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Review Article

Calcium Sodium Phosphosilicate in the Management of Dentin Hypersensitivity - A Review

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Abstract

Dentin hypersensitivity (DH) is a common dental ailment in permanent teeth caused by dentin exposure as a consequence of loss of enamel and/or cementum. It is a source of continuing irritation that can cause severe distress leading to disturbance in eating and drinking habits and can have a significant effect on quality of life. It is physically and psychologically uncomfortable for the patient and can be defined as acute pain of short duration. The increasing life expectancy of the population has resulted increased lifespan of the permanent teeth, leading to increased incidence of dentin hypersensitivity, gingival recession and periodontal disease. The etiology of DH is multi-factorial with several predisposing factors. The diagnosis of DH is based on history and examination. Oral screening for DH should include radiographs, a variety of tests and identification of risk factors. The permeability and fluid movement in open, exposed dentinal tubules leads to the transmission of pain stimulus leading to DH. Occlusion of dentinal tubules has been identified as a potential method of reducing pain associated with sensitive teeth. Calcium sodium phosphosilicate is an inorganic glass material that has proven to occlude dentinal tubules and reduce DH. The objective of this review is to provide a brief overview of the diagnosis, etiology and management of dentin hypersensitivity with an emphasis on calcium sodium phosphosilicate.

Keywords: *Dentin Hypersensitivity; Calcium Sodium Phosphosilicate*

Introduction

Dentin hypersensitivity is defined as a "short, sharp pain arising from exposed dentin in response to stimuli typically thermal, evaporative, tactile, osmotic or chemical and which cannot be ascribed to any other form of dental defect or pathology" [1] and is identified as a distinct clinical entity [2].

In clinical practice, dentin hypersensitivity is described using different terms such as dentinal hypersensitivity, cervical hypersensitivity, root hypersensitivity, cemental hypersensitivity and can be used interchangeably [3].

Factors which predispose to the development of dentin hypersensitivity can be categorized as follows:

- Gingival recession [4]
- Tooth wear lesions [4]:
  - Attrition
  - Abrasion
  - Erosion
  - Abfraction

- Treatment procedures:
  - Scaling and polishing [4]
  - Bleaching [5]
- Physiological causes:
  - Advancing age [5]
  - Dental extrusion [2]
  - Poor oral hygiene [2]

Oral factors contributing to the development of dentin hypersensitivity

At normal intra-oral pH, the saliva is supersaturated with calcium and phosphate in the form of hydroxyapatite and calcium phosphate deposits in the saliva plug the exposed dentinal tubules during acute episodes of hypersensitivity. However, when the pH is reduced, saliva is not supersaturated with free calcium and phosphate and, hence, cannot plug the exposed dentinal tubules, leading to a persistence of dentinal hypersensitivity [6]. Also, acids such as citric, fumaric, malic, and phosphoric acids that are commonly found in foods have a pH of ≤ 3 and can lead to erosion of the tooth. Exposure to such foods even for a brief period may lead to the loss of the mineral and dentinal plugs covering the dentinal tubules [6].

Individuals at risk of developing dentin hypersensitivity [3]

- Bulimics
- Individuals who brush teeth over enthusiastically
- High-acidic food/drink consumers
- People with xerostomia
- Elderly people exhibiting gingival recession
- People who have a habit of chewing smokeless tobacco
- Patients who have undergone periodontal therapy

Prevalence of dentin hypersensitivity

There is a wide discrepancy in literature on the prevalence data of dentin hypersensitivity.[7] Over the years, the prevalence has been reported in several ways [8]:

- Between 4% to 74% across the world [9]
- Up to 30% of adults at some time during their lifetime [8]
- Nearly 14.3% of all dental patients [8]
- Between 8% to 57% of the adult dentate population [8]
- Between 65% to 98% in patients after periodontal treatment or surgery [10]
- Between 3% to 5% as per cross-sectional surveys in dental offices [7]

These variations could be attributed to differences in:

- Population base and settings evaluated [10]
- Methods of investigation (questionnaire or clinical examination) [8]
- Method of diagnosis (self-reported or professional diagnosis) [10]
- Behavioral factors (oral hygiene habits and intake of acidic foods and drinks) [10]

Similar to the variations in the prevalence of dentin hypersensitivity across the world, there are variations in prevalence data from India too.

Author (Year)	Place	Prevalence rate
Hegde (2007) [12]	Southern India	26%
Kaur G (2011) [9]	Derabassi, Punjab	8.7%
Dhaliwal JS (2012) [13]	Punjab	25%
Rane P (2013) [14]	Maharashtra	42.5%
Vijaya [11]	Chhattisgarh	55%
Sonal S (2014) [15]	Mangalore	22.5%
Naidu GM (2014) [9]	Andhra Pradesh	32%

Table 1: *Prevalence of Dentin Hypersensitivity across India.*

Diagnosis of dentin hypersensitivity

Dentin hypersensitivity is usually under-reported by patients [4]. Therefore, the Canadian Advisory Board of Dentin Hypersensitivity recommends that all dentate patients presenting to the dental clinic should be screened for the presence of symptoms and signs of dentin hypersensitivity in order to prevent under- or over-diagnosis of the condition [1].

A thorough and systematic examination of all intra- and extra-oral tissues is essential to arriving at a diagnosis. Radiographs and vitality tests may be used in conjunction with relevant findings in the patient's history [17]. Clinicians should examine the patient for clinical signs, such as attrition, abrasion, erosion, exposed cervical dentin, caries, gingival recession, periodontitis, or tooth fractures [16].

Prior to arriving at a diagnosis, it is important to rule out the presence of other conditions that may mimic dentin hypersensitivity such as chipped and fractured teeth, fractured restorations, etc [18,19].

Management of dentin hypersensitivity

The different strategies for the effective management of dentin hypersensitivity include [20]:

- Establishing an accurate diagnosis based on findings obtained from the patient's history and clinical examination.
- Ruling out other conditions that may mimic pain occurring due to dentin hypersensitivity.
- Treating all secondary conditions that stimulate symptoms similar to dentin hypersensitivity.
- Identifying and eliminating factors that cause or predispose to the development of dentin hypersensitivity.
- Treating patients based on their individual needs.

Several treatment options are available for managing dentinal hypersensitivity and include chemical or physical agents. Dentin hypersensitivity is most commonly managed using a topical agent that can be applied by the dental professional or by the patient, at home.

A satisfactory desensitizing material should be [23]:

- Relatively non-painless to the pulp
- Non-irritant to the pulp
- Easy to apply
- Rapid in action
- Effective for a long time
- Consistently effective
- Without staining effects

Desensitizing agents used to treat dentin hypersensitivity can be classified based on their mechanism of action [24]:

- Interrupt neural response to painful stimuli
- Occlude exposed and open tubules to block the hydrodynamic mechanism of pain stimulation.

Desensitizing agents used to treat dentin hypersensitivity can also be classified as At-home desensitizing agents and In-office desensitizing agents [21].

At-home desensitizing agents potassium salts (potassium nitrate, potassium chloride, or potassium citrate), strontium chloride, sodium fluoride, formaldehyde, dibasic sodium citrate, sodium monofluorphosphate, and stannous fluoride. Patients should be advised to use desensitizing toothpastes with the help of a toothbrush with soft bristles and with minimal amount of water to avoid diluting the active agent. Mouthwashes have also been recommended along with the use of desensitizing toothpastes. Clinicians should review the results of at-home desensitizing therapy after every 3 - 4 weeks. In-office therapy should be initiated if the patient has not achieved success with at-home therapy [21].

In-office desensitizing agents provide immediate relief from the painful symptoms of dentin hypersensitivity. The agents that are used as in-office desensitizing agents can be classified as [21]:

- Materials that undergo a setting reaction: Glass ionomer cement, composites
- Materials that do not undergo a setting reaction: Varnishes, oxalates

Calcium sodium phosphosilicate

Calcium sodium phosphosilicate (CSPS) is an inorganic amorphous glass material that contains calcium, sodium, phosphate, and silica [24,25]. Calcium sodium phosphosilicate can be technically described by the formula $CaO\text{-}Na_2O\text{-}P_2O_5\text{-}SiO_2$. In the early 1970s, CSPS materials were originally developed to be used as bone regenerative materials.

A unique property of CSPS is that when exposed to an aqueous environment, it can chemically bond directly with the calcified tissue and undergo a series of reactions that can lead to the formation of several calcium apatite species, which led to development of the use of CSPS materials to treat tooth sensitivity [26].

Exposure of the CSPS particles to an aqueous environment such as water or saliva leads to an immediate release of sodium ions, which increases the local pH [24]. The rapid release of sodium ions facilitates the precipitation of calcium and phosphate ions to form a carbonated calcium hydroxyapatite (HCA) layer, the composition of which is similar to that of the mineral found in bones and teeth [24,27]. These materials react during brushing and help in the occlusion of exposed dentin surfaces [4]. Once the CSPS material gets deposited onto the tooth surface, it adheres to the dentin and acts as a reservoir that continuously releases calcium and phosphate ions into the local environment [24,27].

The efficacy of CSPS to occlude dentinal tubules has been demonstrated in several *in vitro* studies.

Burwell., *et al*. conducted a series of *in vitro* experiments to demonstrate the mechanism of action and properties of CSPS-containing dentifrice for the treatment of DH [28]:

- When compared with a commercial topical desensitizing agent, treatment with CSPS-containing dentifrice significantly occluded more tubules than the commercial topical desensitizing agent ($p < 0.001$) and led to the formation of a significant calcium phos phate layer with the presence of silica.
- In the 10-day cycling model, one-time brushing with CSPS-containing dentifrice was associated with significantly fewer open visible tubules compared to the untreated control ($p < 0.001$).
- In the other 10-day acid challenge model, the Knoop hardness (KH) of dentin treated with CSPS-containing denti frice during the remineralization cycle was significantly higher than that of sound and demineralized dentin ($p < 0.001$). On the contrary, the KH of dentin treated with another commercial dentifrice was significantly lower than that of sound dentin ($p < 0.001$) and did not vary from the KH of demineralized dentin ($p = 0.358$).
- In the calcium-release model, CSPS-based dentifrices were observed to initially release less calcium when compared to the other commercial dentifrice. However, the calcium release increased after 4 hours and was sustained through 24 hours.

An *in vitro* study by Earl., *et al*. evaluated the formation and robustness of a layer formed on dentin after treatment with a fluoridated dentifrice containing CSPS. Ability of the CSPS-containing formulation to occlude tubules was assessed using the scanning electron microscope (SEM) [29]:

- The SEM analysis revealed that dentin surface treated with CSPS was coated with a confluent layer of material witout any discernible open tubules. The appearance of the surface was similar after one, two, and three days of application. In contrast, specimens treated with water demonstrated open tubules after all five days. The surface was observed to be similar to that of an untreated disc suggesting that neither the brushing regimen nor the storing in artificial saliva affected the dentin surface.
- Exposure of the CSPS-treated samples to common dietary acids did not re-expose the dentinal tubules.
- The layer formed on the dentin discs was firmly adherent and not easily removed by mechanical brushing.
- Electron diffraction and x-ray spectroscopy analysis suggested that the layer and the material plugging the dentinal tubules were calcium phosphate and structurally similar to hydroxyapatite.

An *in vitro* study by Parkinson., *et al*. compared the relative degree of dentin tubule occlusion and dentin mineralization achieved using 5% w/w CSPS/1450 ppm fluoride-containing dentifrice versus several commercial dentifrices reported to occlude dentinal tubules [26]:

- The highest level of occlusion was observed with 5% w/w CSPS/1450 ppm fluoride-containing dentifrice, stannous fluoride containing dentifrice, and strontium acetate-containing dentifrice.
- As per the surface analysis, treatment for 4 days with 5% w/w CSPS/1450 ppm fluoride-containing dentifrice was as sociated with the formation of a distinct layer at the dentin surface.
- Surface microhardness analysis on days 2 and 4 revealed significantly more surface hardening after treat mentwith5% w/w CSPS/1450 ppm fluoride-containing dentifrice than with control dentifrices such as arginine and amine fluoride.

Joshi., *et al*. conducted a study to evaluate and compare the effects of CSPS and a combination of aqueous solution of 35% hydroxyethyl methacrylate and 5% glutaraldehyde on dentinal tubule occlusion when applied for the treatment of DH [30]:

- Treatment with a combination of hydroxyethyl methacrylate and glutaraldehyde was noted to be associated with few er completely occluded tubules (0.402 ± 0.067) and a greater number of partially occluded tubules (0.532 ± 0.067).
- Treatment with CSPS was noted to be associated with greater number of completely occluded tubules (0.545 ±0.051) and fewer partially occluded tubules (0.371 ± 0.049)
- The specimens treated with a combination of hydroxyethyl methacrylate and glutaraldehyde showed a 1 - 2 µm thick resinous layer occluding the tubule surface, while those treated with CSPS showed a 2 - 3 µm thick layer consisting of large crystalline particles.

Clinical evidence on efficacy of calcium sodium phoshosilicate for dentin hypersensitivity

Chalas., *et al*. conducted a clinical study to evaluate the efficacy of a single application of CSPS-containing prophylaxis polishing paste in eliminating DH [31]. The study included 92 hypersensitive teeth in 23 patients aged between 21 - 66 years. The CSPS-containing prophylaxis paste was applied once to the exposed sensitive dentin for 60 sec using a preventive rubber cup on a slow-speed handpiece. The participants were asked to rate the severity of pain on a VAS following application of tactile and dehydrating stimuli, before and 1 week after treatment with a prophylaxis paste [11]. One-week after the application of the CSPS-containing prophylaxis paste, the percentage of teeth with very strong pain (VAS 10), severe pain (VAS 7 - 9) and moderate pain (VAS 4 - 6) on tactile stimuli reduced considerably.

Sensation of pain intensity in VAS									
0		1 - 3		4 - 6		7 - 9		10	
Before	After	Before	After	Before	After	Before	After	Before	After
10.9%	53.3%	29.3%	30.4%	42.4%	12.0%	16.3%	4.3%	1.1%	0.0%

Table 2: *Pain intensity on VAS with tactile stimuli before and after application of CSPS-containing prophylaxis paste [31].*

Sensation of pain intensity in VAS									
0		1 - 3		4 - 6		7 - 9		10	
Before	After	Before	After	Before	After	Before	After	Before	After
12.0%	47.8%	21.7%	37.0%	38.0%	15.2%	28.3%	0.0%	0.0%	0.0%

Table 3: *Pain intensity on VAS with dehydrating stimuli before and after application of CSPS-containing prophylaxis paste [31].*

A case-controlled study was conducted by Rajesh., *et al*. to determine the efficacy of a 5% CSPS-containing dentifrice vs. placebo for the relief of DH. The study involved 30 adults aged between 18 - 65 years with at least two sensitive teeth and a score of > 3 cm on the VAS using air blast. The study participants were advised to brush their teeth twice daily with a soft toothbrush using either a 5% CSPS-containing dentifrice or placebo. Dentin hypersensitivity was assessed by using cold water and air blast stimulation at week 6 and 8 [32].

At week 8, treatment with CSPS-containing dentifrice compared to placebo led to a significant reduction in DH following stimulation with air blast ($p = 0.007$) as well as cold water.

Calcium sodium phosphosilicate vs. arginine

West., *et al*. conducted a trial to determine the effectiveness of a 5% CSPS-based dentifrice and an 8% arginine-based dentifrice to occlude patent dentin tubules in an *in situ* clinical model before and after a dietary acid challenge. The randomized, crossover trial involved 36 subjects, aged ≥ 18 years. The participants wore two intraoral appliances in the lower arch, each retaining four dentin samples for 4 treatment days during the study period. They were instructed to brush the dentin samples twice daily with a test product, i.e. on days 1-4 [33].

Results

- On day 4, the 5% CSPS-containing dentifrice was the only treatment that led to significantly superior occlusion of pat ent dentin tubules compared to the control dentifrice ($p = 0.022$) and water (0.009).
- In contrast, treatment with 8% arginine-containing dentifrice showed no statistically significant difference compared to control dentifrice or water.
- No significant statistical difference was noted among any of the four treatments during the dab-on phase, i.e. both prior to and after the acidic challenge.

The efficacy of CSPS-containing dentifrice vs. arginine-containing dentifrice was also evaluated in a study by Rao., *et al*. The single-centre, randomized clinical study involved 80 subjects (aged 18 - 70 years) with DH in a minimum of two teeth and a minimum score of 3 on the Schiff cold air sensitivity scale. Participants were instructed to brush twice daily with the desensitizing dentifrices for 2 minutes. Additionally, they were asked to topically apply the dentifrice on sensitive teeth and to avoid rinsing till morning. Efficacy was evaluated at baseline, after 1 minute of application, and after 15 days [34].

Results

- A statistically significant difference was observed in both the groups on comparison between baseline and after 1 minute scores.
- A highly significant difference was observed in both the groups after 15 days of treatment, demonstrating better results with CSPS-containing dentifrice.
- Furthermore, after completion of the study, none of the patients in the CSPS group reported moderate pain, while 31 patients in the arginine group continued to experience moderate pain.

Calcium sodium phosphosilicate vs. strontium chloride

A randomized, double-blind, parallel-arm trial by Du., *et al*. evaluated the efficacy of 5% CSPS dentifrice formulation versus strontium chloride and placebo for relieving DH. The study included 75 patients with DH who were randomized to a dentifrice containing 5% w/w CSPS with a silica abrasive and no fluoride, strontium chloride, or placebo twice daily for 6 weeks. Sensitivity was measured using a VAS after the application of evaporative and thermal stimuli and measurements were obtained at baseline, and after 2 and 6 weeks of treatment [35].

Results

- All three groups demonstrated similar changes in sensitivity from baseline to 2 weeks. However, the CSPS group dem onstrated greater percentage reduction in sensitivity from baseline to 6 weeks, compared to the other two groups.
- The average sensitivity reduction was 34.8% for air stimulus and 38.6% for water stimulus in the CSPS group.

Ananthakrishna., *et al*. to compared the effects of CSPS-containing dentifrice with 10% strontium chloride containing dentifrice on DH in a 6-week clinical study which included 40 subjects (aged between 20 - 50 years), and a history of hypersensitivity in at least 2 posterior teeth. The participants were divided into two groups and advised to brush their teeth with the dentifrice provided for 3 minutes twice daily. Sensitivity was evaluated at baseline, week 2, week 4, and week 6 using an air blast and cold water. Patient's response was recorded on a VAS [36].

Results

- A significant difference in mean VAS scores was observed between the two dentifrices ($p < 0.001$). Furthermore, a sig nificant difference was observed in the mean sensitivity scores between the two mediums (air and water stimulus) ($p < 0.001$) and between the time intervals ($p < 0.001$).
- Although both the dentifrices were effective in reducing pain intensity from baseline values over 6 weeks, strontium chloride led to a 50% reduction in baseline scores for pain intensity while CSPS led to a 90% reduction in baseline scores.

Zhu., *et al*. conducted a systematic review and meta-analysis to determine the effect of CSPS in treating DH and to compare the effects with that of placebo. The meta-analysis included 11 clinical trials [13]. A toothpaste containing 5% CSPS was more effective at relieving DH than placebo, the level of evidence was classified as moderate [13]. A prophylaxis paste containing 5% CSPS was favored over placebo for reducing DH occurring after periodontal therapy [37].

Conclusion

Dentin hypersensitivity is sharp pain arising from exposed dentin due to various external stimuli. DH is a highly prevalent condition across the world and various factors predispose to the development of dentin hypersensitivity such as gingival recession, tooth wear, dental procedures, age and poor oral hygiene. Dentin hypersensitivity is usually under-reported by patients and hence patients should be screened for the presence of symptoms and signs of DH. Management of DH involves dentin hypersensitivity establishing an accurate diagnosis, eliminating risk factors and treating the root cause of DH. Desensitizing materials used to treat DH are of various types based on their mechanism of action and their usage. Calcium sodium phosphosilicate (CSPS) is an inorganic amorphous glass material that contains calcium, sodium, phosphate, and silica. Exposure of the CSPS to an aqueous environment leads to an immediate release of sodium ions, facilitating the precipitation of calcium and phosphate ions to form a carbonated calcium hydroxyapatite layer, which helps in the occlusion of exposed dentin tubules. The efficacy of CSPS to occlude dentinal tubules has been demonstrated in several in-vitro studies and clinical studies and has been proven to effectively relieve Dentin hypersensitivity.

Authors' Contributions

All authors contributed equally in the development of this review article.

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Competing Interests

Author NS declares no conflict of interest. Authors SM and SKM are employees of Dr. Reddy's Laboratories Limited, Hyderabad.

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