Journal of Dentistry 136 (2023) 104616

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Treating hypersensitivity in older adults with silver diamine fluoride: A randomised clinical trial

Alice Kit Ying Chan, Yiu Cheung Tsang, Chloe Meng Jiang, Katherine Chiu Man Leung, Edward Chin Man Lo, Chun Hung Chu *

Faculty of Dentistry, The University of Hong Kong, Postal address: 3/F, The Prince Philip Dental Hospital, 34, Hospital Road, Sai Ying Pun, Hong Kong, China

ARTICLE INFO

Keywords:
Older adult
Elderly
Oral health
Prevention
Silver diamine fluoride
Hypersensitivity

ABSTRACT

Objective: This study aimed to evaluate the desensitizing effect of topically applied 38% silver diamine fluoride (SDF) solution on the exposed root surface of hypersensitive teeth in older adults.
Method: This double-blind randomised clinical trial recruited healthy older adults with dentine hypersensitivity. A trained examiner tested the most hypersensitive tooth root surface with a blast of compressed cold air from a three-in-one syringe. The participants gave a sensitivity score (SS) in visual analogue scale from 0 (no pain) to 10 (agonizing) at the baseline visit. Then, they received 38% SDF or 5% potassium nitrate solution (control) as intervention on the root surface. After the intervention, they received a compressed cold air test and reported the SS again. The compressed cold air test followed by intervention was repeated at 4- and 8-week follow ups. The primary outcome was the reduction in SS at 8-week follow-up with reference to the SS at baseline before intervention. Shapiro–Wilk and Mann–Whitney U tests were performed for data analysis following a normality test of SS.
Results: This trial recruited 148 participants, and 139 (94%) participants completed the trial. The median percentage reductions in SS in the SDF and potassium nitrate groups were 60% and 50%, respectively ($p < 0.001$).
Conclusion: According to the results, 38% SDF solution reduced hypersensitivity on the exposed root surface of older adults. In addition, 38% SDF was more effective than 5% potassium nitrate solution to reduce hypersensitivity on the exposed root surface of older adults.
Clinical significance: Dentin hypersensitivity is common amongst older adults and negatively affects their quality of life. To date, there is no gold standard professionally applied desensitizing therapy in treating hypersensitivity. Evidence from this clinical trial could aid clinical practice and improve oral health in older adults.
Trial registration: This study was registered at ClinicalTrials.gov (NCT05392868).

1. Introduction

Dental caries, periodontal disease and tooth wear are widespread oral problems in older adults and are common causes of dentine hypersensitivity [1]. More than one third (38%) of older adults in China [2] and almost half (48%) of the community-dwelling older adults in Hong Kong suffered from dentine hypersensitivity [3]. Thermal, electrical, mechanical, osmotic or chemical stimuli can induce dentine hypersensitivity due to hydrodynamic changes in the dentinal tubules, eliciting nerve impulses [4]. Pain arising from dentine hypersensitivity impedes routine oral hygiene practice and further jeopardizes periodontal health, limits food choices and negatively affects the individual's quality of life [5,6].

Dentine hypersensitivity should first be addressed through proper diagnosis and implementing an appropriate preventive measure, followed by intervention, from the use of desensitizing agents to direct/indirect restorations [5]. Using desensitizing agents is a simple, non-invasive and low-cost treatment modality [5] that is suitable for older adults whose medical condition, physical ability and financial status are compromised when compared with other age groups [1,7]. Desensitizing agents relieve dentine hypersensitivity by blocking the dentinal tubules or modifying the pulpal nerve responses [8]. It can be self-applied daily or professionally applied at regular intervals. Self-applied desensitizing toothpastes are easy to use, readily available and have been proven effective in reducing dentine hypersensitivity [8]. However, it usually takes 4–8 weeks to achieve pain relief [5]. Several

* Corresponding author at: Address: 3/F, The Prince Philip Dental Hospital, 34, Hospital Road, Sai Ying Pun, Hong Kong, China.
E-mail address: chchu@hku.hk (C.H. Chu).

https://doi.org/10.1016/j.jdent.2023.104616
Received 4 April 2023; Received in revised form 4 July 2023; Accepted 11 July 2023
Available online 14 July 2023

desensitizing agents, such as sodium fluoride varnish and silver diamine fluoride solution, are available for clinicians to apply on the exposed root surface. However, there is limited clinical evidence on the use of professionally applied desensitizing agents to manage dentine hypersensitivity [8].

Potassium nitrate was first used as an in-office therapy for managing dentine hypersensitivity in 1974, and in 1986, the American Dental Association accepted it as a desensitizing agent [9,10]. The US Food and Drug Administration had classified the 5% potassium nitrate as a Category I (safe and effective) tooth desensitizer ingredient for over-the-counter products [11]. Potassium ions were believed to interrupt the neural transmission for pain stimuli in the intradental nerves by increasing the extracellular potassium ion concentration to prevent action potential from being generated [12]. Clinical trials showed that self-applied potassium nitrate containing toothpastes or mouthwash effectively reduced dentine hypersensitivity [13,14]. A systematic review concluded there was sufficient evidence to support the use of potassium-containing desensitizing toothpastes for dentin hypersensitivity [15]. Potassium nitrate is one of the most used desensitizing agents and is a conventional method in managing dentine hypersensitivity.

Silver diamine fluoride (SDF) was approved in Japan for clinical use in the 1970s [16] and was cleared as a desensitizing agent by the US Food and Drug Administration in 2014 [17]. SDF forms deposits to occlude the dentinal tubules on both artificial demineralized bovine dentin and the exposed dentine surface of extracted human teeth [18,19]. Only two clinical trials have been conducted to investigate the desensitizing effect of SDF, and they found SDF effective in reducing dentine hypersensitivity, yet the evidence on its clinical use is limited [20,21]. This randomised clinical trial aimed to investigate the effectiveness of topically applied 38% SDF solution in reducing dentine hypersensitivity on hypersensitive teeth with an exposed root surface in older Chinese adults. The hypothesis was that older adults in the test group who received 38% SDF every 4 weeks on the exposed root surface of the hypersensitive teeth would have significantly greater reduction in dentine hypersensitivity than older adults in the control group who received 5% potassium nitrate solution every 4 weeks on the exposed root surface of the hypersensitive teeth at the 8-week follow-up.

2. Methods

2.1. Trial design

This was a double-blind randomised controlled clinical trial with two parallel arms. We obtained ethical approval from the Institutional Review Board of the University and the Hospital Authority (No.: UW 22–517) for this study. We registered the trial protocol at ClinicalTrials.gov (No.: NCT05392868). The trial protocol was published in 2022 [22]. The report of this study followed the Consolidated Standards of Reporting Trials (CONSORT) guidelines (supplementary material) [23].

2.2. Study setting

This clinical trial was conducted in the Prince Philip Dental Hospital, the sole dental teaching hospital in Hong Kong.

2.3. Participant recruitment

A research assistant contacted older adults aged 65 or above who attended the Prince Philip Dental Hospital from February 2022 to August 2022 via phone and invited those who presented with symptoms of dentine hypersensitivity, such as sharp pain when drinking cold or hot drinks or during toothbrushing, for baseline examination. Older adults who were generally healthy, had no known or suspected allergy to the study ingredients or material, had all active dental diseases under control and had dentine hypersensitivity due to exposed root surface (clinically detected gingival recession by a graduated periodontal probe more than 0 mm) were recruited for this study. Those who had major systemic diseases such as cancer, had been using any desensitizing agents within one month, had dentine hypersensitivity due to other dental conditions such as dental caries, were not able to give written consent or had no significant dentine hypersensitivity (self-perceived sensitivity score [SS] greater than 7) were excluded. The research assistant explained the purpose and procedure of this study and obtained written consent from all participants before commencing the study.

2.4. Professionally applied desensitizing agent preparation

The 38% SDF and 5% potassium nitrate solution were used in this study as the intervention. We purchased Saforide (Saforide, Morita, Osaka, Japan) as 38% SDF solution and did an independent analysis to verify the contents for this study [24]. The brand name on the containers was covered for masking and all containers were stored in a cool and dark place before use. We prepared the 5% potassium nitrate solution by mixing 5 g non-sterile potassium nitrate powder (Potassium Nitrate 12, 648, Sigma-Aldrich, Darmstadt, Germany) into 95 millilitre non-sterile distilled water. The potassium powder used in this study was for research and development purposes only and met at food chemicals codex grade, which was suitable for human consumption. The certificate of analysis of potassium nitrate the manufacturer provided was included in supplementary material.

2.5. Clinical examination

A trained dentist performed all clinical examinations at baseline and 4- and 8-week follow-up visits in the Prince Philip Dental Hospital. The dentist used a dental mirror and a dental periodontal graduated (mm) probe for all clinical examinations. The research assistant measured the compressed air pressure and temperature of all the 3-in-1 syringes used for assessing dentine hypersensitivity before all baseline and follow-up clinical examinations with the acceptable ranges at 65 to 75 psi and 18 to 24 °C, respectively [25]. The research assistant collected demographic background information from all participants, including age, gender and dietary habits.

At the baseline visit, the trained dentist examined the participants clinically and excluded those with dentine hypersensitivity due to other dental reasons. The dentist measured the visible plaque index (VPI) to assess the participants' oral hygiene status and recorded the presence of plaque as 0 and the absence of plaque as 1 on the buccal and lingual surfaces of six index teeth (16, 12, 24, 36, 32 and 44) [26]. Hypersensitive teeth with exposed root surfaces were isolated by cotton rolls, and the severity of dentine hypersensitivity was assessed using compressed air from a 3-in-1 syringe placed perpendicular to the exposed root surface at a distance of approximately 1 cm for 5 s [27]. The participant gave a self-perceived SS from 0 to 10 for all teeth under assessment for dentine hypersensitivity [25]. An SS of 0 indicated no discomfort, whereas an SS of 10 indicated maximal pain causing the individual great distress (Fig. 1) [25]. SS is a visual analogue scale modified with the addition of adjective words and facial expression diagrams according to the verbal descriptor scale and has been utilized in pain assessment in our previous study [25]. Participants were asked to mark the score along

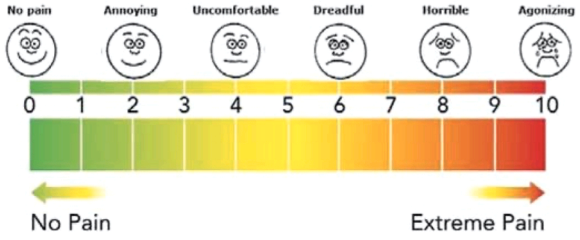

Fig. 1. Sensitivity score.

the SS scale printed on a paper, indicating the severity of the perceived dentine hypersensitivity after each assessment. For each participant, the most hypersensitive tooth (the one with the highest SS more than 7) with exposed root surface was selected for assessing dentine hypersensitivity at the baseline visit after intervention and the follow-up visits. The maximum amount of gingival recession of the selected hypersensitive tooth was measured using a dental periodontal graduated probe to the nearest millimetre.

The same examiner assessed dentine hypersensitivity using the same tools and procedures as in the baseline clinical examination before intervention again at three time points, baseline visit after intervention and at the 4- and 8-week follow-up visits before intervention, and collected SS from participants immediately after the assessment. One tenth of the participants were randomly selected to be retested later (with at least 30 min apart between test and retest) on the same day to evaluate the reliability of the outcome measures (the SS of the most hypersensitive tooth) at the baseline before and after intervention and follow-up visits before intervention. The randomly selected 10% of participants on baseline visit before intervention differed from 10% of those at baseline after intervention and at 4- and 8-week follow-ups. Fig. 2 illustrates the flowchart to outline the steps of the trial.

2.6. Intervention

The participants received 38% SDF solution or 5% potassium nitrate solution on the exposed root surface of the selected hypersensitive tooth after clinical examination at baseline visit and at 4- and 8-week follow-up visits. An independent operator dried the exposed root surface of the selected hypersensitive tooth and used a micro-brush to apply either 38% SDF solution or 5% potassium nitrate solution, according to the assigned intervention group, on the exposed root surface for 60 s for each participant [28]. The adjacent hypersensitive tooth or teeth also received the same intervention. The participants were instructed not to drink or eat for 30 min after receiving the intervention. They were advised to follow the dietary advice and oral hygiene instructions with the use of a toothbrush and regular fluoridated toothpaste (1450 ppm) received at the baseline visit throughout the whole study period. They would report if they received any desensitizing therapy during the study period.

2.7. Randomization, intervention group allocation and blinding

An independent statistician generated a random number sequence in a computer and delivered it to an independent research assistant for the intervention group allocation procedure. The eligible participants were randomly allocated to two intervention groups with a block randomization of 6 with a 1:1 ratio as follows:

- Group 1 (test) participants received topical application of 38% SDF solution on the exposed root surface of the most hypersensitive tooth every 4 weeks.
- Group 2 (control) participants received topical application of 5% potassium nitrate solution on the exposed root surface of the most hypersensitive tooth every 4 weeks.

The research assistant concealed the allocation sequence in opaque sealed envelopes until the moment of assignment. The examiner and all participants were blinded to the group allocation. An independent operator dispended into a dappen dish the desensitizing agent in which both SDF and potassium nitrate were colourless and the independent operator applied the agent to the participants according to their assigned allocated groups after clinical examination.

2.8. Harms

The dentist provided to each participant a 24-hour mobile contact number in case there of were any problems. The dentist would record adverse effects such as pain in the treated tooth, allergic reactions and gingival irritation around the treated tooth. The dentist would also report the adverse effect to the Independent Review Board within 48 h.

2.9. Sample size calculation

With an anticipated percentage change in SS in the test and control groups of 52% and 40% with a common standard deviation of 22% and 23%, respectively [25], at least 148 participants, with 74 participants per group, were needed for a study with a power of 0.8 and a statistical significance of 0.05, which was calculated via the Mann–Whitney U test using the software G*Power 3.1 (Franz Faul, Kiel University, Kiel, Germany) [29].

2.10. Statistical analysis

The outcome measure was the change in dentine hypersensitivity of the most hypersensitive tooth at the 8-week follow-up visit. This study applied the intention-to-treat (ITT) principal for analysis [30]. We analysed the data using the statistical software SPSS for Windows (IBM Corporation, Armonk, NY, USA). We analysed the difference in distribution of gender, tooth position and tooth type between the two intervention groups using a chi-square test. We assessed the data for normality using the Shapiro–Wilk test. We investigated the difference in SS and the percentage reduction of SS at different assessment time points

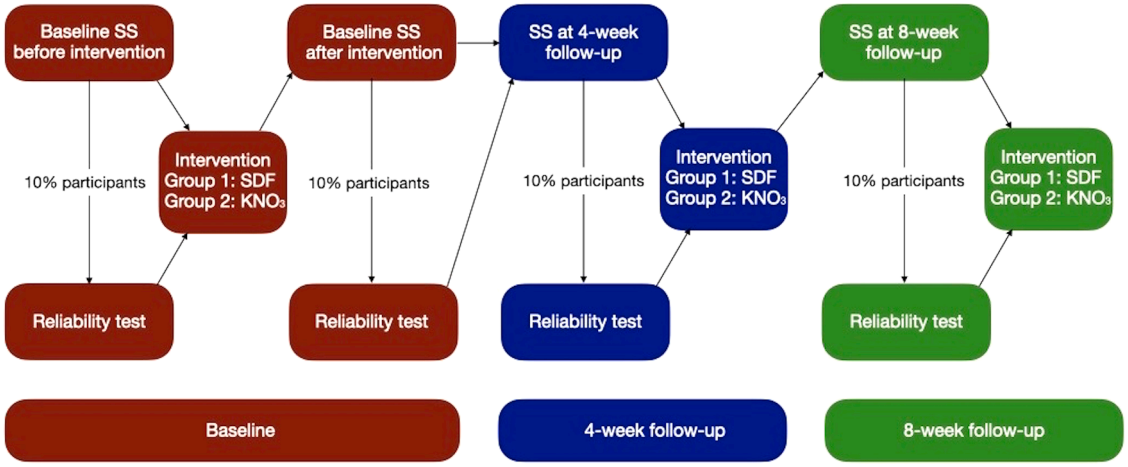

Fig. 2. Flowchart of the trial.

(baseline, immediately after intervention, 4-week follow-up and 8-week follow-up) between the two intervention groups using a Mann–Whitney U test because the data were not normally distributed. The level of statistical significance for all tests was set at 0.05. Intraclass correlation was used to assess the test and retest reliability from duplicated measures on 10% of randomly selected patients on the same day at baseline before and after intervention, 4-week follow-up and 8-week follow-up, respectively.

3. Results

A total of 176 participants aged 65 or above with reported dentine hypersensitivity agreed to screening, and 148 participants (84%), 74 participants in each intervention group, were recruited. Fig. 3 shows the CONSORT flow diagram of the study.

There were 87 female (58.8%) and 61 male (41.2%) participants recruited in this study. Their mean age (SD) was 70.3 (4.2), ranging from 65 to 86 (Table 1). A total of 91 (61.5%) upper teeth and 57 (38.5%) lower teeth with the highest SS were recorded, with 87 (58.8%) of them located on the left side. The most common tooth type with the highest SS was the premolar (61, 41.2%). The mean SS (SD) at the baseline visit was 8.7 (0.9) and 8.9 (0.9) in the test and control groups, respectively. There was no significant difference in mean age ($P = 0.670$), gender distribution ($P = 0.616$), tooth type ($P = 0.859$), mean maximum gingival recession ($P = 0.116$) and baseline SS ($P = 0.224$) between the two intervention groups. After SDF application, the examiner noted no adverse effects. This clinical trial received no post-treatment complaint and no patient reported post-treatment adverse effects.

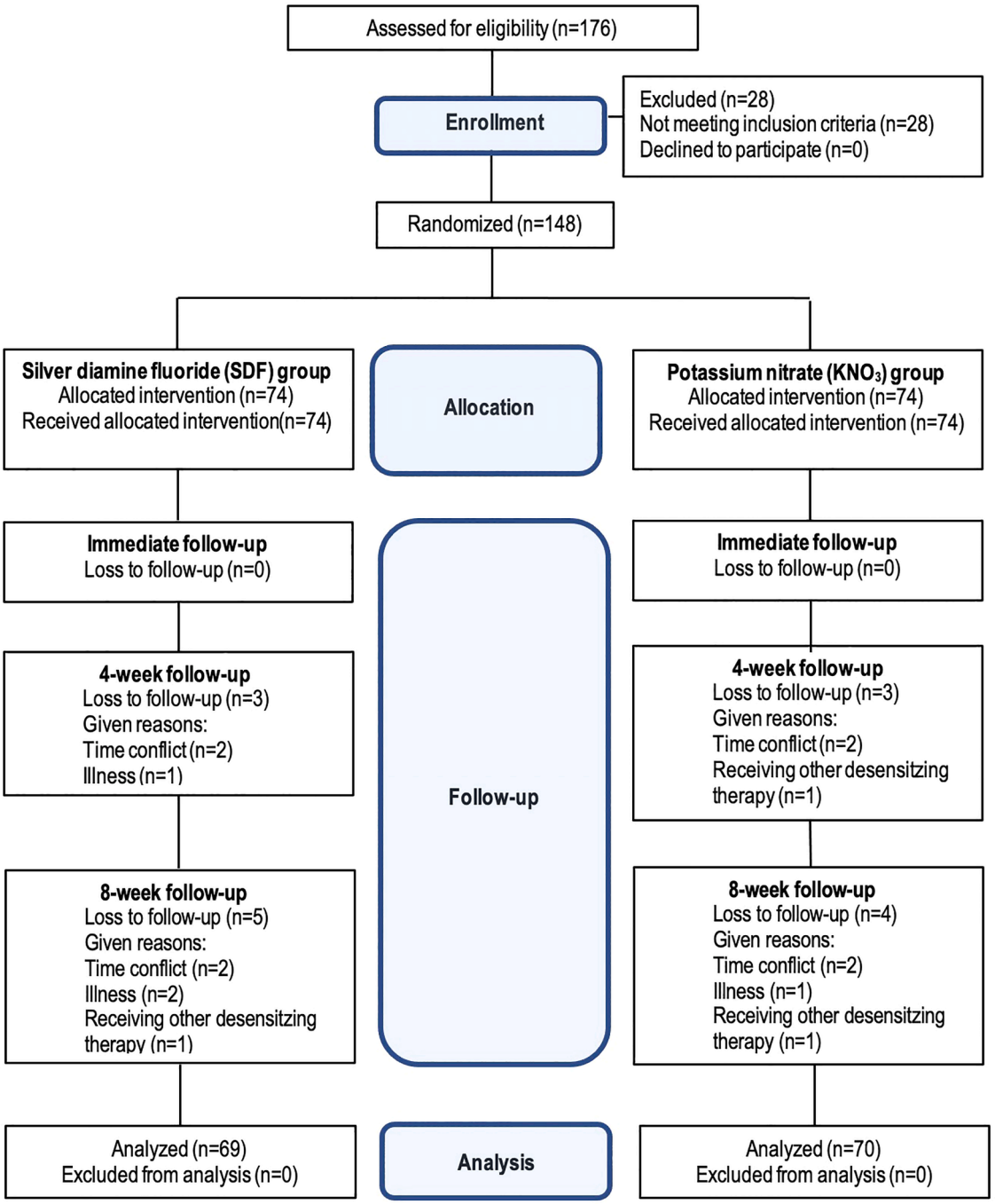

Fig. 3. CONSORT flow diagram.

Table 1
Baseline demographic information of the older adults ($n = 74$ per group).

	Silver diamine fluoride	Potassium nitrate	Total	*P* value [a]
Age (Mean ± SD)	70.4 ± 4.1	70.1 ± 4.4	70.3 ± 4.2	0.670
Gender (%, n)				0.616
Male	43.2% (32)	39.2% (29)	41.2% (61)	
Female	56.8% (42)	60.8% (45)	58.8% (87)	
Tooth arch (%, n)				0.866
Upper	62.2% (46)	60.8% (45)	61.5% (91)	
Lower	37.8% (28)	39.2% (29)	38.5% (57)	
Tooth side (%, n)				0.616
Right	39.2% (29)	43.2% (32)	41.2% (61)	
Left	60.8% (45)	56.8% (42)	58.8% (87)	
Tooth type (%, n)				0.859
Incisor	9.5% (7)	13.5% (10)	11.5% (17)	
Canine	10.8% (8)	9.5% (7)	10.1% (15)	
Premolar	43.2% (32)	39.2% (29)	41.2% (61)	
Molar	36.5% (27)	37.8% (28)	37.2% (55)	
Baseline sensitivity score (Mean ± SD)	8.7 ± 0.9	8.9 ± 0.9	8.8 ± 0.9	0.224
Visible plaque% (Mean ± SD)	38.0% ± 32.1%	41.2% ± 28.9%	39.6% ± 30.4%	0.510
Maximum gingival recession (Mean ± SD)	3.0 ± 1.5	2.6 ± 1.0	2.8 ± 1.3	0.116
% adults consuming sour food/drink	29.7% (22)	25.7% (19)	27.7% (41)	0.582

[a]Chi-square test for percentages, two-sample *t*-test for mean age and Mann–Whitney U test for mean baseline sensitivity score and mean maximum gingival recession.

After 8 weeks, 139 (94%) participants remained in the study. The majority of participants showed improvement in dentine hypersensitivity; only 4 participants (2 in the test group and 2 in the control group) reported no reduction in SS after intervention at the 8-week follow-up.

Table 2 presents the mean, median and interquartile range of SS and the percentage reduction in SS at each assessment time point (baseline before and after intervention, 4-week follow-up and 8-week follow-up) in both intervention groups. There was a significant difference ($P = 0.003$) in the percentage change in SS between the test and control groups at baseline after intervention, with the control (potassium nitrate) group showing a greater percentage reduction in SS. However, there was a significant difference ($P < 0.001$) in the percentage reduction in SS between the two groups with the test (SDF) group showing a greater percentage reduction in SS than the control group did at the 8-week follow-up. Both the SDF and the potassium nitrate groups showed significant reduction in SS at the 8-week follow-up. However, participants who received SDF presented with continuous significant reduction in SS between each time point from baseline up to the 8-week follow-up, whereas those who received potassium nitrate showed significant reduction in SS up to the 4-week follow-up, but no significant reduction in SS was observed between the 4-week and 8-week follow-up visits (Table 3).

4. Discussion

The hypothesis was retained in this study, which detected a significantly greater reduction in dentine hypersensitivity (regarding SS) on hypersensitive teeth with exposed root surface in older adults who received 38% SDF solution every 4 weeks than in those who received 5%

Table 2
Sensitivity score (SS) and its percentage reduction in older adults receiving silver diamine fluoride and potassium nitrate.

	Silver diamine fluoride [1]	Potassium nitrate [2]	*P* value [a]
Baseline SS before intervention (SS_B)	*n = 74*	*n = 74*	0.224
Mean ± Standard deviation	8.7 ± 0.9	8.9 ± 0.9	
Median (Range)	8 (8–10)	9 (8–10)	
Interquartile range	8–10	8–10	
Baseline SS after intervention (SS_0)	*n = 74*	*n = 74*	0.011 (1>2)
Mean ± Standard deviation	7.5 ± 1.8	6.5 ± 2.5	
Median (Range)	8 (0–10)	7 (0–10)	
Interquartile range	6–8	5–8	
Percentage reduction in SS (SS_0 vs SS_B)			*0.003 (1<2)*
Mean ± SD	14.7% ± 18.8%	27.0% ± 26.5%	
Median *(Range)*	11.1% (−12.5%–100%)	25.0% (−25.0%–100%)	
Interquartile range	0%–25.0%	0%–40.0%	
SS at 4-week follow-up (SS_4)	*n = 71*	*n = 71*	0.367
Mean ± Standard deviation	5.1 ± 2.2	5.5 ± 2.2	
Median (Range)	5 (0–10)	5 (0–10)	
Interquartile range	4–6	4–7	
Percentage reduction in SS (SS_4 vs SS_B)			0.465
Mean ± Standard deviation	42.1% ± 25.3%	39.1% ± 24.3%	
Median (Range)	37.5% (−12.5%–100%)	37.5% (−11.1%–100%)	
Interquartile range	25.0%–50.0%	21.1%–50.0%	
SS at 8-week follow-up (SS_8)	*n = 69*	*n = 70*	<0.001 (1<2)
Mean ± Standard deviation	3.6 ± 2.2	5.0 ± 1.7	
Median (Range)	4 (0–9)	5 (0–10)	
Interquartile range	2–5	4–6	
Percentage reduction in SS (SS_8 vs SS_B)			<0.001 (1>2)
Mean ± Standard deviation	59.2% ± 25.6%	43.5% ± 19.9%	
Median (Range)	60.0% (−12.5%–100%)	50.0% (−11.1%–100%)	
Interquartile range	44.4%–75.0%	30.0%–55.6%	

[a] Mann–Whitney U test for *P* value.

Table 3
Sensitivity score (SS) at different time points in each intervention group.

	Silver diamine fluoride ($n = 69$)	Potassium nitrate ($n = 70$)
Baseline SS before intervention (SS_B)		
Mean ± Standard deviation	8.8 ± 0.9	8.9 (0.9)
Median	8	9
Interquartile range	8–10	8–10
Baseline SS after intervention, SS_0		
Mean ± Standard deviation	7.5 ± 1.8	6.6 ± 2.4
Median	8	7
Interquartile range	6–9	5 –8
SS at 4-week follow-up, SS_4		
Mean ± Standard deviation	5.0 ± 2.3	5.5 ± 2.2
Median	5	5
Interquartile range	4–6	4–7
SS at 8-week follow-up, SS_8		
Mean ± Standard deviation	3.6 ± 2.2	5.0 ± 1.7
Median	4	5
Interquartile range	2–5	4–6
P value of Friedman test	$p < 0.001$	$p < 0.001$
Pairwise comparison	$SS_B > SS_0 > SS_4 > SS_8$	$SS_B > SS_0 > SS_4, SS_8$

The intraclass correlation coefficients were 0.87, 0.86, 0.88 and 0.86 at baseline before and after intervention, 4-week follow-up and 8-week follow-up, respectively.

potassium nitrate solution every 4 weeks at the 8-week follow-up.

Prior to this study, clinical trials on the anti-hypersensitivity effect of SDF were limited. One study observed that a single application of SDF was more effective in reducing dentine hypersensitivity in buccal cervical defects than a placebo was [20]. However, this study included buccal cervical defects with and without untreated decay [20]. Bacterial invasion from untreated decayed cavities may affect the pulpal health as well as the individuals' pain perception [31]. Pain perception evaluated in this study may come from dentine hypersensitivity to irreversible pulpitis. However, this study did not state how the researchers distinguished and compared these different pain outcomes.

Another pilot study showed that SDF/potassium iodide treatment reduced dentine hypersensitivity [21]. However, this study was conducted in a split-mouth design without addressing how to avoid the crossover effect between test and control desensitizing agents, and the role of potassium iodide in dentine hypersensitivity in this study was not clearly stated [21]. Both studies followed up to 7 days to investigate the anti-hypersensitivity effect of SDF. For studies investigating dentine hypersensitivity, those that assessed dentine hypersensitivity immediately after intervention or at a time point up to 1 week after intervention were defined as short-term studies, whereas those that assessed dentine hypersensitivity at 2 weeks or longer after intervention were defined as long-term studies [8]. Therefore, both studies only investigated the short-term anti-hypersensitivity effect of SDF, and no studies have been conducted to investigate its long-term effects. In clinical practice, patients and clinicians want not only to improve the symptoms but also to maintain the improvement in the long term.

According to Grossman's principles, a treatment for dentine hypersensitivity should be easy to administer, effective and safe, and it should have fast-acting and long-lasting treatment effects [32]. This study was the first clinical trial to find that topical application of 38% SDF solution every 4 weeks could reduce dentine hypersensitivity both in the short and long term. It also demonstrated that topical application of 38% SDF solution every 4 weeks could cause a significantly greater reduction in dentine hypersensitivity on hypersensitive teeth due to the exposed root surface in older adults than a control desensitizing (potassium nitrate) solution at 8-week follow-up. SDF contains both silver and fluoride ions, which may contribute to reduce dentine hypersensitivity. It has been hypothesized that fluoride ions form deposits with free calcium ions to occlude the exposed dentinal tubules [33] and silver ions cause protein denaturation and aggregation in the dentinal tubules [34].

This study found that the most common tooth type dentine hypersensitivity affected in older adults was the premolar. This matched the findings in our previous study conducted in Hong Kong adults [25] and it was consistent with previous studies conducted in adults from other countries [35,36]. This study noted another finding in common with previous studies that more female participants reported dentine hypersensitivity than male participants did; it had been proposed that this was due to different levels of awareness regarding oral and general health [36,37].

No single professionally applied desensitizing agent is superior to others in managing dentine hypersensitivity; hence, no gold standard product is recognized as a control in clinical trials investigating dentine hypersensitivity [38,39]. Potassium nitrate was chosen as a control due to its long history and widespread use in managing dentine hypersensitivity in clinical dentistry. It was prepared as a 5% solution to blind participants to minimize the bias from the examiner and the placebo effect from the participants, which may be anticipated in studies assessing pain outcomes [40]. Potassium nitrate incorporated into self-applied desensitizing toothpastes improved dentin hypersensitivity in 4 weeks or longer, yet this study found significant reduction in SS in older adults immediately after receiving topical application of potassium nitrate solution.

Self-applied desensitizing agents are difficult to deliver to the specific affected sites, are affected by individuals' compliance and require continuous use, whereas dentists can apply the professionally applied desensitizing agents directly to the specific affected sites, which enhances the immediate mode of action in managing dentine hypersensitivity [14]. This study also recorded a significant difference in baseline SS after intervention between the two groups, with participants who received potassium nitrate solution showing greater reduction in dentine hypersensitivity than those who received the SDF solution. This result may be due to the different mechanisms by which the treatments reduce dentine hypersensitivity, with SDF occluding the dentinal tubules by forming deposits and potassium nitrate decreasing the excitability of nerve endings that transmit pain sensation [5,18].

Deposit formation from SDF may take some time, but the effect of potassium nitrate on nerves can be instant. However, this difference did not continue at the 4-week follow-up and was reversed at the 8-week follow-up, with participants who received SDF solution having significantly greater reduction in dentine hypersensitivity than those who received potassium nitrate solution. SDF reduced dentine hypersensitivity continuously between each time point, from immediately after intervention up to the 8-week follow-up, whereas potassium nitrate reduced dentine hypersensitivity up to the 4-week follow up with no significant reduction between the 4- and 8-week follow-up visits. Occlusion of dentinal tubules through deposit formation made them less permeable to external stimuli and seemed to provide more persistent relief from dentine hypersensitivity than blocking the nerve impulses did. However, future studies should be conducted to investigate further the differences in the modes of action of various desensitizing agents in reducing dentine hypersensitivity to provide more insights on their clinical application.

There were some good points for this clinical trial. This was the first clinical trial investigating both the short- and long-term anti-hypersensitivity effect of SDF on hypersensitive teeth due to exposed root surface in older adults. It was also sufficiently powered and blinded to both the examiners and the participants. It used a parallel design with two intervention arms rather than the split-mouth design that many previous clinical trials used to minimize the sample size for participant recruitment. Professionally applied desensitizing agents, mostly in solution, gel or varnish form are difficult to confine to the affected tooth surface; hence it is difficult to estimate the crossover effect in a split-mouth design. This study only recruited the most hypersensitive tooth from each participant for evaluation to avoid recruiting hypersensitive teeth from the same individual, causing a clustering effect due to the within-group similarity.

There were some limitations in this clinical trial. Recruiting older adults from a dental teaching hospital may ensure a low dropout rate, yet it also limited the pool of patients and made the results less generalizable. Future community-based clinical trials should be conducted for further investigation. A tactile test, thermal stimulus and a compressed cold air test were commonly used for assessing dentine hypersensitivity [8]. It had been recommended that at least two independent stimuli, separated by a sufficient time interval to avoid interaction between stimuli, should be used to assess dentine hypersensitivity [39], yet no guideline had been suggested for the time interval for separation. Therefore, only one stimulus was utilized in this study to simplify the procedure for older adults, who may have a lower tolerance for dental treatment, and to avoid interaction between stimuli.

Using a compressed air blast from a 3-in-1 syringe was a simple, non-invasive and easily available method for assessing dentine hypersensitivity. Although the tooth under investigation was isolated, the air blast was difficult to control and could have affected a larger area than expected. Adjacent hypersensitive teeth my affect the result, and the effect cannot be calculated. For this reason, adjacent hypersensitive teeth also received the same intervention simultaneously to provide a better evaluation of the improvement in dentine hypersensitivity at the follow-up visits.

Pain is a complex and subjective experience and it is associated with environmental, psychological and emotional factors [41]. There is neither a standardized objective method for pain measurement nor a

gold standard for subjective pain assessment [41]. This study utilized a self-perceived SS scale that was used in our previous study [25]. The self-perceived SS scale is a subjective measuring method to assess dentine hypersensitivity. Pain is an unpleasant sensory and emotional experience associated with objectionable stimuli. Its severity is a subjective symptom and its measurement relies on self-reported pain from individuals. Hence, its quantification is not as straightforward as measuring blood pressure. The placebo effect has been found to affect significantly the subjective outcomes in pain intervention [40]. Therefore, we prepared both professionally applied desensitizing agents in solution form to blind both the examiner and all the participants to the group allocation to minimize bias. However, this study did not include a placebo group for ethical reasons, which may not totally remove the placebo effect. This study applied a unidimensional scale to measure dentine hypersensitivity in pain intensity using the SS scale. This measurement simplified the assessment procedure for the older adult group, who may have less tolerance and more difficulty in comprehending different measuring tools than other age groups do. Due to its complex nature, pain is often measured using multi-dimensional scales regarding pain intensity, duration, frequency, and the effects of pain experience on functioning and quality of life to capture truly its impact [41]. Because psychological factors such as anxiety can affect pain perception [42], we tried to perform all the clinical examinations and assessments on the participants in a simple and less stressful clinical setting. Future clinical trials can be conducted using different assessment and measuring methods to investigate further the anti-hypersensitivity effect of SDF. Individuals from different cultures may express their pain differently. This study used the SS scale, which was used in a previous study in Hong Kong [25]. An advantage of SS is that it can be modified with verbal descriptor scales. Thus, it is suitable to evaluate pain intensity in older adults [43]

5. Conclusion

According to this randomised clinical trial, 38% SDF solution reduced hypersensitivity on exposed root surface of older adults. In addition, 38% SDF was more effective than 5% potassium nitrate solution was to reduce hypersensitivity on exposed root surface of older adults.

CRediT authorship contribution statement

Alice Kit Ying Chan: Writing – original draft, Project administration, Formal analysis. **Yiu Cheung Tsang:** Writing – review & editing, Formal analysis. **Chloe Meng Jiang:** Formal analysis. **Katherine Chiu Man Leung:** Writing – review & editing, Supervision. **Edward Chin Man Lo:** Conceptualization, Methodology. **Chun Hung Chu:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors thank Ms Samantha Li for her statistical advice. They also thank the student helpers, Ms Janet Cheng, Ms Stephanie Chu and Ms Candy Wong and certified dental surgery assistant Ms Tammy Cheng for their assistance in this study.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jdent.2023.104616.

References

[1] A.K.Y. Chan, M. Tamrakar, C.M. Jiang, E.C.M. Lo, K.C.M. Leung, C.H. Chu, Common medical and dental problems of older adults: a narrative review, Geriatrics 6 (3) (2021) 76, https://doi.org/10.3390/geriatrics6030076.
[2] Y. Wang, K. Que, L. Lin, D. Hu, X. Li, The prevalence of dentine hypersensitivity in the general population in China, J. Oral Rehabil. 39 (2012) 812–820, https://doi.org/10.1111/j.1365-2842.2012.02334.x.
[3] Department of Health, HKSAR, Oral Health Survey, 2011. https://www.toothclub.gov.hk/en/en_pdf/Oral_Health_Survey_2011/Oral_Health_Survey_2011_WCAG_20141112_(EN_Full).pdf (Accessed 3 April 2023).
[4] M. Brannstrom, A hydrodynamic mechanism in the transmission of pain-producing stimuli through the dentine, in: D.J. Anderson (Ed.), Sensory Mechanisms in Dentine, Pergamon Press, United Kingdom, Oxford, 1963, pp. 73–79.
[5] C.H. Chu, A. Lam, E.C. Lo, Dentin hypersensitivity and its management, Gen. Dent. 59 (2) (2011), 115-22 quiz 23-4.
[6] K. Bekes, C. Hirsch, What is known about the influence of dentine hypersensitivity on oral health-related quality of life? Clin. Oral Investig. 17 (Suppl 1) (2013) S45–S51, https://doi.org/10.1007/s00784-012-0888-9.
[7] A.K.Y. Chan, M. Tamrakar, K.C.M. Leung, C.M. Jiang, E.C.M. Lo, C.H. Chu, Oral health care of older adults in Hong Kong, Geriatrics 6 (2021) 97, https://doi.org/10.3390/geriatrics6040097.
[8] N.X. West, J. Seong, M. Davies, Management of dentine hypersensitivity: efficacy of professionally and self-administered agents, J. Clin. Periodontol. 42 (Suppl 16) (2015) S256–S302, https://doi.org/10.1111/jcpe.12336.
[9] M. Hodosh, A superior desensitizer—potassium nitrate, J. Amer. Dent. Assoc. 88 (4) (1974) 831–832, https://doi.org/10.14219/jada.archive.1974.0174.
[10] Ad Hoc Advisory, Committee on dentinal hypersensitivity council on dental therapeutics, recommendations for evaluating agents for the reduction of dentinal hypersensitivity, J. Am. Dent. Assoc. 112 (5) (1986) 709–710, https://doi.org/10.1111/j.1600-9657.1986.tb00606.x.
[11] D. Cummins, Dentin hypersensitivity: from diagnosis to a breakthrough therapy for everyday sensitivity relief, J. Clin. Dent. 20 (1) (2009) 1–9.
[12] J.M. Peacock, R. Orchardson, Effects of potassium ions on action potential conduction in A- and C-fibers of rat spinal nerves, J. Dent. Res. 74 (2) (1995) 634–641, https://doi.org/10.1177/00220345950740020301.
[13] N. Wara-aswapati, D. Krongnawakul, D. Jiraviboon, S. Adulyanon, N. Karimbux, W. Pitiphat, The effect of a new toothpaste containing potassium nitrate and triclosan on gingival health, plaque formation and dentine hypersensitivity, J. Clin. Periodontol. 32 (1) (2005) 53–58, https://doi.org/10.1111/j.1600-051X.2004.00631.x.
[14] S. Sharma, N.J. Shetty, A. Uppoor, Evaluation of the clinical efficacy of potassium nitrate desensitizing mouthwash and a toothpaste in the treatment of dentinal hypersensitivity, J. Clin. Exp. Dent. 4 (1) (2012) e28–e33, https://doi.org/10.4317/jced.50665.
[15] J.H. Bae, Y.K. Kim, S.K. Myung, Desensitizing toothpaste *versus* placebo for dentin hypersensitivity: a systematic review and meta-analysis, J. Clin. Periodontol. 42 (2) (2015) 131–141, https://doi.org/10.1111/jcpe.12347.
[16] R. Yamaga, Arrestment of caries of deciduous teeth with diamine silver fluoride, Dent. Outlook 33 (1969) 1007–1013.
[17] J.A. Horst, H. Ellenikiotis, P.L. Milgrom, UCSF protocol for caries arrest using silver diamine fluoride: rationale, indications and consent, J. Calif. Dent. Assoc. 44 (1) (2016) 16–28.
[18] I. Willershausen, D. Schulte, A. Azaripour, V. Weyer, B. Briseño, B. Willershausen, Penetration potential of a silver diamine fluoride solution on dentin surfaces. an ex vivo study, Clin. Lab. 61 (11) (2015) 1695–1701, https://doi.org/10.7754/clin.lab.2015.150401.
[19] L. Han, T. Okiji, Dentin tubule occluding ability of dentin desensitizers, Am. J. Dent. 28 (2) (2015) 90–94.
[20] J.L. Castillo, S. Rivera, T. Aparicio, R. Lazo, T.C. Aw, L.L. Mancl, P. Milgrom, The short-term effects of diammine silver fluoride on tooth sensitivity: a randomized controlled trial, J. Dent. Res. 90 (2) (2011) 203–208, https://doi.org/10.1177/0022034510388516.
[21] G.G. Craig, G.M. Knight, J.M. McIntyre, Clinical evaluation of diamine silver fluoride/potassium iodide as a dentine desensitizing agent. A pilot study, Aust. Dent. J. 57 (3) (2012) 308–311, https://doi.org/10.1111/j.1834-7819.2012.01700.x.
[22] A.K.Y. Chan, M. Tamrakar, C.M. Jiang, Y.C. Tsang, K.C.M. Leung, C.H. Chu, Effectiveness of 38% silver diamine fluoride in reducing dentine hypersensitivity on exposed root surface in older Chinese adults: study protocol for a randomised double-blind study, Dent. J. 10 (10) (2022) 194, https://doi.org/10.3390/dj10100194.
[23] K.F. Schulz, D.G. Altman, D. Moher, CONSORT 2010 Statement: updated guidelines for reporting parallel group randomised trials, BMC Med. 8 (2010) 18, https://doi.org/10.1186/1741-7015-8-18.
[24] I.G. Yan, F.M. Zheng, S.S. Gao, D. Duangthip, E.C.M. Lo, C.H. Chu, Ion concentration of silver diamine fluoride solutions, Int. Dent. J. 72 (6) (2022) 779–784, https://doi.org/10.1016/j.identj.2022.04.005.

[25] C.H. Chu, E.C. Lo, Immediate post-application effect of professional prophylaxis with 8% arginine-calcium carbonate desensitizing paste on hypersensitive teeth. A practitioner-based clinical trial, Am. J. Dent. 27 (1) (2014) 7–11.
[26] J. Ainamo, I. Bay, Problems and proposals for recording gingivitis and plaque, Int. Dent. J. 25 (4) (1975) 229–235.
[27] M. Vano, G. Derchi, A. Barone, R. Pinna, P. Usai, U. Covani, Reducing dentine hypersensitivity with nano-hydroxyapatite toothpaste: a double-blind randomized controlled trial, Clin. Oral Investig. 22 (1) (2018) 313–320, https://doi.org/10.1007/s00784-017-2113-3.
[28] I.G. Yan, F.M. Zheng, S.S. Gao, D. Duangthip, E.C.M. Lo, C.H. Chu, A review of the protocol of SDF therapy for arresting caries, Int. Dent. J. 72 (5) (2022) 579–588, https://doi.org/10.1016/j.identj.2022.06.006.
[29] UCLA, USA, G*Power sample size calculation 2021. https://stats.oarc.ucla.edu/other/gpower/ (Accessed 20 January 2023).
[30] S.K. Gupta, Intention-to-treat concept: a review, Perspect. Clin. Res. 2 (3) (2011) 109–112, https://doi.org/10.4103/2229-3485.83221.
[31] I.B. Bender, Pulpal pain diagnosis–a review, J. Endod. 26 (3) (2000) 175–179, https://doi.org/10.1097/00004770-200003000-00012.
[32] L.I. Grossman, A systematic method for the treatment of hypersensitive dentin, J. Amer. Dent. Assoc. (1922), https://doi.org/10.14219/jada.archive.1935.0110.
[33] W.J. Thrash, D.L. Jones, W.J. Dodds, Effect of a fluoride solution on dentinal hypersensitivity, Am. J. Dent. 5 (6) (1992) 299–302.
[34] Y. Zhou, M. Yang, Q. Jia, G. Miao, L. Wan, Y. Zhang, Study on occluding dentinal tubules with a nanosilver-loaded silica system in vitro, ACS Omega 6 (30) (2021) 19596–19605, https://doi.org/10.1021/acsomega.1c02123.
[35] D.G. Gillam, A. Aris, J.S. Bulman, H.N. Newman, F. Ley, Dentine hypersensitivity in subjects recruited for clinical trials: clinical evaluation, prevalence and intra-oral distribution, J. Oral Rehabil. 29 (3) (2002) 226–231, https://doi.org/10.1046/j.1365-2842.2002.00813.x.
[36] C. Fischer, R.G. Fischer, A. Wennberg, Prevalence and distribution of cervical dentine hypersensitivity in a population in Rio de Janeiro, Brazil, J. Dent. 20 (5) (1992) 272–276, https://doi.org/10.1016/0300-5712(92)90043-c.
[37] C. Rahiotis, A. Polychronopoulou, K. Tsiklakis, A. Kakaboura, Cervical dentin hypersensitivity: a cross-sectional investigation in Athens, Greece, J. Oral Rehabil. 40 (12) (2013) 948–957, https://doi.org/10.1111/joor.12109.
[38] P.Y. Lin, Y.W. Cheng, C.Y. Chu, K.L. Chien, C.P. Lin, Y.K. Tu, In-office treatment for dentin hypersensitivity: a systematic review and network meta-analysis, J. Clin. Periodontol. 40 (1) (2013) 53–64, https://doi.org/10.1111/jcpe.12011.
[39] G.R. Holland, M.N. Narhi, M. Addy, L. Gangarosa, R. Orchardson, Guidelines for the design and conduct of clinical trials on dentine hypersensitivity, J. Clin. Periodontol. 24 (11) (1997) 808–813, https://doi.org/10.1111/j.1600-051x.1997.tb01194.x.
[40] A. Hróbjartsson, P.C. Gøtzsche, Placebo interventions for all clinical conditions, Cochrane Database Syst. Rev. (1) (2010), CD003974, https://doi.org/10.1002/14651858.CD003974.pub3, 2010.
[41] J. Younger, R. McCue, S. Mackey, Pain outcomes: a brief review of instruments and techniques, Curr. Pain Headache Rep. 13 (1) (2009) 39–43, https://doi.org/10.1007/s11916-009-0009-x.
[42] R.B. Fillingim, RB, Individual differences in pain: understanding the mosaic that makes pain personal, Pain 158 (Suppl 1) (2017), https://doi.org/10.1097/j.pain.0000000000000775. S11-s8.
[43] K.A. Herr, K. Spratt, P.R. Mobily, G. Richardson, Pain intensity assessment in older adults: use of experimental pain to compare psychometric properties and usability of selected pain scales with younger adults, Clin. J. Pain 20 (4) (2004) 207–219, https://doi.org/10.1097/00002508-200407000-00002.