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Efficacy of a dissolvable strip with calcium sodium phosphosilicate (NovaMin®) in providing rapid dentine hypersensitivity relief☆

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ABSTRACT

Objective: To evaluate the efficacy of a dissolvable strip containing 15% w/w calcium sodium phosphosilicate (CSPS) (Novamin®) in providing rapid relief from dentine hypersensitivity (DH).

Methods: In this examiner-blind, proof-of-principle study, 120 healthy adults with DH were randomized 1:1 to the Test strip, professionally applied to facial surfaces of two selected teeth, or to No treatment. Sensitivity was assessed at baseline and 10 min, 2 h and 4 h post-application in response to evaporative (air) and tactile stimuli (measured by Schiff sensitivity scale/a numeric rating scale and tactile threshold, respectively). Change from baseline was analyzed by ANCOVA.

Results: At 10 min post-application, mean Schiff score change from baseline (primary endpoint) was statistically significant with the Test strip (−0.46; 95% confidence intervals [CI]: −0.563, −0.356; $p < 0.0001$) but not with No treatment (−0.02; 95% CI: −0.119, 0.088; $p = 0.7664$). The between-treatment group difference favored the Test strip (difference: −0.44; 95% CI: −0.591, −0.297; $p < 0.0001$). Similar improvements with the Test strip were reported for all other evaporative (air) and tactile sensitivity endpoints ($p < 0.0001$ vs no-treatment) at all timepoints (10 min, 2 h, 4 h). Test strips were considered by most staff and participants slightly/moderately easy to apply (98%). Many participants rated the overall usage experience as "like moderately" (40%) or "like extremely" (20%). There were no treatment-related adverse events.

Conclusion: This new CSPS-based technology may provide a novel treatment option for rapid relief from DH (Clinicaltrials.gov NCT02937623).

Clinical significance: A dissolvable strip containing 15% w/w calcium sodium phosphosilicate (CSPS) demonstrated significantly greater dentine hypersensitivity reductions following a single application compared with no treatment. Strips were well-liked by participants and generally well tolerated. A strip containing CSPS, which dissolves within 10 min, may provide rapid relief from dentine hypersensitivity.

Introduction

Dentine hypersensitivity (DH) is characterized by a transient and sharp burst of pain arising from exposed cervical dentine in response to external thermal, evaporative, tactile, osmotic or chemical stimuli, not attributed to other forms of dental defect or disease [1]. Global prevalence of DH is increasing, partly due to people retaining their natural dentition longer and the rise in erosive tooth wear [2]. A cross-sectional study of general dental practice adults in the United States (US) reported a DH prevalence of 12.3% [3], while a European study showed that 42.0% of young adults reported some degree of pain on cold air tooth stimulation [4].

The hydrodynamic theory of DH proposes that exposure of dentine to an external stimulus causes fluid movement within dentinal tubules [5]. If these tubules are patent from the pulp to the oral environment [1], the dentinal shift activates nerve terminals near the tubule base, eliciting a pain response [6]. This theory has led to development of two approaches to DH management: physical occlusion of exposed ends of dentinal tubules, which reduces fluid shift and subsequent nociceptor activation, or use of desensitizing agents such as potassium nitrate, which are believed to reduce intradental nerve excitability [7].

Tubule-occluding agents form chemical precipitates on the dentine surface and within dentinal tubules. Calcium sodium phosphosilicate (CSPS; Novamin®, GSK Consumer Healthcare [GSKCH], Weybridge, UK)

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is a particulate, bioactive glass material that degrades in the aqueous oral environment to release calcium and phosphate ions, leading to formation of hydroxycarbonate apatite on the dentine surface [8–11]. This process creates a physical barrier that mitigates the impact of external stimuli on fluid movement within dentinal tubules [8,9,12–14]. Clinical studies have shown that incorporation of 5% w/w CSPS into toothpastes is efficacious for DH relief when used over a number of days or weeks [15–20]. Additionally, studies have demonstrated DH relief following a single treatment with an occlusive toothpaste when applied to affected teeth by dabbing or focused brushing prior to whole mouth brushing [21–28].

Incorporation of CSPS into a dissolvable strip may be a pragmatic and effective method of exposing a sensitive tooth to sufficient active ingredient to allow hydroxycarbonate apatite to form on the surface of exposed dentine. *In-vitro* data showed that CSPS delivered from a hydroxypropyl cellulose (HPC) polymer strip led to dentine occlusion, apatite formation and a reduction in dentine permeability (Unpublished results).

The primary objective of this study was to evaluate immediate DH relief with use of an experimental dissolvable strip containing 15% w/w CSPS compared with no treatment, assessed using an evaporative (air) stimulus and the Schiff Sensitivity Scale [29] at 10 min after application. The 'No treatment' group did not receive any treatment so any effects cannot be reliably attributed to the specific inclusion of CSPS, rather than the vehicle strip; however, the main purpose of this proof-of-principle study, which was the first to investigate the delivery of CSPS via such a strip, was to determine overall efficacy and safety of the experimental strip.

Secondary objectives were to assess DH efficacy as above at 2 and 4 h after application, by evaporative (air) stimulus and a numeric rating scale (NRS) at 10 min, 2 h and 4 h after application, and by a tactile stimulus (Yeaple probe) at the same time points. Other objectives were to assess ease of strip use, strip dissolution time, and the sensory experience of study participants when using the strip.

Materials and methods

This was a single-center, randomized, two-arm, examiner-blind, parallel-group, proof-of-principle study in healthy participants with self-reported and clinically diagnosed DH and at least two sensitive teeth. The study was conducted at a US-based clinical research facility in accordance with the Declaration of Helsinki, the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use and local laws and regulations. The protocol was approved by the US Investigational Review Board, Inc (IRB no. U.S. IRB2016SRG/06); the study was registered at clinicaltrials.gov (NCT02937623). Anonymized individual participant data and study documents can be requested for further research from www.clinicalstudydatarequest.com.

Participants

Study participants were required to be aged 18–65 y with ≥20 natural teeth, in good general health, with a self-reported history of DH of between 0.5–10 y. Participants were recruited from the existing study site database. At screening, eligible participants had at least two accessible non-adjacent teeth in different quadrants with signs of erosion, abrasion, or facial/cervical gingival recession (EAR) as assessed by a visual examination; a modified gingival index (MGI) score of 0 [30], clinical mobility of ≤1 [31]; and a positive response to a qualifying evaporative (air) assessment. At baseline, eligible participants had a minimum of two accessible, non-adjacent teeth with signs of DH, as determined by a qualifying tactile stimulus threshold of ≤20 g [32] and a Schiff sensitivity score of ≥2 [29] (see 'Clinical procedures' for details).

Participants were excluded if they had a chronic debilitating disease; had any condition/medication causing xerostomia; received daily doses of treatments that could interfere with pain perception; had current/recent (2 weeks) use of antibiotics; were pregnant or breastfeeding; had known/suspected allergy/intolerance to study materials/ingredients; had tongue/lip piercings; or had undergone dental prophylaxis within 4 weeks, desensitizing treatment or tooth bleaching within 8 weeks, scaling or root planing within 3 months of screening; had gross periodontal disease or treatment of periodontal disease within 12 months; or had participated in another clinical study or received an investigational drug within 30 d of screening.

Specific dentition exclusions for test teeth included: evidence of current/recent caries, or reported treatment of decay within 12 months of screening; exposed dentine but with deep, defective, or facial restorations; teeth used as abutments for dentures; dental implants; full crowns or veneers; orthodontic bands; cracked enamel; sensitive teeth with etiologies other than EAR; or sensitive teeth not expected to respond to an over-the-counter DH toothpaste.

Clinical procedures

At the screening visit, participants gave written informed consent to participate, and their demographic characteristics, medical history and concomitant medications were recorded. Participants underwent oral soft tissue (OST) and oral hard tissue examinations and assessments to determine eligible teeth. Dentition was assessed sequentially for evidence of EAR, gingival health status (MGI score = 0), tooth mobility ≤1, and sensitivity to an air-jet stimulus (where a "yes" response indicated sensitivity). Eligible participants were supplied with a standard fluoride toothpaste (Crest® Cavity Protection, 0.15% w/v fluoride as sodium fluoride ion; Procter & Gamble, Cincinnati, OH, USA) and a toothbrush (Oral-B Sensi-soft® manual tooth brush; Procter & Gamble), which they used twice daily for a 1 or 2 week acclimatization period (depending on scheduling of the baseline visit) between screening and baseline visits.

Participants could not use any oral care products indicated for DH relief within 8 weeks of screening until study completion or chew gum throughout the study. Before visits, participants refrained from all oral hygiene procedures or from taking analgesics for at least 8 h, from eating and drinking for at least 4 h, and from excessive alcohol consumption for 24 h. Small sips of water were permitted within 4 h of visits (but not within 1 h). Participants were requested to delay any non-emergency elective dental treatment or prophylaxis until after study completion. During the study, participants could only use the oral care products provided.

At the baseline visit, prior to treatment, ongoing eligibility was assessed; any adverse events (AEs), incidents and changes to concomitant medications were recorded, and acclimatization toothpaste adherence was confirmed. An OST examination was completed by the first examiner (non-index reading examiner). Sensitivity of the identified clinically eligible teeth was then evaluated by the second examiner (index scoring examiner) by the participant's response to a tactile stimulus. Tactile sensitivity was assessed using an electronic constant-pressure force-sensing (Yeaple) probe [32] that allowed application of a known force to the dentine surface, starting at 10 g and rising in increments of 10 g. The gram setting that elicited two consecutive "yes" responses from the participant (where "yes" indicated that the stimulus caused pain/discomfort) was recorded as the tactile threshold. At baseline, the maximum force used was 20 g; after treatment, it was 80 g. Pain at 80 g was recorded as such; no pain at 80 g was recorded as >80 g.

As recommended, two independent stimulus-based efficacy measures were used to assess DH [33]. Following a 5-min break to allow for tooth recovery, teeth with a tactile threshold ≤20 g were evaluated for sensitivity to an evaporative (air) stimulus. The examiner directed a maximum 1 s air blast from a distance of 1 cm onto the exposed dentine surface of each test tooth in turn, having first isolated the surface to prevent adjacent teeth or surrounding soft tissue being exposed to the stimulus. The examiner assessed the participant's response to the stimulus using the 4-point Schiff Sensitivity Scale (from 0 = participant does not

respond to air stimulus to 3 = participant responds to stimulus, considers stimulus to be painful, and requests discontinuation of the stimulus) [28]. Participants also rated the intensity of their response to the evaporative (air) stimulus using a 10-point NRS (from 1 = 'no pain' to 10 = 'intense pain'). From those that met the qualifying sensitivity assessments, the investigator selected two non-adjacent teeth to be evaluated for the remainder of the study.

Study groups

Eligible participants were randomized (1:1) according to a schedule provided by the Biostatistics Department of the study sponsor. Randomization was stratified by maximum baseline Schiff sensitivity score (either 2 or 3) of the two selected test teeth. Participants were randomised to either receive the test product applied to the chosen teeth or to receive no treatment. The test product was an experimental dissolvable HPC polymer strip containing 15% w/w CSPS, which was evenly-distributed throughout the strip. One strip was applied to the facial surface of each of the two selected test teeth by a member of the site staff not involved in collection of efficacy data and OST measures. The strip was positioned using light finger pressure, targeting the center of the strip with the center of the tooth. All areas of exposed dentine were covered, especially at the gingival margin. Any excess film was folded over the tooth's occlusal surface.

The dental examiner (for the sensitivity assessments), study statisticians and other employees of the study sponsor who could have influenced study outcomes were blinded to treatment allocation. Participants were instructed not to disclose to the examiners or other study participants whether or not the Test strip had been applied.

Following strip application, the staff member completed a three-item questionnaire (see Supplemental information for full details): 1) How easy was the strip to apply? (from 1 = not easy at all to 5 = extremely easy); 2) How long did it take for the strip to dissolve on the facial tooth surface? (from 1 = up to 5 min to 3 = not dissolved at 10 min); and 3) After 10 min following strip application was any visible residue observed? (from 1 = no residue to 4 = residue present on both facial surface and interproximally). Strip dissolution and the presence of any residue was monitored by the staff member who applied it by carefully mobilizing the adjacent labial/buccal mucosa at 5 and 10 min following application using a dental mirror and lighting as appropriate and taking care not to potentially disrupt strip dissolution. If any visible residue was present at 10 min, the staff member removed it using a cotton bud or a blunt/ball-ended probe for the interproximal surfaces. Care was taken not to instrument the tooth surface.

Immediately following application, participants in the Test strip group completed a 2-item questionnaire (see Supplemental information for full details): 1) Please describe how the strip felt on your tooth before it dissolved (free text answer); 2) How would you rate the strength of the taste? (from 1 = slightly too weak to 3 = slightly too strong).

At 10 (+5) min, 2 h (±10 min) and 4 h (±10 min) following treatment (or from a designated study start time for those not receiving treatment), the sensitivity of the two test teeth was evaluated by tactile stimulus response and evaporative (air) stimulus response, performed at least 5 min apart. Another examiner was assigned to the OST evaluation to assess gingival irritation associated with the strip or strip residue prior to (and following) the second examiner conducting sensitivity evaluations.

At 4 h (±10 min), all participants underwent an OST examination; those in the Test strip group completed a 5-item questionnaire: 1) How comfortable was the strip to wear (from 1 = not at all comfortable to 5 = extremely comfortable); 2) How much residue of the strip do you feel was left on your teeth? (from 1 = a lot of residue to 4 = no residue at all); 3/4) What are the things you liked/disliked about the usage experience with this product (free text answers); 5) How much did you like the overall usage experience? (from 1 = dislike extremely to 7 = like extremely).

Safety

AEs were recorded from first use of acclimatization toothpaste until 5 d after last administration of the Test strip. OST abnormalities were included as AEs if they appeared or worsened after administration of the acclimatization toothpaste. AEs were regarded as treatment emergent if they occurred on or after strip application (or randomization for no treatment group). Clinical judgement was exercised by the investigator to assess the relationship between the Test strip and any AE occurrence, with intensity graded as mild, moderate or severe. The safety population included all randomized participants who received the study treatment.

Statistical analysis

Sufficient participants were screened so that at least 118 (approximately 59 per group) could be randomized to the study, ensuring that approximately 110 evaluable participants completed the study. This would permit a mean difference of 0.35 (standard deviation [SD] 0.6464) in change from baseline Schiff sensitivity score after 10 min to be detected with 80% power, based on results from previous studies (Unpublished results). Statistical analyses were conducted under the null hypothesis of no difference between treatments versus the alternate hypothesis of a difference between treatments. All tests were 2-sided with a significance level of 5%. Analyses were performed using Statistical Analysis System version 9.2 (SAS Institute Inc., Carey, NC, USA). The efficacy analysis was performed on a modified intent-to-treat (ITT) population, defined as all participants who received the study treatment and had at least one post-baseline efficacy measurement. The per protocol (PP) population was defined as all participants in the ITT population who had at least one assessment of efficacy considered unaffected by protocol violations.

Change from baseline in Schiff sensitivity score was analyzed using analysis of covariance (ANCOVA) with treatment as a factor and baseline Schiff sensitivity score as a covariate. Change from baseline in tactile threshold and NRS scores were analyzed using ANCOVA with treatment and baseline Schiff sensitivity score stratification as factors and corresponding baseline variable as a covariate. Staff and participant questionnaires were summarized in terms of the number and percentage of participants.

Results

The first participant was enrolled in November 2016; the final participant completed the study in December 2016. Of the 135 individuals screened, 120 were randomized to treatment and all participants completed the study (Fig. 1). Participants were aged between 20 and 63 y (mean 38.2; SD 11.52), and the majority were female (65.8%). Study groups were well balanced at baseline (Table 1). Twenty-four participants had an acclimatization period of 1 week and 96 participants had an acclimatization period of 2 weeks. Mean baseline Schiff sensitivity scores were similar: 2.52 (SD 0.375) and 2.51 (0.429), respectively.

Schiff sensitivity scores

At 10 min after Test strip application or no treatment, the mean changes in Schiff sensitivity score from baseline (primary endpoint) was statistically significant in the Test strip group (−0.46; $p < 0.0001$) but not the No treatment group (−0.02) (Fig. 2a; Table 2). The between-treatment group mean adjusted difference was statistically significant in favor of the Test strip ($p < 0.0001$). Significant adjusted mean differences between treatments were also observed in favor of the Test strip at 2 and 4 h after application ($p < 0.0001$ at both time points) with treatment difference increasing over time (Table 2).

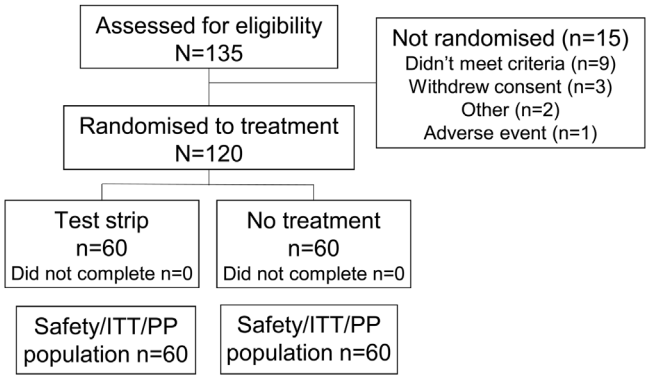

Fig. 1. Study flow.

Table 1
Participant demographics and baseline characteristics.

		Test strip (N = 60)	No treatment (N = 60)
Gender, n (%)	Female	40 (66.7)	39 (65.0)
	Male	20 (33.3)	21 (35.0)
Race, n (%) White		34 (56.7)	26 (43.3)
Black/African-American		15 (25.0)	25 (41.7)
Asian		5 (8.3)	0
Other/Multiple		6 (10.0)	9 (15.0)
Mean age (SD), range (years)		37.6 (11.75)	38.8 (11.36)
		20–59	20–63
Maximum baseline Schiff	2.0	20 (33.3)	20 (33.3)
sensitivity score, n (%)	3.0	40 (66.7)	40 (66.7)

Tactile threshold

At the 10 min, 2 h and 4 h time points, the mean changes in tactile threshold values from baseline were statistically significant in the Test strip group ($p < 0.0001$ at each time point) but not in the No treatment group (Fig. 2b; Table 2). The between-treatment group mean adjusted difference was statistically significant in favor of the Test strip at each evaluation point ($p < 0.0001$ at all time points) (Table 2).

NRS

At the 10 min, 2 h and 4 h time points, the mean changes in NRS from baseline were statistically significant in the Test strip group ($p < 0.0001$ at each time point) (Fig. 2c; Table 2). A statistical difference compared with baseline was seen at 2 h only in the No treatment group ($p = 0.0124$). The between-treatment group mean adjusted difference was statistically significant in favor of the Test strip at each time point ($p < 0.0001$ at all time points) (Table 2).

Staff and participant questionnaires

A summary of staff questionnaire responses made immediately following Test strip application is presented in Table 3. Test strips were most frequently reported as "slightly easy to apply" (68.3%). Most strips had dissolved within 10 min (95.0%).

Responses to the participant questionnaires are presented in Table 4. Most participants (85%) reported the strength of taste as "just right". Strips were most frequently reported as "very comfortable" (38.3%) or "somewhat comfortable" (33.3%) with no residue (45.0%) or a slight amount of residue (33.3%) left on the teeth at 10 min. Sixty percent of participants rated the overall strip usage experience as "like moderately/extremely".

Safety

Three AEs (cough, traumatic ulcer and chronic cheek biting) were reported by three participants; none of these AEs were treatment emergent or treatment-related. All reported AEs were mild in nature and resolved without action. There were no serious AEs or incidents and no participants were withdrawn/withdrew because of an AE.

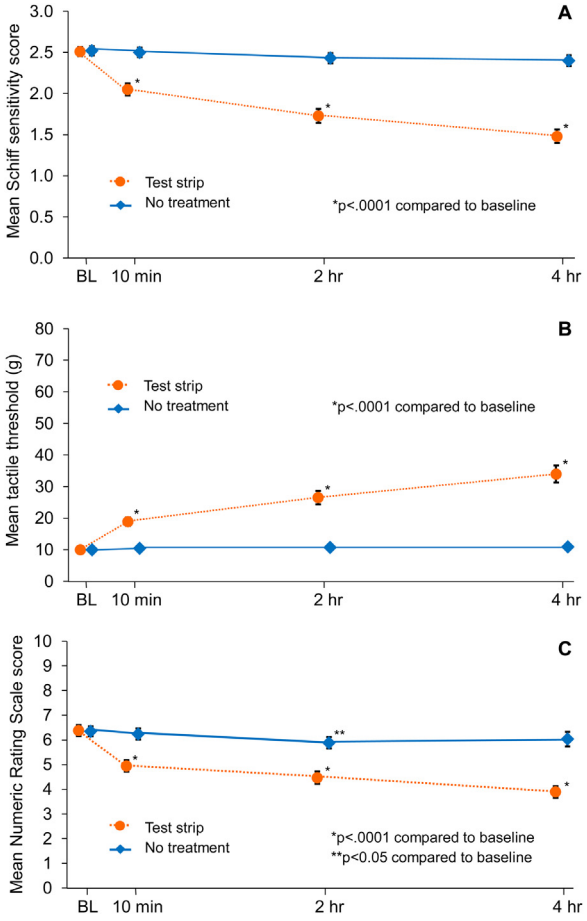

Fig. 2. A) Schiff sensitivity score; B) Tactile threshold; C) Numeric rating scale (NRS) by treatment and time (mean ± standard error; Intent-to-treat population). **Data are offset for clarity. Lower Schiff sensitivity and NRS scores are favorable; higher tactile thresholds are favorable. BL, baseline.**

Discussion

This proof-of-principle clinical study was the first to investigate the delivery of CSPS via a dissolvable strip. There were statistically significantly greater reductions in DH, as elicited by evaporative (air) and tactile stimuli, in participants using the dissolvable strip containing CSPS compared with those not receiving treatment. Participant-elicited pain intensity ratings in response to the evaporative (air) stimulus, measured using an NRS, were also less in the Test strip group. There is no consensus as to what level of response is clinically significant. However, according to criteria set out by Orchardson et al. [34], a treatment can be deemed clinically effective if there is at least "a 33% reduction in mean baseline sensitivity." In this study, the difference from baseline for Schiff scores with the Test strip was 18% at 10 min, 31% at 2 h and 41% at 4 h, indicating that this treatment may be clinically effective. Further studies (posited below) would be needed to confirm this.

Differences were seen as early as 10 min after application and appeared to increase over the 4 h test period. This is an important aspect of a DH treatment as people experiencing DH report the detrimental impact that symptoms can have on quality of life aspects including eating, drinking, talking and social interactions [35]. An easy-to-apply strip that delivers rapid relief from DH to affected teeth only would be convenient for individuals with DH to use inside and outside the home both for symptom relief and in anticipation of a DH-stimulating activity such as eating.

Table 2
Summary Statistics of evaporate (Air) sensitivity (Schiff Sensitivity Score and Numeric Rating Scale) and tactile threshold (g) scores plus adjusted mean change vs baseline in efficacy parameters at each time point (Intent-to-treat population). Primary/secondary analyses.

	Test strip (n = 60)	No treatment (n = 60)	Test strip (n = 60)	No treatment (n = 60)	
	Mean (standard error) (% change from baseline)		Adjusted mean change from baseline (95% CI) p-value		Difference (95% CI) p-value
Schiff sensitivity score[a]					
BL	2.51 (0.054)	2.52 (0.054)			
10 min	2.05 (0.074) (18.3%)	2.50 (0.057) (0.8%)	−0.46 (−0.563, −0.356) **0.0001**	−0.02 (−0.119, 0.088) 0.7664	−0.44 (−0.591, −0.297) **0.0001**
2 h	1.73 (0.084) (31.1%)	2.43 (0.061) (3.6%)	−0.78 (−0.905, −0.648) **0.0001**	−0.08 (−0.210, 0.046) 0.2082	−0.69 (−0.876, −0.513) **0.0001**
4 h	1.48 (0.081) (41.0%)	2.40 (0.065) (4.8%)	−1.03 (−1.161, −0.893) **0.0001**	−0.11 (−0.249, 0.019) 0.0926	−0.91 (−1.102, −0.723) **0.0001**
Tactile threshold (g)[b]					
BL	10.00 (0)	10.00 (0)			
10 min	18.92 (1.366) (88.2%)	10.50 (0.308) (5%)	8.92 (6.998, 10.835) **0.0001**	0.50 (−1.419, 2.419) 0.6068	8.42 (5.703, 11.130) **0.0001**
2 h	26.50 (2.120) (165.5%)	10.75 (0.310) (7.5%)	16.50 (13.550, 19.450) **0.0001**	0.75 (−2.200, 3.700) 0.6155	15.75 (11.578, 19.922) **0.0001**
4 h	34.00 (2.673) (240.0%)	10.92 (0.303) (9.2%)	24.00 (20.310, 27.690) **0.0001**	0.92 (−2.774, 4.607) 0.6237	23.08 (17.864, 28.302) **0.0001**
Numeric Rating Scale[a]					
BL	6.38 (0.220)	6.35 (0.207)			
10 min	4.94 (0.232) (22.6%)	6.24 (0.226) (1.7%)	−1.44 (−1.753, −1.122) **0.0001**	−0.11 (−0.428, 0.203) 0.4819	−1.33 (−1.771, −0.880) **0.0001**
2 h	4.47 (0.250) (30.0%)	5.88 (0.236) (7.4%)	−1.91 (−2.280, −1.545) **0.0001**	−0.47 (−0.838, −0.104) **0.0124**	−1.44 (−1.961, −0.922) **0.0001**
4 h	3.89 (0.233) (39.0%)	6.03 (0.230) (5.0%)	−2.49 (−2.845, −2.126) **0.0001**	−0.33 (−0.691, 0.029) 0.0710	−2.15 (−2.663, −1.646) **0.0001**

P-values indicating statistically significant within and between-treatment comparisons are highlighted in bold; BL: Baseline.
[a] Difference is Test strip minus No treatment such that a negative difference favors the Test strip.
[b] Difference is Test strip minus No treatment such that a positive difference favors the Test strip.

Table 3
Staff and participant questionnaire responses to Test strip application (n = 60) (Intent-to-treat population; only in group receiving test strip).

Question	Response	n (%)
How easy was the strip to apply?	Not easy at all	0
	Slightly easy	41 (68.33)
	Moderately easy	18 (30.00)
	Very easy	1 (1.67)
	Extremely easy	0
How long did it take for strip to dissolve on facial tooth surface?	Up to 5 min	0
	Up to 10 min	57 (95.00)
	Not dissolved at 10 min	3 (5.00)
10 min following application, was any visible residue observed?	No residue	25 (41.67)
	Facial surface only	0
	Interproximally only	20 (33.33)
	Facial surface and interproximally	15 (25.00)

Table 4
Participant questionnaire responses for Test strip (n = 60) (Intent-to-treat population; only in group receiving test strip).

Question	Response	n (%)
How would you rate the strength of the taste? (10 min)	Slightly too weak	6 (10.00)
	Just right	51 (85.00)
	Slightly too strong	3 (5.00)
How comfortable was the strip to wear? (4 h)	Not at all comfortable	1 (1.67)
	Not very comfortable	7 (11.67)
	Somewhat comfortable	20 (33.33)
	Very comfortable	23 (38.33)
	Extremely comfortable	9 (15.00)
How much residue do you feel was left on your teeth? (4 h)	A lot of residue	3 (5.00)
	A moderate amount of residue	10 (16.67)
	A slight amount of residue	20 (33.33)
	No residue at all	27 (45.00)
How much did you like the overall usage experience? (4 h)	Dislike extremely	1 (1.67)
	Dislike moderately	1 (1.67)
	Dislike slightly	2 (3.33)
	Neither liked nor disliked	11 (18.33)
	Like slightly	9 (15.00)
	Like moderately	24 (40.00)
	Like extremely	12 (20.00)

In-vitro testing of CSPS on HPC polymer strips demonstrated dentine occlusion and apatite formation in a dose-response manner with increasing CSPS content (Unpublished results). The most effective formulation in terms of apatite formation (important for long-term substantively of the occluding layer) was 15% w/w CSPS. A reduction in dentine permeability (fluid flow) was recorded for different CSPS concentrations; however, this included reduction with the polymer strip without CSPS.

It is important to note that there are limitations to this current study. While it met its primary and secondary endpoints, the 'No treatment' group did not receive a non-CSPS vehicle control strip; it is therefore not possible to ascertain whether DH relief was due to the action of CSPS or to the strip itself. However, this was a proof-of-principle, first-in-human study whose main purpose was to determine overall efficacy and safety profile of this novel CSPS treatment delivery option. Further clinical studies would need to include a placebo control strip and different concentrations of active ingredients to establish the role of CSPS in this novel format.

No treatment-emergent AEs were reported with the Test strip and there were no observations of abnormalities that appeared or worsened after initial assessment. As such, data obtained from this study provide an important insight into the overall safety profile of CSPS delivered within the vehicle strip. This will form the basis for additional clinical testing.

In terms of usability, the study staff who applied the strips to the participants generally found them moderately/slightly easy to apply, with most strips taking between 5 and 10 min to dissolve. Only three of the 60 participants receiving the Test strip felt that there was a lot of residue left on their teeth, and most participants liked the overall usage experience. This suggests that such a strip would be an acceptable option for the rapid treatment of DH symptoms.

In conclusion, the experimental dissolvable strip containing 15% w/w CSPS was well tolerated and demonstrated statistically significant, greater reductions in DH after 10 min, 2 h, and 4 h following a single-use compared with no treatment. This new technology may provide a novel treatment option for rapid relief from the symptoms of DH. Further studies are required to fully understand the efficacy of this product.

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Declaration of Competing Interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jjodo.2019.100003.

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