. 1997, 1998). McCarthy et al. (1997) however reported that both Nd:YAG and Er:YAG lasers caused alteration of the dentin surface either by melting and re-solidification of the dentin with partially blocked tubules (Nd:YAG) or by ablation of the dentin surface leaving craters and open tubules (in the dentin discs) or blocked tubules (on the root surface) (Er:YAG), but neither lasers produced a smooth glazed impermeable surface. There are a number of different laser systems that have been recommended by investigators for the treatment of DH, for example, neodymium-doped yttrium, aluminium and garnet (Nd:YAG); erbium and chromium to yttrium, scandium and gallium (Er,Cr:YSG); erbium and chromium doped to yttrium, scandium, gallium and garnet (Er,Cr:YSGG); carbon dioxide (CO_2); and diode lasers. Several investigators have also combined various lasers with fluoride varnishes and potassium nitrate gels in order to treat DH, for example, GaAlAs (BDP 600), Co_2, Er:YAG or Nd:YAG lasers and a sodium fluoride gel or varnish (Corona et al. 2003; Ipci et al. 2009); Kara and Orbak 2009 or a 810 nm diode laser and a 10 % potassium nitrate bioadhesive gel (Sicilia et al. 2009). These investigators reported positive results with the combined application of a laser and fluoride gel or varnish; however these studies had relatively small numbers of subjects per group, and therefore further well-controlled studies are required to determine whether there would be an added benefit to the patient. Several investigators have recently undertaken reviews (systematic review/meta-analysis) on the efficacy of in-office treatments or laser therapy for the treatment of DH (Lin et al. 2013; Sgolastra et al. 2013). These investigators reported that laser therapy was efficacious in reducing DH compared to a placebo control. Lin et al. (2013) however indicated that there were no significant differences between the different treatment modalities. Although laser therapy appears to be an area of interest from a research viewpoint, there appears to be limited use of lasers in dental practice when treating DH (Cunha-Cruz et al. 2010).

6. *Other Miscellaneous Treatment*

   A large number of anecdotal reports support alternative approaches for treating DH. Although these reports are not truly evidence based, they may be applied to some clinical situations. For example, periodontal surgery involving coronally positioned flaps reportedly eliminates dentin hypersensitivity in exposed root dentin (See Sect. 5.5). If DH is associated with an abfraction lesion, occlusal adjustment may also be effective (Coleman et al. 2003). Other miscellaneous procedures for the treatment of DH were reported, for example, burnishing exposed root surfaces (Ling and Gillam 1996; Pashley 2000), crown restorations, pulp extirpation, extraction (Ong and Strahan 1989) and hypnosis (Starr et al. 1989; Eitner et al. 2010).

5.5.1 Post-operative Sensitivity from Restorative Approaches

A review of the published literature would indicate that post-operative sensitivity from restorative treatment is a commonly reported feature in dental practice. One of the problems in determining the actual prevalence of the problem however, was that some of the published studies were mainly anecdotal reports in nature and as such were prone to reporting bias when claiming the elimination of post-operative sensitivity with products which use dental adhesive liners. According to Haywood (2002), there are a number of factors associated with the placement of restorations in vivo, for example, certain amalgam materials have been shown to cause post-operative sensitivity (restorative

sensitivity) of up to 48 h due to shrinkage of the material rather than the predicted expansion during setting. Other factors include the contamination of composites during placement or improper etching of the tooth during tooth preparation which may result in micro-leakage; improper technique when drying the tooth or incorrect preparation of materials such as glass ionomer or zinc phosphate cements may also be problematic. The techniques involved in cavity preparation may also affect the integrity of the pulp initiating an inflammatory response and subsequent pain as well as thermal changes due to the choice of the restorative material used to restore the tooth. Galvanic reactions due to dissimilar metals have also been reported to cause post-operative pain (Haywood 2002). Porto (2012) has also suggested that there are a number of factors that may initiate post-operative sensitivity with the placement of direct resin composite restorations (Table 5.5). As previously indicated tooth sensitivity has been reported to be associated with bleaching procedures (Haywood 2000; Tredwin et al. 2006), and a number of treatment strategies have been recommend as indicated above.

Table 5.5 Possible causes of pre- and post-operative sensitivity from direct resin composites

Preoperative causes	Operative causes	Post-operative causes
Cracks and fractures	Abusive dental structure wear by instruments	Restorative finishing and polishing
Cervical dentin exposure	Dehydration of the dentin	Occlusal interference
Condition of the pulp	Incomplete caries removal	Cervical dentin exposure
	Negligence in protecting the dentin–pulp complex Increase in cavity depth Inadequate isolation of the operative field Failure in dental tissue hybridisation Handling the restorative material Polymerisation shrinkage (contraction stress). Incomplete resin composite polymerisation Flow characteristics of composites	

From Porto (2012)

According to Berkowitz et al. (2009), post-operative sensitivity following the placement of posterior resin-based composites is a common concern in general dental practice although the evidence for this statement is limited.

Several investigators have however suggested that one method of relieving post-operative sensitivity is by the adjunctive use of oxalate desensitisers on acid-etched dentin prior to adhesive application (Pashley et al. 2001; Tay et al. 2003). Yiu et al. (2005) however urged caution on the use of oxalate desensitisers under certain conditions, in particular with acidic, fluoride-containing total-etch adhesives due to their incompatibility problems.

According to Gillam and Orchardson (2006), DH is a common occurrence following periodontal surgery and root scaling/debridement although with well-controlled oral hygiene procedures, this problem appears to resolve over time (Tammaro et al. 2000). Several investigators have also reported that the prevalence of DH is in the region of 9–27 % before and 54–55 % following periodontal therapy (von Troil et al. 2002; Lin and Gillam 2012). The reported intensity from DH increased up to 4 weeks following these procedures, after which the recorded values returned back to the original baseline scores (Gillam and Orchardson 2006). A number of studies have also indicated that a relatively small number of patients (1.3–7 %) complain of severe DH following treatment of infrabony defects with an enamel matrix derivative (Zetterstrom et al. 1997; Heard et al. 2000; Froum et al. 2004). It is important to note that for most patients post-operative sensitivity is of a transient nature and may be adequately managed by the clinician using the recommended materials and procedures outlined in Chaps. 5 and 6. If the post-operative sensitivity has not resolved within 6 weeks, it is recommended that further investigations be undertaken to determine the cause of the problem and treat accordingly.

5.6 Periodontal Surgical Techniques

According to Gillam and Orchardson (2006), periodontal grafts and guided tissue regeneration (GTR) procedures have been described in the published literature for the treatment of gingival recession with DH. These procedures generally have predictable outcomes and may therefore be the treatment of choice for patients since this may provide a good aesthetic as well as palliative solution to their clinical problem (Drisko 2002). Both aesthetics and pain from DH have been reported as the main concerns of patients when seeking treatment (Pagliaro et al. 2003; Zaher et al. 2005). Previously one of the problems when evaluating the efficacy of the root coverage procedures and associated DH was that there was only limited evidence-based data available on the actual extent of the problem of DH before and following the procedure(s) (Gillam and Orchardson 2006). Furthermore the results from the published clinical studies generally evaluated the success or failure of specific technique and procedures with DH as an unpleasant side effect from the surgical procedure rather than specifically evaluate patients with exposed root dentin with associated DH. For example, Al-Hamdan et al. (2003) in a meta-analysis review while acknowledging that the indications for initiating root coverage procedures included DH reported that the 40 papers included in the review provided no evidence to either determine the prevalence or extent of the problem in patients with gingival recession. This observation was also substantiated by Pagliaro et al. (2003) who reported that out of the 90 accepted papers included in the review, DH was generally identified as being either present or absent in 19 papers (21.1 %) and only nine articles (10 %) recorded any pre- and post-treatment data, with only two of these studies quantifying DH on a recognised 10-point pain scale.

Several investigators have suggested that if the root coverage of the gingival defect cannot be predictably treated by conventional surgical root coverage procedures, then the remaining exposed cervical dentin could be treated with a more invasive restorative material (Tugnait and Clerehugh 2001; Drisko 2002). This may be as a result of either patient-related factors or an extensive loss of interdental gingival and bone tissue as a result of periodontal disease. Open gingival embrasures, also called 'black triangles', may be produced interfering with the aesthetics of the smile (Sharma and Park 2010). A relatively simple nonsurgical approach to this problem was proposed by Greene (1998) who suggested the construction of a flexible gingival mask of silicone using a simple two-stage impression technique. Localised recession defects may also be addressed by using a partial laminate porcelain veneer technique (Capa 2007). Zalkind and Hochman (1997) also recommended the use of tooth-coloured composite as a minimally invasive adhesive restoration. The latter restorative technique may also resolve associated carious lesions and alleviate pain symptoms from DH (Zalkind and Hochman 1997). Restoration of a non-carious/carious cervical lesion with glass ionomer cements may also have the added advantage of fluoride release over a prolonged period of time (Özgünaltay and Önen 2002). A combined surgical and restorative approach has been described by Santamaria et al. (2007) in three case reports of patients with Miller's Class I gingival margin defect with associated non-carious cervical lesions. These authors recommended a combined surgical/restorative approach using a coronally advanced flap procedure with/without a connective tissue graft together with a resin-modified glass ionomer restoration when dealing with this particular problem. However as these investigators acknowledged, further longitudinal randomised clinical trials are required to support this combined approach to correcting gingival recession defects and associated non-carious cervical lesions. If the non-carious cervical lesion is below the cementum–enamel junction, this may cause problems when adapting the gingival flap to the root surface, and modification of the root surface to eliminate the concavity of the lesion may require reshaping of the root surface using diamond finishing burs (Santamaria et al. 2007). It is however imperative that clinicians should avoid placing subgingival restorations whenever possible in order to prevent plaque retention as well as maintaining the biological width when placing crowns (Drisko 2002).

Several investigators have reported that there is an increase in DH following scaling and periodontal surgery although this effect may be transient in nature (von Troil et al. 2002; Gillam and Orchardson 2006). One possible explanation for this observation is that periodontal procedures such as scaling may initially uncover the dentin tubules (a created smear layer) exposing them to the oral environment thus causing patients transient pain when eating or drinking in the days following the procedures. It is evident however that a smear layer may be covering the dentinal tubules since the cementum would have been removed in order for the root dentine to be exposed (Pashley 1984). Natural occlusion may also occur due to the precipitation of salivary constituents onto the tooth surface (Kerns et al. 1991; Kawasaki et al. 2001). Several investigators have speculated that scaling and root planing procedures may remove 20–50 μm of cementum thus exposing the dentinal tubules to external stimuli (Nishida et al. 1976; Wallace and Bissada 1990). It has also been suggested that bacterial invasion of exposed cementum associated with periodontal disease occurs after the cementum has been altered by physiological, bacterial or environmental factors (Love and Jenkinson 2002). The implications on the integrity of the pulp as a result of bacterial invasion of the dentin tubules may therefore depend on whether the pulpo-dentin defences are able to withstand this insult. According to Love and Jenkinson (2002), it is likely that the dentin fluid components including albumin, fibrinogen and IgG are involved in host defence by interacting directly with bacteria and metabolites and by reducing the permeability of dentin. It has been speculated that any bacterial invasion of the dentin tubules would have a greater impact on outward fluid flow than with inward diffusion of noxious substances due to changes in the tubular radius rather than with diffusion characteristics of bulk fluid movements per se (Pashley 1992a, b). This speculation was however based on in vitro observations and does not appear to have been substantiated in clinical practice. Several investigators have recommended the use of a topical fluoride or a desensitising polishing paste application with a view to alleviate patient discomfort following scaling and root planing procedures (Paine et al. 1998; Hamlin et al. 2009; Schiff et al. 2009a, b; Milleman et al. 2012; Li et al. 2013; Neuhaus et al. 2013). Oxalate solutions have also been advocated for post-operative hypersensitivity, for example, Wang et al. (1993) applied a 6 % ferric oxalate solution during periodontal surgery and Pillon et al. (2004) applied a 3 % potassium oxalate application following subgingival scaling and root planing. Both investigators reported a reduction in post-operative hypersensitivity following application of the oxalate solutions.

From a treatment and management perspective, a number of classifications have been previously proposed in the published literature in order to facilitate both a diagnosis and a template for the correction of gingival margin defects. Currently the classification used in root coverage procedures is the Miller classification system ([I–IV] (Miller 1985). An example of Miller's Class I defect may be seen in Fig. 5.3. The advantage of this classification is the ability to correlate treatment prognosis/outcome and anatomical features, whereas previous classification systems used either anatomical features or treatment prognosis only. A number of materials and techniques have been reported in the literature, and these include guided tissue regeneration (GTR), coronally advanced flap and Emdogain (CAF + EMD), connective tissue graft (CTG) and free gingival graft (acellular dermal matrix allograft/Mucograft ADM) (Table 5.6, Fig. 5.4a, b). A recent systemic review by Douglas de Oliveira et al. (2013), however, suggested that currently there is insufficient scientific evidence to

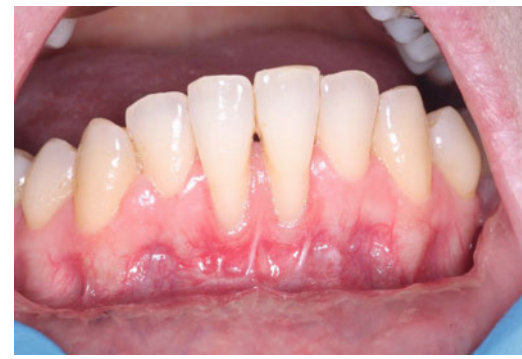

Fig. 5.3 Miller Class I defect of a patient complaining of DH following completion of the orthodontic treatment. The patient was referred in order to provide root coverage of the lower central incisors (Acknowledgement KN Al Shayeb)

Table 5.6 Periodontal flap surgery/periodontal plastic surgical techniques

Material/technique	Proposed mode of action
Guided tissue regeneration (GTR)	Root coverage of the exposed dentin by connective tissue flaps, guided tissue regeneration (GTR) with or without enamel matrix derivatives or acellular dermal matrix/Mucograft (e.g., Saadoun 2008, Sanz et al. 2009, Dominiak et al. 2012). In vitro and clinical evidence for these products and procedures has been demonstrated, and there is some histological evidence that these products have the potential to regenerate bone. For example, selective repopulation of a root surface by periodontal ligament cells forming new connective tissue attachment between the root surface and alveolar bone may be achieved using GTR procedures. Connective tissue grafts with or without enamel matrix derivatives or acellular dermal matrix/Mucograft may also result in increased keratinisation of the gingiva (Alghamdi et al. 2009). Successful coverage of the root surface would therefore provide a physical barrier that may in turn decrease DH
Coronally advanced flap and Emdogain (CAF + EMD)	
Connective tissue graft (CTG)	
Free gingival graft (acellular dermal matrix allograft/ Mucograft ADM)	

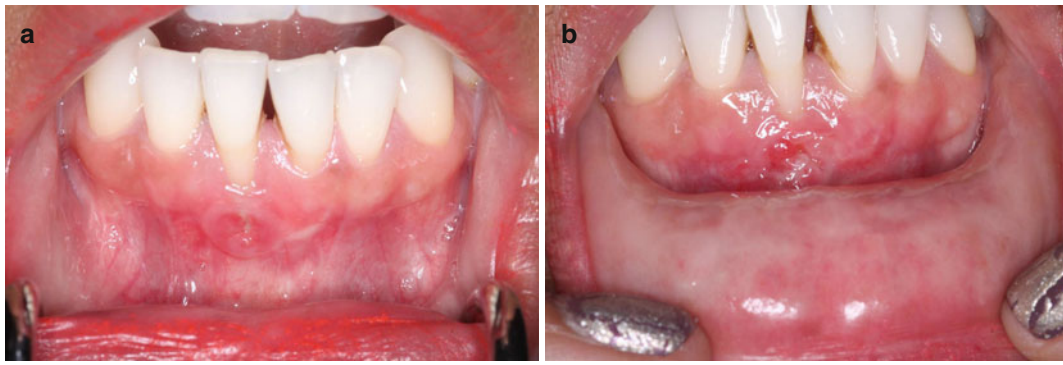

Fig. 5.4 (**a**) Clinical photograph of a Miller Class III with fenestration (Pre-operative). Patient was complaining of gingival sensitivity associated with the mandibular lower left central incisor (Acknowledgement KN Al Shayeb). (**b**) Clinical photograph of the Miller Class III defect 1 week post op

conclude that surgical root coverage procedures predictably reduce DH.

Conclusions

The hydrodynamic theory promotes two basic approaches based on in vitro, in situ, animal and human studies for treating DH, namely, blocking dentin tubules and nerve desensitising. There have been a number of reviews that have investigated the vast array of products and treatment approaches (both in-office or OTC) that dental professionals have used in order to treat DH, and it is evident that there is no widespread agreement as to which is the best material or procedure to treat DH (Gillam 1992; Orchardson and Gillam 2006; Cunha-Cruz et al. 2010; Lin et al. 2013). One of the problems however in evaluating the effectiveness of desensitising products is the variability in the methodology, sample size and duration used in the published clinical trials. Other factors that may influence the efficacy of the product under test in clinical studies include the impact of placebo and non-placebo effects, the random variation in patient symptoms over time (regression to the mean/mode) and the relationship between the subject and the examiner. It is also evident that patients may experience post-operative sensitivity from the various procedures in the dental office, for example, from restorative procedures, restorations, crowns, bleaching of the teeth and nonsurgical and surgical procedures. Although these effects may be of a transient nature, they may cause undue distress to the patient and their quality of life which may in turn necessitate further treatment. This may include simple reassurance and monitoring or further investigation and

treatment of the particular problem. It is essential that the patient is monitored within a practical management programme, and in most situations a stepwise approach (minimally invasive) including preventive measures may be incorporated (see Chap. 6). The use of this stepwise approach as proposed by Orchardson and Gillam (2006) may enable the dental professional to use a combination of products, restorative approaches and treatment philosophies in order to successfully treat DH.

References

ADA Acceptance Program Guidelines (2012) Products for the treatment of dentinal hypersensitivity. American Dental Association, Council for Scientific Affairs, April 2012, Chicago, IL, USA. www.ada.org/sections/scienceAndResearch/pdfs/Products. Accessed Jan 2014

Addy M, Dowell P (1983) Dentine and hypersensitivity-a review. Clinical and in vitro evaluation of treatment agents. J Clin Periodontol 10:351–366

Addy M, Mostafa P, Newcombe R (1987) Dentine hypersensitivity. A comparison of five toothpastes used during a 6-week treatment period. BDJ 163:45–50

Addy M, Loyn T, Adams D (1991) Dentine hypersensitivity – effects of some proprietary mouthwashes on the dentine smear layer. A SEM Study J Dent 19:148–152

Addy M, West NX, Barlow A, Smith S (2007) Dentine hypersensitivity: is there both stimulus and placebo responses in clinical trials? Int J Dent Hygiene 5:53–59

Ajcharanukul O, Kraivaphan P, Wanachantararak S, Vongsavan N, Matthews B (2007) Effects of potassium ions on dentine sensitivity in man. Arch Oral Biol 52:632–639

Ajcharanukul O, Chidchuangchai W, Charoenlarp P, Vongsavan N, Matthews B (2011) Sensory transduction in human teeth with inflamed pulps. J Dent Res 90(5):678–682

Ajcharanukul O, Wanachantararak S, Vongsavan N, Matthews B (2012) Repeated hydrostatic pressure stimulation of dentin in man. In: Presentation (abstract no. 3249), 90th general session and exhibition of the IADR Iguaçu Falls, Brazil, 20–23 June

Alghamdi H, Babay N, Sukumaran A (2009) Surgical management of gingival recession: a clinical update. Saudi Dent J 21(2):83–94

Al-Hamdan K, Eber R, Sarment D, Kowalski C, Wang H-L (2003) Guided tissue regeneration-based root coverage: meta-analysis. J Periodontol 74:1520–1533

Anderson DJ (1968) The pulp as a sensory organ. In: Finn SB (ed) Biology of the dental pulp organ. University of Alabama Press, Birmingham, pp 273–280

Anderson DJ (1972) Human and animal studies on sensory mechanisms in teeth. J Dent Res 22:33–38

Anderson DJ, Naylor MN (1962a) Chemical excitants of pain in human dentine. Arch Oral Biol 7:413–415

Anderson DJ, Ronning GA (1962b) Osmotic excitants of pain in human dentine. Arch Oral Biol 7:513–523

Anderson DJ, Curwen MP, Howard LV (1958) The sensitivity of human dentin. J Dent Res 37:669–677

Aranha ACC, Pimenta LAF, Marchi GM (2009) Clinical evaluation of desensitizing treatments for cervical dentin hypersensitivity. Braz Oral Res 23(3):333–339

Aparna S, Setty S, Thakur S (2010) Comparative efficacy of two treatment modalities for dentinal hypersensitivity: a clinical trial. Indian J Dent Res 21(4):544–548. doi:10.4103/0970-9290.74213

Ayad F, Ayad N, Delgado E, Zhang YP, DeVizio W, Cummins D, Mateo LR (2009) Comparing the efficacy in providing instant relief of dentin hypersensitivity of a new toothpaste containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride to a benchmark, desensitizing toothpaste containing 2% potassium ion and 1450ppm fluoride, and to a control toothpaste with 1450ppm fluoride. A three-day clinical study in Mississauga, Canada. J Clin Dent 20:115–122

Azarpazhooh A, Limeback H (2008) Clinical efficacy of casein derivatives: a systematic review of the literature. J Am Dent Assoc 139(7):915–924

Baysan A, Lynch E (2003) Treatment of cervical sensitivity with a root sealant. Am J Dent 16(2):135–138

Beecher HK (1955) The powerful placebo. J Am Med Assoc 159:1602–1606

Berkowitz GS, Horowitz AJ, Fredrick A, Curro FA, Craig RG et al (2009) Postoperative hypersensitivity in class I resin-based composite restorations in general practice: interim results. Compend Contin Educ Dent 30(6):356–363

Bhandary S, Hedge MN (2012) A clinical comparison of in-office management of dentin hypersensitivity in a short term treatment period. IJBAR 03(03):69–174. ijbar.ssjournals.com/index.php/journal/article/download/114/638

Blitzer B (1967) A consideration of the possible causes of dental hyper- sensitivity: treatment by a strontium-ion dentifrice. Periodontics 5:318–321

Brännström M (1963) A hydrodynamic mechanism in the transmission of pain-produced stimuli through the dentine. In: Anderson DJ (ed) Sensory mechanisms in dentine. Pergamon, Oxford, pp 73–79

Brännström M, Johnson G, Nordenvall K-J (1979) Transmission and control of dentinal pain: resin impregnation for the desensitization of dentin. JADA 99:612–618

Brauer DS, Karpukhina N, O'Donnell MD, Law RV, Hill RG (2010) Fluoride-containing bioactive glasses: effect of glass design and structure on degradation, pH and apatite formation in simulated body fluid. Acta Biomater 6:3275–3282

Brough KM, Anderson DM, Love J, Overman PR (1985) The effectiveness of iontophoresis in reducing dentin hypersensitivity. J Am Dent Assoc 111(5):761–765

Burrow MF, Banomyong D, Harnirattisai C, Messer HH (2009) Effect of glass-ionomer cement lining on

postoperative sensitivity in occlusal cavities restored with resin composite–a randomized clinical trial. Oper Dent 34(6):648–655
Burwell A (2006) Tubule occlusion of a Novamin-containing dentifrice compared to Recaldent-containing dentifrice – a Remin/Demin study in vitro. Novamin research reports
Burwell AK, Litkowski LJ, Greenspan DC (2009) Calcium sodium phosphosilicate (NovaMin): remineralization potential. Adv Dent Res 21(1):35–39
Camps J, Pashley D (2003) In vivo sensitivity of human root dentin to air blast and scratching. J Periodontol 74:1589–1594
Capa N (2007) Alternative treatment approach to gingival recession: gingival-colored partial porcelain veneer: a clinical report. J Prosthet Dent 98:82–84
Charig AJ, Chapin CA, Major EE, Thong S et al (2009) Mechanism of action of a desensitizing fluoride toothpaste delivering calcium and phosphate ingredients in the treatment of dental hypersensitivity. Part I: in vitro Sem, Edx, profilometry, and dentin permeability studies. Compendium 30(8). Online access only
Charles C (1998) Bonding orthodontic brackets with glass-ionomer cement. Biomaterials 19(6):589–591
Cherng AM, Chow LC, Takagi S (2004) Reduction in dentin permeability using mildly supersaturated calcium phosphate solutions. Arch Oral Biol 49(2):91–98
Chesters R, Kaufman HW, Wolff MS, Huntington E, Kleinberg I (1992) Use of multiple sensitivity measurements and logit statistical analysis to assess the effectiveness of a potassium citrate-containing dentifrice in reducing dentinal hypersensitivity. J Clin Periodontol 19:256–261
Clark GE, Troullos ES (1990) Designing hypersensitivity clinical studies. Dent Clin North Am 34:531–544
Cohen S (1961) Efficacy of a dentifrice containing potassium. J Periodontol 32:49–53, 56
Coleman TA, Grippo JO, Kinderknecht KE (2003) Cervical dentin hyper-sensitivity. Part III: resolution following occlusal equilibration. Quintessence Int 34:427–434
Collaert B, De Bruyn H, Söderholm G, Brattthall GT (1991) Evaluation of a fluoride varnish for dentine sensitivity treatment. J Dent Res 70:83 (Abstr no 102)
Corona SAM, Nascimento NT, Catirse ABE, Lizarelli RFZ et al (2003) Clinical evaluation of low-level laser therapy and fluoride varnish for treating cervical dentinal hypersensitivity. J Oral Rehabil 30:1183–1189
Croll TP (2003) Bleaching sensitivity. JADA 134(9):1168
Cummins D (2009) Dentin hypersensitivity: from diagnosis to a breakthrough therapy for everyday sensitivity relief. J Clin Dent 20(Special Issue):1–9
Cummins D (2010) Recent advances in dentine hypersensitivity: clinical proven treatments for instant and lasting sensitivity relief. Am J Dent 23(Special Issue A 5):3A–13A
Cummins D (2011) Clinical evidence for the superior efficacy of a dentifrice containing 8.0% arginine and calcium carbonate in providing instant and lasting relief of dentin hypersensitivity. J Clin Dent 22(4):97–99
Cunha-Cruz J, Wataha JC, Zhou L, Manning W et al (2010) Treating dentin hypersensitivity therapeutic choices made by dentists of the Northwest PRECEDENT network. J Am Dent Assoc 141(9):1097–1105
Cunha-Cruz J, Stout JR, Heaton LJ, Wataha JC (2011) Dentin hypersensitivity and oxalates a systematic review. J Dent Res 90(3):304–310
Curro FA, Friedman M, Leight RS (2000) Design and conduct of clinical trials on dentine hypersensitivity. In: Addy M, Embery G, Edgar WM, Orchardson R (eds) Tooth wear and sensitivity. Clinical advances in restorative dentistry. Martin Dunitz Ltd, London, pp 299–314
Day TT, Einwag JJ, Hermann JS, He TT, Kay M et al (2010) A clinical assessment of the efficacy of a stannous-containing sodium fluoride dentifrice on dentinal hypersensitivity. J Contemp Dent Pract 11(1):E001–E008
de Assis CA, Antoniazzi RP, Zanatta FB, Rösing CK (2006) Efficacy of Gluma Desensitizer® on dentin hypersensitivity in periodontally treated patients. Braz Oral Res 20(3):252–256
Definition of active placebo (2013) www.thefreedictionary.com. Accessed 23 Apr 2013
Definition of nocebo effect (2013) http://www.medterms.com. Accessed 23 Apr 2013
Definition of placebo (2013) http://www.medterms.com. Accessed 23 Apr 2013
Docimo R, Montesani L, Maturo P, Costacurta M, Bartolino M, DeVizio W, Zhang YP, Cummins D, Dibart S, Mateo LR (2009) Comparing the efficacy in reducing dentin hypersensitivity of a new toothpaste containing 8.0%arginine, calcium carbonate, and 1450 ppm fluoride to a commercial sensitive toothpaste containing 2% potassium ion: An eight-week clinical study in Rome, Italy. J Clin Dent 20(Spec Iss):17–22
Dominiak M, Mierzwa D, Puzio M, Gedrange T (2012) Clinical evaluation of the effectiveness of using a collagen matrix (Mucograft® prototype) in gingival recession coverage-pilot study. J Stoma 65(2):184–197
Dondi dall'Orologio G, Malferrari S (1993) Desensitizing effects of Gluma and Gluma 2000 on hypersensitive dentin. Am J Dent 6(6):283–286
Dondi dall'Orologio G, Lorenzi R, Anselmi M, Opisso V (1999) Dentin desensitizing effects of Gluma Alternate, Health-Dent Desensitizer, and Scotchbond Multi-Purpose. Am J Dent 12(3):103–106
Dondi dall'Orologio G, Lone A, Finger WJ (2002) Clinical evaluation of the role of glutardialdehyde in a one-bottle adhesive. Am J Dent 15(5):330–334
Douglas de Oliveira DW, Oliveira-Ferreira F, Flecha OD, Gonçalves PF (2013) Is surgical root coverage effective for the treatment of cervical dentin hypersensitivity? A systematic review. J Periodontol 84(3):295–306
Drisko C (2002) Dentine hypersensitivity: dental hygiene and periodontal considerations. Int Dent J 52:385–393
Dunne SM, Hannington-Kiff JG (1993) The use of topical guanethidine in the relief of dentine hypersensitivity: a controlled study. Pain 54(2):165–168

Duran I, Sengun A (2004) The long-term effectiveness of five current desensitizing products on cervical dentine sensitivity. J Oral Rehabil 31:351–356

Ebisu S (2002) Calcium phosphate precipitation method for the treatment of dentin hypersensitivity. Am J Dent 15:220–226

Einwag J, Hermann J, He T, Day T, Zhang Y, Anastasia MK, Barker ML (2010) A clinical assessment of the efficacy of a stannous-containing sodium fluoride dentifrice on dentinal hypersensitivity. J Contemp Dent Pract 11:E001–E008, 26

Eitner S, Bittner C, Wichmann M, Nickenig HJ, Sokol B (2010) Comparison of conventional therapies for dentin hypersensitivity versus medical hypnosis. Int J Clin Exp Hypn 58(4):457–475

Felton DA, Bergenholtz G, Kanoy BE (1991) Evaluation of the desensitizing effect of Gluma Dentin Bond on teeth prepared for complete-coverage restorations. Int J Prosthodont 4(3):292–298

Ferrari M, Cagidiaco MC, Kugel G, Davidson CL (1999) Clinical evaluation of a one-bottle bonding system for desensitizing exposed roots. Am J Dent 12(5): 243–249

Francisconi LF, Scaffa PM, de Barros VR, Coutinho M, Francisconi PA (2009) Glass ionomer cements and their role in the restoration of non-carious cervical lesions. J Appl Oral Sci 17(5):364–369

Frechoso SC, Menéndez M, Guisasola C, Arregui I, Tejerina JM, Sicilia A (2003) Evaluation of the efficacy of two potassium nitrate bioadhesive gels (5% and 10%) in the treatment of dentine hypersensitivity. A randomised clinical trial. J Clin Periodontol 30(4):315–320

Froum S, Weinberg M, Novak J, Mailhot J et al (2004) A multicentre study evaluating the sensitization potential of enamel matrix derivative after treatment of two infrabony defects. J Periodontol 75:1001–1008

Furseth R (1970) A study of experimentally exposed and fluoride treated dental cementum in pigs. Acta Odontol Scand 28(6):833–850

Gaffar A (1999) Treating hypersensitivity with fluoride varnish. Compend Contin Educ Dent 20(1 Suppl): 27–33

Gandolfi MG, Taddei TA, Prati C (2010) Apatite-forming ability (bioactivity) of ProRoot MTA. Int Endod J 43(10):917–929

Gangarosa LP, Park NH (1978) Practical considerations in iontophoresis of fluoride for desensitizing dentin. J Prosthet Dent 39(2):173–178

Gedalia I, Brayer L, Katter N, Richter M, Stabholz A (1978) The effect of fluoride and strontium application on dentine. In vivo and in vitro studies. J Periodontol 49:269–272

Geiger S, Matalon S, Blasbalg J, Tung M, Eichmiller FC (2003) The clinical effect of amorphous calcium phosphate (ACP) on root surface hyper- sensitivity. Oper Dent 28:496–500

Gillam DG, Newman HN (1990) Iontophoresis in the treatment of cervical dentinal sensitivity–a review. J West Soc Periodontol Periodontal Abstr 38(4):129–133

Gillam DG (1992) The assessment and treatment of cervical dentinal sensitivity. DDS thesis, University of Edinburgh, Scotland

Gillam DG (1997) Clinical trial designs for testing of products for dentine hypersensitivity – a review. Periodontal Abstr 45:37–46

Gillam DG (2011) An overview on conducting clinical studies for the evaluation of desensitising products for the treatment of dentine hypersensitivity. Oral Health Dialog 2:6–14

Gillam DG, Orchardson R (2006) Advances in the treatment of root dentine sensitivity: mechanisms and treatment principles. Endod Topics 13:13–33

Gillam DG, Jackson RJ, Bulman JS, Newman HN (1996) Comparison of 2 desensitizing dentifrices with a commercially available fluoride dentifrice in alleviating cervical dentine sensitivity. J Periodontol 67:737–742

Gillam DG, Coventry J, Manning R, Newman HN, Bulman JS (1997a) Comparison of two desensitizing agents for the treatment of dentine hypersensitivity. Endod Dent Traumatol 13:36–39

Gillam DG, Mordan NJ, Newman HN (1997b) The Dentin Disc surface: a plausible model for dentin physiology and dentin sensitivity. Adv Dent Res 11(4):487–501

Gillam DG, Mordan NJ, Sinodinou AD, Tang JY et al (2001) The effects of oxalate-containing products on the exposed dentine surface: an SEM investigation. J Oral Rehabil 28:1037–1044

Gillam DG, Tang JY, Mordan NJ, Newman HN (2002) The effects of a novel Bioglass® dentifrice on dentine sensitivity: a scanning electron microscopy investigation. J Oral Rehabil 29(4):305–313

Gillam DG, Newman HN, Davies EH, Bulman JS, Troullos ES, Curro FA (2004) Clinical evaluation of ferric oxalate in relieving dentine hypersensitivity. J Oral Rehabil 31:245–250

Giniger M, Macdonald J, Ziemba S et al (2005) The clinical performance of professionally dispensed bleaching gel with added amorphous calcium phosphate. J Am Dent Assoc 136(3):383–392

Green BL, Green ML, McFall WT (1977) Calcium hydroxide and potassium nitrate as desensitizing agents for hypersensitive root surfaces. J Periodontol 48:667–672

Greene PR (1998) The flexible gingival mask: an aesthetic solution in periodontal practice. Br Dent J 184: 536–540

Greenhill JD, Pashley DH (1981) The effects of desensitizing agents on the hydraulic conductance of human dentin in vitro. J Dent Res 60(3):686–698

Gupta M, Pandit IK, Srivastava N, Gugnani N (2010) Comparative evaluation of 2% sodium fluoride iontophoresis and other cavity liners beneath silver amalgam restorations. J Indian Soc Pedod Prev Dent 28(2): 68–72

Gutentag H (1965) The effect of strontium chloride on peripheral nerve in comparison to the action of "stabilizer" and "labilizer" compounds. Penn Dent J (Phila) 68(2):37–43

Hamlin D, Williams KP, Delgado E, Zhang YP, DeVizio W, Mateo LR (2009) Clinical evaluation of the efficacy of a desensitizing paste containing 8% arginine and calcium carbonate for the in-office relief of dentin hypersensitivity associated with dental prophylaxis. Am J Dent 22(Sp Is A):16A–20A

Hannington-Kiff JG, Dunne SM (1993) Topical guanethidine relieves dentinal hypersensitivity and pain. J R Soc Med 86(9):514–515

Hansen EK (1992) Dentin hypersensitivity treated with a fluoride-containing varnish or a light-cured glass-ionomer liner. Eur J Oral Sci 100(6):305–309

Haywood VB (2000) Current status of night guard vital bleaching. Compend Contin Educ Dent 21(Suppl 28):S10–S17

Haywood VB (2002) Dentine hypersensitivity: bleaching and restorative considerations for successful management. Int Dent J 52(5):366–396

Haywood VB, Caughman F, Frazier KB, Myers ML (2001) Tray delivery of potassium nitrate-fluoride to reduce bleaching sensitivity. Quintessence Int 32:105–109

Haywood VB, Cordero R, Wright K, Gendreau L, Rupp R, Kotler M, Littlejohn S, Fabyanski J, Smith S (2005) Brushing with a potassium nitrate dentifrice to reduce bleaching sensitivity. J Clin Dent 16:17–22

Hazen SP, Volpe AR, King WJ (1968) Comparative desensitising effect of dentrifices containing sodium monofluorophosphate, stannous fluoride and formalin. Periodontics 6:230–232

He S, Wang Y, Li X, Hu D (2011) Effectiveness of laser therapy and topical desensitising agents in treating dentine hypersensitivity: a systematic review. J Oral Rehabil 38(5):348–358

Heard RH, Mellonig JT, Brunsvold MA, Lasho DJ et al (2000) Clinical evaluation of wound healing following multiple exposures to enamel matrix protein derivative in the treatment of infrabony periodontal defects. J Periodontol 71:1715–1721

Hench LL (2006) The story of Bioglass®. J Mater Sci Mater Med 17:967–978

Hill R, Gillam D, Karpukhina N (2012) The tubular occluding properties of a novel biomimetic hydroxyapatite toothpaste. In: Poster presentation (Abstr no. 640) IADR/PER Pan-European region meeting Helsinki, 12–15 Sept

Hoang-Dao BT, Hoang-Tu H, Tran-Thi N, Koubi G et al (2009) Clinical efficiency of a natural resin fluoride varnish (Shellac F) in reducing dentin hypersensitivity. J Oral Rehabil 36(2):124–131

Hodash M (1974) A superior desensitiser-potassium nitrate. J Am Dent Assoc 88:831–832

Holland GR, Narhi MN, Addy M, Gangarosa L, Orchardson R (1997) Guidelines for the design and conduct of clinical trials on dentine hypersensitivity. J Clin Periodontol 24:808–813

Homeopathic remedy for sensitive teeth (plantago). www.hpathy.com. Accessed 23 Apr 2013

Hróbjartsson A, Gøtzsche PC (2001) Is the placebo p? — An analysis of clinical trials comparing placebo with no treatment. N Engl J Med 344:1594–1602

http://www.medterms.com. Accessed 23 Apr 2013

Hughes N, Mason S, Jeffery P et al (2010) A comparative clinical study investigating the efficacy of a test dentifrice containing 8% strontium acetate and 1040 ppm sodium fluoride versus a marketed control dentifrice containing 8% arginine, calcium carbonate, and 1450 ppm sodium monofluorophosphate in reducing dentinal hypersensitivity. J Clin Dent 21(2):49–55

Ilnyckyj A, Shanahan F, Anton PA, Cheang M, Bernstein CN (1997) Quantification of the placebo response in ulcerative colitis. Gastroenterology 112:1854–1858

Ipci SD, Cakar G, Kuru B, Yilmaz S (2009) Clinical evaluation of lasers and sodium fluoride gel in the treatment of dentine hypersensitivity. Photomed Laser Surg 27(1):85–91

Jackson RJ (2000) Potential treatment modalities for dentine hypersensitivity: home use products. In: Addy M, Embery G, Edgar WM, Orchardson R (eds) Tooth wear and sensitivity. Clinical advances in restorative dentistry. Martin Dunitz, London, pp 327–338

Jeffcott M (1993) Chemical plaque control: how do you advise your patients? Int Dent J 43:415–421

Kakaboura A, Rahiotis C, Thomaidis S, Doukoudakis S (2005) Clinical effectiveness of two agents on the treatment of tooth cervical hypersensitivity. Am Dent J 18(4):291–295

Kang S-J KY-H, Park J-B Herr Y, Chung J-H (2009) The effects of hydroxyapatite toothpaste on tooth hypersensitivity. J Korean Acad Periodontol 39:9–16 (Korean)

Kara C, Orbak R (2009) Comparative evaluation of Nd:YAG laser and fluoride varnish for the treatment of dentinal hypersensitivity. J Endod 35(7):971–974

Karim BFA, Gillam DG (2013) The efficacy of strontium and potassium toothpastes in treating dentine hypersensitivity: a systematic review. Int J Dent 2013(2013), Article ID 573258, 13 p. http://dx.doi.org/10.1155/2013/573258

Kawasaki A, Ishikawa K, Suge T, Shimizu H et al (2001) Effects of plaque control on the patency and occlusion of dentine tubules in situ. J Oral Rehabil 28:439–449

Kerns DG, Scheidt MJ, Pashley DH, Horner JA, Strong SL, Van Dyke TE (1991) Dentinal tubule occlusion and root hypersensitivity. J Periodontol 62:421–428

Kielbassa AM, Attin T, Hellwig E, Schade-Brittinger C (1997) In vivo study on the effectiveness of a lacquer containing CaF2/NaF in treating dentine hypersensitivity. Clin Oral Invest 1:95–99

Kim S (1986) Hypersensitive teeth. Desensitization of pulpal sensory nerves. J Endod 12:482–485

Kim SH, Park JB, Lee CW, Koo KT, Kim TI, Seol YJ et al (2009) The clinical effects of a hydroxyapatite containing toothpaste for dentine hypersensitivity. J Korean Acad Periodontol 39(1):87–94 (Korean)

Kimura Y, Wilder-Smith P, Yonaga K, Matsumoto K (2000) Treatment of dentine hypersensitivity by lasers: a review. J Clin Periodontol 27:715–721

Kleinberg I (2002) SensiStat, a new saliva-based composition for simple and effective treatment of entinal sensitivity pain. Dent Today 21:42–47

Kolker JL, Vargas MA, Armstrong SR, Dawson DV (2002) Effect of desensitizing agents on dentin permeability and dentin tubule occlusion. J Adhes Dent 4(3):211–221

Kun L (1976) Biophsical study of dental tissues under the effect of a local strontium application Schweiz Monatsschr Zahnheilkd. 86(7):661–76. [Article in French]

Leonard RH, Smith LR, Garland GE, Caplan DJ (2004) Desensitising agent efficacy during whitening in an at-risk population. J Esthet Restor Dent 16(1):49–55; discussion 56

Li Y, Lee S, Mateo LR, Delgado E, Zhang YP (2013) Comparison of clinical efficacy of three professionally applied pastes on immediate and sustained reduction of dentin hypersensitivity. Compend Contin Educ Dent 34(1):6–12 (online access 10 May 2013)

Lin YH, Gillam DG (2012) The prevalence of root sensitivity following periodontal therapy: a systematic review. Int J Dent 2012:407023. doi:10.1155/2012/407023, Epub 2012 Oct 31

Lin PY, Cheng YW, Chu CY, Chien KL, Lin CP, Tu YK (2013) In-office treatment for dentin hypersensitivity: a systematic review and network meta-analysis. J Clin Periodontol 40:53–64

Ling TYY, Gillam DG (1996) The effectiveness of desensitizing agents for the treatment of cervical dentine sensitivity (CDS) – a review. Periodontal Abstr 44(1):5–12

Litkowski LJ, Quinlan KB, McDonald NJ (1998) Teeth hypersensitivity reduction by a novel Bioglass® dentifrice. J Dent Res 77(Suppl 1):199

Love RM, Jenkinson HF (2002) Invasion of dentinal Tubules by oral bacteria. Crit Rev Oral Biol Med 13(2):171–183

Low T (1981) The treatment of hypersensitive cervical abrasion cavities using ASPA cement. J Oral Rehabil 8(1):81–89

Lukomsky EH (1941) Fluoride therapy for exposed dentin and alveolar atrophy. J Dent Res 20:649–654

Mahmound AS, Almas K, Dahlan Al-Raheem AA (1999) The effect of propolis on dentinal hypersensitivity and level of satisfaction among patients from a university hospital Riyadh, Saudi Arabia. Indian J Dent Res 10:130–137

Markowitz K (2010) Pretty painful: why does tooth bleaching hurt? Med Hypotheses 74(5):835–840

Markowitz K, Kim S (1985) The effects of various ionic solutions on pulpal nerve sensitivity. J Dent Res 64:309 (Abstr no. 1213)

Markowitz K, Kim S (1990) Hypersensitive teeth. Experimental studies of dentinal desensitizing agents. Dent Clin North Am 34(3):491–501. Review

Markowitz K, Nârhi M, Ngassapa D, Kim S (1990) The effect of KCI on intradental nerve activity evoked by hypertonic NaCl solution and natural stimuli ¡abstract 1492. J Dent Res 69(special issue 1):295

Markowitz K, Bilotto G, Kim S (1991) Decreasing intradental nerve activity in the cat with potassium and divalent cations. Arch Oral Biol 36:1–7

Mason S, Hughes N, Sufi F, Bannon L, Maggio B, North M, Holt J (2010) A comparative clinical study investigating the efficacy of a dentifrice containing 8% strontium acetate and 1040 ppm fluoride in a silica base and a control dentifrice containing 1450 ppm fluoride in a silica base to provide immediate relief of dentin hypersensitivity. J Clin Dent 21(Spec Iss):42–48

McCarthy D, Gillam DG, Parson DJ (1997) In vitro effects of laser radiation on dentine surfaces. J Dent Res 76(Special issue):233

McCormack K, Davies R (1996) The enigma of potassium ion in the management of dentine hypersensitivity: is nitric oxide the elusive second messenger? Pain 68:5–11

McFall WT (1986) A review of active agents available for the treatment of dentinal hypersensitivity. Endod Dent Traumatol 2:141–149

Mehmood Z, Shah JA, Javed MU, Manzoor MA et al (2011) Efficacy of GLUMA desensitizer® and Duraphat™ in relieving dentinal hypersensitivity in non-carious cervical lesions. Pak Oral Dent J 31(1): 183–186

Merika K, Hefti AF, Preshaw PM (2006) Comparison of two topical treatments for dentin sensitivity. Eur Prosthodont Restor Dent 14(1):38–41

Milleman JL et al (2012) NUPRO Sensodyne prophylaxis paste with NovaMin for the treatment of dentin hypersensitivity: a 4-week clinical study. Am J Dent 25:262–268

Miller PD Jr (1985) A classification of marginal tissue recession. Int J Periodontics Restorative Dent 5:9–13

Miller JT, Shannon IL, Kilgore WG, Bookman JE (1969) Use of a water-free stannous fluoride-containing gel in the control of dental hypersensitivity. J Periodontol 40(8):490–491

Mneimne M, Hill RG, Bushby AJ, Brauer DS (2011) High phosphate content significantly increases apatite formation of fluoride-containing bioactive glasses. Acta Biomater 7:1827–1834

Mordan NJ, Gillam DG, Critchell J, Curro FA, Ley F (2002) Effects of abrasive components on dentine: an SEM study. IADR meeting San Diego, Poster abstract no. 3010

Morris MF, Davis RD, Richardson BW (1999) Clinical efficacy of two dentin desensitizing agents. Am J Dent 12:72–76

Mostafa P, Addy M, Morgan T (1983) Scanning electron-microscopic, X-ray diffraction analysis, atomic absorption and fluoride probe measurements of the uptake of toothpaste ingredients onto dentine. J Dent Res 62:433 (Abstr no. 165)

Mount GJ, Tyas MJ, Ferracane JL, Nicholson JW et al (2009) A revised classification for direct tooth-colored restorative materials. Quintessence Int 40(8):691–697

Muzzin KB, Johnson R (1989) Effects of potassium oxalate on dentin hypersensitivity in vivo. J Periodontol 60:151–158

Nathoo S, Delgado E, Zhang YP, DeVizio W, Cummins D, Mateo LR (2009) Comparing the efficacy in providing instant relief of dentin hypersensitivity of a new

toothpaste containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride to a benchmark, desensitizing toothpaste containing 2% potassium ion and 1450ppm fluoride, and to a control toothpaste with 1450ppm fluoride. A three–day clinical study in New Jersey, USA. J Clin Dent 20:123–130

Neuhaus KW, Milleman JL, Milleman KR, Mongiello KA et al (2013) Effectiveness of a calcium sodium phosphosilicate containing prophylaxis paste in reducing dentine hypersensitivity immediately and 4 weeks after a single application: a double-blind randomized controlled trial. J Clin Periodontol 40(4): 349–357

Ni LX, He T, Chang A, Sun L (2010) The desensitizing efficacy of a novel stannous-containing sodium fluoride dentifrice: an 8-week randomized and controlled clinical trial. Am J Dent 23(Sp Is B):17B–21B

Nishida M, Katamsi D, Uchida A et al (1976) Hypersensitivity of the exposed root surfaces after surgical periodontal treatment. J Osaka Univ Dent Soc 16:73–77

Oken BS (2008) Placebo effects: clinical aspects and neurobiology. Brain 131:2812–2823

Ong G, Strahan JD (1989) Effect of a desensitizing dentifrice on dentinal hypersensitivity. Endod Dent Traumatol 5:213–218

Orchardson R, Gillam D (2000) The efficacy of potassium salts as agents for treating dentin hypersensitivity. J Orofac Pain 14(1):9–19

Orchardson R, Gillam D (2006) Managing dentin hypersensitivity. J Am Dent Assoc 137(7):990–998

Orchardson R, Peacock JM, Whitters CJ (1997) Effect of pulsed Nd:YAG laser radiation on action potential conduction in isolated mammalian spinal nerves. Lasers Surg Med 21(2):142–148

Orchardson R, Peacock JM, Whitters CJ (1998) Effects of pulsed Nd:YAG laser radiation on action potential conduction in nerve fibres inside teeth in vitro. J Dent 26:421–426

Orsini G, Procaccini M, Manzoli L, Giuliodori F, Lorenzini A, Putignano A (2010) A double-blind randomized-controlled trial comparing the desensitizing efficacy of a new dentifrice containing carbonate/hydroxyl- apatite nanocrystals and a sodium fluoride/potassium nitrate dentifrice. J Clin Periodontol 37:510–517

Özgünaltay G, Önen A (2002) Three-year clinical evaluation of a resin modified glass–ionomer cement and a composite resin in non-carious class V lesions. J Oral Rehabil 29:1037–1041

Pagliaro U, Nieri M, Franceschi D, Clauser C, Pini-Prato G (2003) Evidenced-based mucogingival therapy. Part 1: a critical review of the literature on root coverage procedures. J Periodontol 74:709–740

Paine ML, Slots J, Rich SK (1998) Fluoride use in periodontal therapy: a review of the literature. J Am Dent Assoc 129:69–76

Pamir T, Dalgar H, Onal B (2007) Clinical evaluation of three desensitizing agents in relieving dentin hypersensitivity. Oper Dent 32:544–548

Pandurić V, Knežević A, Tarle Z, Šutalo J (2001) The efficiency of dentine adhesives in treating non-caries cervical lesions. J Oral Rehabil 28(12):1168–1174

Pardi V, Pereira AC, Mialhe FL, Meneghim Mde C, Ambrosano GM (2003) A 5-year evaluation of two glass-ionomer cements used as fissure sealants. Community Dent Oral Epidemiol 31(5):386–391

Park JJ, Park JB, Kwon YH, Herr Y, Chung JH (2005) The effect of microcrystalline hydroxyapatite containing toothpaste in the control of tooth hypersensitivity. J Korean Acad Periodontol 35:577–590

Pashely DH, Tay FR, Haywood HB et al (2008) Consensus-based recommendations for the diagnosis and management of dentin hypersensitivity. Comp Contin Educ Dent 29(8 Suppl):1S–35S

Pashley DH (1992a) Dentin permeability and dentin sensitivity. Proc Finn Dent Soc 88(Suppl 1):215–224

Pashley DH (1992b) Dentin bonding agents. Curr Opin Dent 2:46–51

Pashley DH (2000) Potential treatment modalities for dentine hyper- sensitivity: in-office products. In: Addy M, Embery G, Edgar WM, Orchardson R (eds) Tooth wear and sensitivity. Martin Dunitz, London, pp 351–365

Pashley DH (1984) Smear layer: physiological considerations. Oper Dent Suppl 3:13–29

Pashley DH, Kalathoor S, Burnham D (1986) The effects of calcium hydroxide on dentin permeability. J Dent Res 65(3):417–420

Pashley DH, Carvalho RM, Pereira JC, Villanueva R, Tay FR (2001) The use of oxalate to reduce dentin permeability under adhesive restorations. Am J Dent 14:89–94

Paternak MA, Zimmerman M (2007) Therapeutic effect of follow-up assessments on antidepressant and placebo response rates in antidepressant efficacy trials. Br J Psychiatry 190:287–292

Pawlowska J (1956) Strontium chloride its importance in dentistry and prophylaxis. Czas Stomal 9:353–361

Pearce N, Addy M, Newcombe RG (1994) Dentine hypersensitivity: a clinical trial to compare 2 strontium desensitising toothpastes with a conventional fluoride toothpaste. J Periodontol 65:113–119

Petrou I, Heu R, Stranick M, Lavender S, Zaidel L, Cummins D, Sullivan RJ, Hsueh C, Gimzewski JK (2009) A breakthrough therapy for dentin hypersensitivity: how dental products containing 8% arginine and calcium carbonate work to deliver effective relief of sensitive teeth. J Clin Dent 20(Spec Iss):23–31

Pillon FL, Romani IG, Schmidt ER (2004) Effect of a 3% potassium oxalate topical application on dentinal hypersensitivity after subgingival scaling and root planing. J Periodontol 75:1461–1464

Pol DG, Jonnala J, Chute M, Gunjikar T, Pol S (2010) Potassium nitrate in the treatment of dentinal hypersensitivity- a mini analysis of studies. JIDA 4:399–403

Polderman RN, Frencken JE (2007) Comparison between effectiveness of a low-viscosity glass ionomer and a resin-based glutaraldehyde containing primer in

treating dentine hypersensitivity-a 25.2-month evaluation. J Dent 35:144–149
Porto ICCM (2012) Post-operative sensitivity in direct resin composite restorations: clinical practice guidelines. IJRD 1:1–12
Poulsen S, Errboe M, Lescay Mevil Y, and Glenny A-M (2006) Potassium containing toothpastes for dentine hypersensitivity. Cochrane Database Syst Rev (Issue 3). Art no. CD001476. doi:10.1002/14651858.CD001476.pub2
Pradeep AR, Sharma A (2010) Comparison of clinical efficacy of a dentifrice containing calcium sodium phosphosilicate to a dentifrice containing potassium nitrate and to a placebo on dentinal hypersensitivity: a randomized clinical trial. J Periodontol 81(8):1167–1173
Prati C, Cervellati F, Sanasi V, Montebugnoli L (2001) Treatment of cervical dentin hypersensitivity with resin adhesives: 4-week evaluation. Am J Dent 14(6):378–382
Que K, Fu Y, Lin L, Hu D, Zhang YP, Panagakos FS et al (2010) Dentin hypersensitivity reduction of new toothpaste containing 8.0% arginine and 1450 ppm fluoride: an 8-week clinical study on Chinese adults. Am J Dent 23A(Special Issue):28A–35A
Renton-Harper P, Midda M (1992) NdYAG laser treatment of dentinal hypersensitivity. Br Dent J 172(1): 13–16
Reynolds EC (1998) Anticariogenic complexes of amorphous calcium phosphate stabilized by casein phosphopeptides: a review. Spec Care Dentist 18(1):8–16
Rimondini L, Palazzo B, Iafisco M, Canegallo F et al (2007) The remineralizing effect of a carbonate-hydroxyapatite microparticles on dentine on dentine. Mater Sci Forum 539:602–605
Ritter AV, de Dias WL, Miguez P, Caplan DJ et al (2006) Treating cervical dentin hypersensitivity with fluoride varnish a randomized clinical study. JADA 137:1013–1020
Ross MR (1961) Hypersensitive teeth: effect of strontium chloride in a compatible dentifrice. J Periodontol 32:49–53
Saadoun AP (2008) Root coverage with Emdogain/Alloderm: a new way to treat gingival recessions. Eur J Esthet Dent 3(1):46–65
Salvato A, Troullos ES, Curro FA, Merola MR et al (1990) The effectiveness of Ferric Oxalate (FO) in relieving dentinal hypersensitivity. J Dent Res 69 (Special Issue):169 (Abstr no. 482)
Sandoval E, Shannon IL (1969) Stannous fluoride and dentin solubility. Tex Rep Biol Med 27(1):111–116
Santamaria MP, Suaid FF, Nociti FH Jr, Zaffalon M et al (2007) Periodontal surgery and glass ionomer restoration in the treatment of gingival recession associated with a non-carious cervical lesion: report of three cases. J Periodontol 78(6):1146–1153
Sanz M, Lorenzo R, Aranda JJ, Martin C et al (2009) Clinical evaluation of a new collagen matrix (Mucograft® prototype) to enhance the width of keratinized tissue in patients with fixed prosthetic restorations: a randomized prospective clinical trial. J Periodontol 36:868–876
Schiff T, Saletta L, Baker RA, Winston JL, He T (2005) Desensitizing effect of a stabilized stannous fluoride/sodium hexametaphosphate dentifrice. Compend Contin Educ Dent 26(Supp 1):35–40
Schiff T, He T, Sagel L, Baker R (2006) Efficacy and safety of a novel stabilized stannous fluoride and sodium hexametaphosphate dentifrice for dentinal hypersensitivity. J Contemp Dent Pract 7(2):1–008
Schiff T, Delgado E, Zhang YP, DeVizio W, Mateo LR (2009a) Clinical evaluation of the efficacy of a desensitizing paste containing 8% arginine and calcium carbonate in providing instant and lasting in-office relief of dentin hypersensitivity. Am J Dent 22(Sp Is A):8A–15A
Schiff T, Delgado E, Zhang YP, DeVizio W, Cummins D, Mateo LR (2009b) The clinical effect of a single direct topical application of a dentifrice containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride on dentin hypersensitivity: the use of a cotton swab applicator versus the use of a fingertip. J Clin Dent 20(4):131–136
Schiff T, Mateo LR, Delgado E, Cummins D, Zhang YP, DeVizio W (2011) Clinical efficacy in reducing dentin hypersensitivity of a dentifrice containing 8.0% arginine, calcium carbonate, and 1450 ppm fluoride compared to a dentifrice containing 8% strontium acetate and 1040 ppm fluoride under consumer usage conditions before and after switch-over. J Clin Dent 22(4):128–138
Schwarz F, Arweller N, Georg T, Reich E (2002) Desensitizing effects of an Er:YAG laser on hypersensitive dentine: a controlled, prospective clinical study. J Clin Periodontol 29(3):211–215
Sena FJ (1990) Dentinal permeability in assessing therapeutic agents. Dent Clin North Am 34(3):475–490
Sgolastra F, Petrucci A, Severino M, Gatto R, Monaco A (2013) Lasers for the treatment of dentin hypersensitivity: a meta-analysis J Dent Res 92(6)492–9. doi:10.1177/0022034513487212.[Epub 2013 Apr 22].
Sharif MO, Iram S, Brunton PA (2013) Effectiveness of arginine-containing toothpastes in treating dentine hypersensitivity: a systematic review. J Dent 41(6):483–492
Sharma AA, Park JH (2010) Esthetic considerations in interdental papilla: remediation and regeneration. J Esthet Restor Dent 22:18–30, _307 18
Sicilia A, Cuesta-Frechoso S, Suarez A, Angulo J et al (2009) Immediate efficacy of diode laser application in the treatment of dentine hypersensitivity in periodontal maintenance patients: a randomized clinical trial. J Clin Periodontol 36(8):650–660
Skurnik H (1963) Control of dental hypersensitivity: preliminary report on a strontium containing dentifrice. J Periodontol 34:183
Starr CB, Mayhew RB, Pierson WP (1989) The efficacy of hypnosis in the treatment of dentin hypersensitivity. Gen Dent 37:13–15
Stead WJ, Orchardson R, Warren PB (1996) A mechanical model of potassium ion diffusion in dentinal tubules. Arch Oral Biol 41:679–687
Stewardson DA, Crisp RJ, McHugh S, Lendenmann U, Burke FJ (2004) The Effectiveness of Systemp.

desensitizer in the treatment of dentine hypersensitivity. Prim Dent Care 11(3):71–76
Suge T, Ishikawa K, Kawasaki A, Suzuki K, Matsuo T, Noiri Y, Imazato S (2002) Calcium phosphate precipitation method for the treatment of dentin hypersensitivity. Am J Dent 15:220–226
Swift EJ Jr, May KN Jr, Mitchell S (2001) Clinical evaluation of Prime & Bond 2.1 for treating cervical dentin hypersensitivity. Am J Dent 14(1):13–16
Swift EJ (2005) Tooth sensitivity and whitening. Compend Contin Educ Dent 26(9 Suppl 3):4–10; quiz 23
Tai BJ, Bian Z, Jiang H, Greenspan DC, Zhong J, Clark AE, Du MQ (2006) Anti-gingivitis effect of a dentifrice containing bioactive glass (NovaMin®) particulate. J Clin Periodontol 33(2):86–91
Tammaro S, Wennstrom JL, Bergenholtz G (2000) Root–dentin sensitivity following non-surgical periodontal treatment. J Clin Periodontol 27:690–697
Tantbirojn D, Poolthong S, Leevailoj C, Srisawasdi S et al (2006) Clinical evaluation of a resin-modified glass-ionomer liner for cervical dentin hypersensitivity treatment. Am J Dent 19(1):56–60
Tay FR, Pashley DH, Mak YF, Carvalho RM, Lai SC, Suh BI (2003) Integrating oxalate desensitizers with total-etch two-step adhesive. J Dent Res 82:703–707
Thrash WJ, Jones DL, Dodds WJ (1992) Effect of a fluoride solution on dentinal hypersensitivity. Am J Dent 5:299–302
Tjan AHL, Chan CAC (1987) Effects of resin-compatible cavity varnishes on the polymerization of visible light cured composites. J Prosthet Dent 58:559–563
Tjan AHL, Grant BE, Nemetz H (1987) The efficacy of resin-compatible cavity varnishes in reducing dentin permeability to free monomer. J Prosthet Dent 57:179–185
Tredwin CJ, Naik S, Lewis NJ, Scully C (2006) Hydrogen peroxide tooth-whitening (bleaching) products: review of adverse effects and safety issues. Br Dent J 200(7):371–376
Tschoppe P, Zandim DL, Martus P, Kielbassa AM (2011) Enamel and dentine remineralization by nano-hydroxyapatite toothpastes. J Dent 39:430–437
Tugnait A, Clerehugh V (2001) Gingival recession-its significance and management. J Dent 29:381–394
Tyas MJ, Burrow MF (2004) Adhesive restorative materials: a review. Aust Dent J 49(3):112–121
Uchida A, Wakano Y, Fukuyama O, Miki T, Iwayama Y, Okada H (1980) Controlled clinical evaluation of a 10% strontium chloride dentifrice in treatment of dentin hypersensitivity following periodontal surgery. J Periodontol 51:578–581
Umberto R, Claudia R, Gaspare P, Tenore G, Alessandro DV (2012) Treatment of dentine hypersensitivity by diode laser: a clinical study. Int J Dent Article ID 858950, 8 pages
Veitz-Keenan A, Barna JA, Strober B, Matthews AG et al (2013) Treatments for hypersensitive noncarious cervical lesions: a Practitioners Engaged in Applied Research and Learning (PEARL) Network randomized clinical effectiveness study. J Am Dent Assoc 144(5):495–506
Vollenweider M, Brunner TJ, Knecht S, Grass RN, Zehnder M, Imfeld T, Stark WJ (2007) Remineralization of human dentin using ultrafine bioactive glass particles. Acta Biomater 3:936–943
von Troil BV, Needleman I, Sanz M (2002) A systematic review of the prevalence of root sensitivity following periodontal therapy. J Clin Periodontol 29(Suppl 3): 173–177
Voth ED, Phillips RW, Swartz ML (1966) Thermal diffusion through amalgam and various liners. J Dent Res 45:1184–1190
Wallace JA, Bissada NF (1990) Pulpal and root sensitivity rated to periodontal therapy. Oral Surg Oral Med Oral Pathol 69:743–747
Walsh LJ (2010) The effects of GC Tooth Mousse on cervical dentinal sensitivity: a controlled clinical trial. Int Dent SA 12(1):4–12
Wang H-L, Yeh C-T, Smith F, Burgett FG et al (1993) Evaluation of ferric oxalate as an agent for use during surgery to prevent post-operative root hypersensitivity. J Periodontol 64(11):1040–1044
Wang ZJ, Sa Y, Sauro S, Chen H, Xing WZ, Ma X et al (2010) Effect of desensitising toothpastes on dentinal tubule occlusion: a dentine permeability measurement and SEM in vitro study. J Dent 38(5):400–410
West NX (2007) The dentine hypersensitivity patient – a total management package. Int Dent J 57(Suppl 1): 411–419
West NX, Addy M, Jackson RJ, Ridge DB (1997) Dentine hypersensitivity and the placebo response. A comparison of strontium acetate, potassium nitrate and fluoride toothpastes. J Clin Periodontol 24:209–215
Wolfart S, Wegner SM, Kern M (2004) Comparison of using calcium hydroxide or a dentine primer for reducing dentinal pain following crown preparation: a randomized clinical trial with an observation time up to 30 months. J Oral Rehabil 31(4):344–350
www.thefreedictionary.com. Accessed 23 Apr 2013
Wycoff SJ (1982) Current treatment for dentinal hypersensitivity. In-office treatment. Compend Contin Educ Dent (Suppl 3):S113–5
Yilmaz HG, Kurtulmus-Yilmaz S, Cengiz E, Bayindir H, Aykac Y (2011a) Clinical evaluation of Er, Cr:YSGG and GaAlAs laser therapy for treating dentine hypersensitivity: a randomized controlled clinical trial. J Dent 39(3):249–254
Yilmaz HG, Cengiz E, Kurtulmus-Yilmaz S, Leblebicioglu B (2011b) Effectiveness of Er, Cr:YSGG laser on dentine hypersensitivity: a controlled clinical trial. J Clin Periodontol 38(4):341–346
Yan B, Yi J, Li Y, Chen Y, Shi Z (2013) Arginine-containing toothpastes for dentin hypersensitivity: systematic review and meta-analysis. Quintessence Int 44(9):709–723
Yiu CKY, King NM, Suh BI, Sharp LJ et al (2005) Incompatibility of oxalate desensitizers with acidic, fluoride-containing total-etch adhesives. J Dent Res 84(8):730–735
Yuan P, Shen X, Liu J, Hou Y, Zhu M et al (2012) Effects of dentifrice containing hydroxyapatite on dentinal

tubule occlusion and hexavalent chromium cations sorption: a preliminary study. PLoS ONE 7(12):e45283. doi:10.1371/journal.pone.0045283

Zaher CA, Hachem J, Puhan MA, Mombelli A (2005) Interest in periodontology and preferences for treatment of localized gingival recessions. A survey among Swiss dentists. J Clin Periodontol 32:375–382

Zalkind M, Hochman N (1997) Alternative method of conservative aesthetic treatment for gingival recession. J Prosthet Dent 77:561–563

Zetterstrom O, Andersson C, Eriksson L, Fredriksson A et al (1997) Clinical safety of enamel matrix derivative (EMDOGAIN) in the treatment of periodontal defects. J Clin Periodontol 24(Part 2):697–704