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ORIGINAL ARTICLE

The prevalence, clinical features, and related factors of dentin hypersensitivity in the Turkish population

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Abstract

Objectives The purpose of this study was to identify the prevalence and predisposing and etiologic factors of dentin hypersensitivity (DH), as well as the demographic characteristics of patients.

Materials and methods The 1210 patients were examined. The research was based on a two-step investigation: questionnaire and clinical examination. DH was evaluated by the response of the patient to tactile and air-blast stimuli. Loss of attachment and gingival recession of sensitive teeth was measured on the buccal and lingual surfaces. Also, the tooth wear of sensitive teeth was graded on the buccal and lingual surfaces. Comparisons of nonnormally distributed continuous variables were performed using the Mann–Whitney *U* test and Kruskal–Wallis one-way analysis of variance (ANOVA) and Dunn's post hoc test. Comparisons of categorical variables were performed using Pearson's chi-square, Fisher's exact chi-square, Yates's chi-square, and the Monte Carlo chi-square test.

Results One hundred twenty-four patients reported DH, showing a prevalence for self-reported DH of 10.2%. Eight hundred forty teeth were diagnosed as having DH, giving a clinical diagnosis rate of DH of 29.4%. Females (76.8%), the 31–40 years age group (26%), housewives (36.8%), and high school education level (38%) had the highest prevalence of DH as demographic properties. A cold stimulus was the most common stimuli trigger for hypersensitivity (97.1%). Occasional pain (55.5%) showed the highest prevalence in terms of frequency of DH. A higher rate of DH was found with the use of medium brushes (47.4%) and brushing twice per day (59.4%) for 1–2 min (56.2%) with the circular method (33.8%) as oral hygiene habits. The buccal surface of the lower right central incisors (5.7%) had the highest prevalence. The most affected teeth by DH were incisors (38.4%). The buccal surfaces (86.3%) of teeth showed a higher high prevalence of DH compared with the lingual surface (52.7%), similar to gingival recession (40.9% vs. 15.7%) and loss of attachment (68.3% vs. 42.6%).

Conclusions Clinically diagnosed DH was more common than self-reported DH. Some factors related to patients such as sex (female), the 31–40 years age group, housewives, high school students, using medium brushes, brushing twice per day, and the circular brushing method were more likely to have a risk for DH. Also, buccal surfaces of teeth, gingival recession, and loss of attachment on the buccal surface of teeth should be considered as predisposing factors for DH.

Clinical relevance To control and prevent DH, clinicians should consider patients' demographics, predisposing factors, and etiologic factors.

Keywords Dentin hypersensitivity · Tooth sensitivity · Predisposing factors · Etiologic factors · Demographic factors

Introduction

Dentin hypersensitivity (DH) is defined as short, sharp pain caused by exposed dentin in response to thermal, evaporation, tactile, osmotic, or chemical stimuli [1–3]. According to the hydrodynamic theory, hypersensitivity lesions have large numbers of widened dentinal tubules at the surface and are patent to the pulp [2]. The hydrodynamic theory, which was widely accepted, explains the mechanism of DH. It explains that shifts in fluid in response to stimuli occur across exposed dentin with open tubules, which, in turn, mechanically activates the nerves located at the inner ends of the dentin tubules or in the outer layers of the pulp, causing DH [4, 5]. Numerous and varied etiologic and

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predisposing factors may cause dentin sensitivity. DH may occur due to the exposure of underlying dentin as a result of loss of enamel and cementum. Enamel loss occurs as a result of tooth wear caused by attrition, abrasion, or erosion. Although tooth wear usually involves attrition, abrasion, or erosion, in actuality, it is a combination of these but often with differing proportional effects [6, 7].

DH is a significant and permanent problem that causes a significant challenge for clinicians and affects patients' quality of life [8]. Many risks or predisposing factors have been identified in several studies. In these studies, the risk factors for DH were found as tooth wear, especially in the form of erosion in occlusal or facial/buccal or lingual/palatal surfaces [9–17], gingival recession [12, 13, 17–22], age [4, 10, 21–28], sex (female) [10, 12, 17, 23, 24, 27–30], education level [22, 23], and occupation or social class [31]. Also, type of stimulus [20, 23, 27, 28, 31–35] and tooth type [11, 17, 21, 27, 31–34, 36, 37] have been identified as most common initiating factors for DH. Drinking habits [38], the temperature of drink [20, 30, 31, 34], frequency of drinking [15], oral hygiene habits such as toothpaste abrasiveness [38], toothbrush filament stiffness [13, 30, 38, 39], toothbrushing techniques [18], frequency of toothbrushing [29, 37], and toothbrushing force [29] are other contributing factors. Smoking has been also reported as another predisposing factor for DH [31]. It was revealed that smoking was a major risk factor for periodontal disease and that exposure of root surfaces and gingival recession leading to DH was a common sequela of periodontal disease [24, 31, 40].

A systematic literature review on DH found that prevalence rates ranged from 3 to 98%. This wide range is partially due to differences in selection criteria for study samples, as well as the diversity in diagnostic methods or time frames [36]. A recent systematic review and meta-analysis on the prevalence of DH reported the rate as 1.3% as the lowest and 92.1% as the highest [8]. It was explained that the patient age range, type of recruitment strategy, and the number of study sites were effect modifiers for DH prevalence [8]. Multifactorial causes of DH should be investigated and evaluated. It is important to identify the factors that cause DH. DH therapy should be approached by minimizing or eliminating the cause of DH [4]. It was reported that the results of the prevalence and risk factors of DH were conflicting in the literature and that further epidemiologic studies in this area were still required to accurately identify the risk factors and implement the most suitable preventive measures [29]. A few prevalence studies conducted on the Turkish population found sensitivity rates as 5.1%, 8.4%, and 51.6% [20, 30, 41]. However, there is a lack of current data on the prevalence, clinical features, and associated factors of DH in the Turkish population. There was a study from 10 years ago [20], but related factors were not examined as thoroughly as in our study. A few studies were conducted only using a patient questionnaire with no subsequent clinical examination [30, 41]. It was reported that epidemiologic studies should also investigate the relation of DH with its possible causative factors to suggest the appropriate preventive measures for that specific population [29, 42]. Also, it is important to perform DH evaluations at different time points, detecting possible changes in lifestyles that influence the condition. Therefore, the aim of this study was to identify the prevalence of DH in Turkish dental patients who visited a dental university clinic. Another aim of the study was to define the relationship between DH and predisposing and etiologic factors in detail, as well as the demographic characteristics of patients.

Materials and methods

This study was designed as an observational, cross-sectional, and single-center study, which was performed in the clinics of Oral Diagnosis and Radiology at the Faculty of Dentistry, Istanbul University. The participants were those who came to the clinic for a first oral examination due to oral health problems from different districts, including urban and rural areas, representing various populations. They lived in Istanbul, which is Turkey's most populous city (with a population of 16 million). The study was approved by the Clinical Research Ethics Committee of the Faculty of Dentistry, Istanbul University, with protocol 2016/49. All patients were informed about the purpose of the study and all the procedures, and all patients gave consent to participate. The study was conducted from September 2018 to September 2019.

In the absence of current data to estimate the prevalence of sensitivity in Turkey and given that we needed the maximum large sample size, for the calculation, the sample size was calculated using the worst-case scenario considering a prevalence of 50% for any of the outcomes evaluated in the study [24]. According to the calculation, the required sample size was calculated as statistical significance level at 95% and margin of error set at 5% [24, 29, 43]. It was calculated that 1200 patients should be examined. Ten percent was added to the number of patients to prevent losses [43]. As a result, the total number of patients was estimated to be 1300.

The calibration was initially conducted to train two examiners about inclusion and exclusion criteria, the structure of the questionnaire questions, and the administration of the questionnaire, data collection, examination of patients, and the diagnosis of DH. The entire calibration process was supervised by one professor and an associate professor of restorative dentistry. Then the consistency between examiners was tested before starting the study by examining a group of patients who were not included in the study population [29]. These patients were reevaluated a second time by one professor. A standard K test was conducted to evaluate the data obtained in the clinical examinations. When K was over

0.80, the examiner was considered calibrated. Otherwise, new examinations were continued, and the necessary clarifications were given by the supervisor (one professor) [18, 29].

The research protocol for the present study was based on a two-step investigation: questionnaire and clinical examination. First, all patients attending a routine dental appointment were routinely examined for diagnosis and treatment of dental problems. During the examination, patients answered a single question about the presence or absence of hypersensitive teeth. The patients with sensitivity were subjected to a DH evaluation according to the research protocol of the study. Inclusion criteria for these patients were age between 18 and 70 years, having hypersensitivity, having good general health, having at least 5 teeth, and agreeing to participate in the study [16, 29, 43, 44]. The exclusion criteria were having psychological or systemic physical health problems; any disease requiring drugs such as analgesics, tranquilizers, or mood-altering medications; patients on anticoagulants or who had bleeding disorders; the use of orthodontic appliances and periodontal therapy or use of tooth-whitening agents in the 6 months before the study; use of desensitizing toothpaste or mouth rinse in the 6 weeks before the examination in the study; fewer than 5 teeth; and taking analgesics or had undergone oral local anesthesia in the last 24 h [4, 12, 16]. Teeth with the following characteristics were excluded from the study: partially erupted teeth, decayed teeth, crowned teeth, pulp pathologies, teeth with cracks or fractures in the enamel, abutment teeth for dentures and bridgework, chipped teeth, teeth with palatogingival grooves, teeth with gingival inflammation, root-filled teeth, teeth with restorations of any type, and third molars [4, 18, 25, 44, 45].

Datasheets were prepared to record data of questionnaires and clinical examinations. The trained examiners questioned patients in face-to-face interviews while completing the questionnaire, followed by a clinical examination. The data obtained were recorded on datasheets. The questionnaire included the patient's name, sex, age, occupation [46, 47], medical history detecting any underlying systemic disease, and education level. Questions related to the characteristics of DH were asked: types of DH (sharp, dull, throbbing for variable periods), stimuli that trigger DH (cold, hold, sweet, sour, toothbrushing, chewing), frequency of sensitivity (occasionally, often, all the time), location of the sensitive teeth (upper right, upper left, lower right, and lower left jaw), and treatment attempts before. Some of the questions were about oral hygiene habits such as bristle hardness of toothbrush used (hard, medium, and soft manual), daily frequency of toothbrushing (once per day, twice per day, and 3 or more times per day), toothbrushing with excessive force, and toothbrushing techniques (horizontal, horizontal–vertical, vertical, circular, and random). Questions of dietary habits were also asked, which included the names of fruits and juices, carbonated drinks and fruit teas consumed, daily frequency of the consumption of fresh fruits and juices, carbonated drinks, fruit teas, chewing or effervescent vitamin C tablet (often, occasionally, infrequently, not consuming), the consumption amount of fresh fruits and juices, carbonated drinks and fruit teas, chewing or effervescent vitamin C tablet (once per day, twice or three times per day, 4 or more times per day, once or twice per week, once or twice per month). A few questions were about the awareness of bruxism or clenching habits (present or not), frequency of smoking (often, occasionally, infrequently, none), and daily consumption of cigarettes (1–5, 6–10, 11–15, 16–20, 21–40, more than 40).

DH was assessed by the response of the patient to tactile and air-blast stimuli. To identify the DH in each tooth, a tactile stimulus (TS) was performed using a probe, which was applied with slight pressure perpendicular to the cervical third of each tooth (buccal and lingual), and the tip of the explorer was moved to scratch the surface in a mesial–distal direction. If sensitivity was determined, a simplified score system based on a descriptive category scale was used because the aim was only to give an overview of the degree of sensitivity in that population [29]. Patients were asked to define the sensitivity according to the verbal rating scale (VRS): grade 0 — no discomfort, grade 1 — discomfort without severe pain, grade 2 — severe pain during stimulation, and grade 3 — severe pain for at least 4 s after stimulation [4, 12, 29]. Ten minutes after the TS, the patient's response to cold air stimulus (AS) was evaluated using a blast of cold air from a dental air syringe, which was applied perpendicular to the cervical area of the tooth (buccal and lingual) at a distance of approximately 1 cm for 3 s [4, 12, 25, 29]. At the same time, the adjacent teeth were isolated during testing using a cotton roll so as not to affect the evaluation. If sensitivity was detected, patients were asked to define the sensitivity according to the scale described earlier.

Attachment loss and gingival recession of sensitive teeth were also measured using a 1-mm graduated periodontal probe (Williams periodontal probe). For loss of attachment, the tip of the periodontal probe tip was placed into the gingival sulcus with light pressure and kept parallel to the line angle of the root of the tooth. The deepest pocket depth around the sensitive tooth was recorded for buccal and lingual surfaces [11, 25, 27]. For gingival recession, the distance from the enamel cementum junction to the free gingival margin was measured using a periodontal probe and recorded in mm for the buccal and lingual surfaces [12, 21]. Furthermore, erosion, abrasion, and abfraction of sensitive teeth were identified and graded according to tooth wear index: 0—no loss enamel, no loss of contour; 1—enamel loss, minimal loss of contour; 2—enamel loss exposing dentin for less than one third of the surface, defects less than

1 mm deep; 3—enamel loss exposing dentin for more than one third of the surface, defects less 1–2 mm deep; and 4—complete enamel loss, pulp exposure, or exposure secondary dentin, defect more than 2 mm deep [48]. Besides, when patients with DH self-reported bruxism, clinical examination was performed including the presence of masticatory muscle hypertrophy, as well as indentations on the tongue or lip and/or a linea alba on the inner cheek, damage to the dental hard tissues (e.g., cracked teeth), and mechanical wear of the teeth (i.e., attrition) [49].

All statistical analyses were performed using the IBM SPSS for Windows version 20.0 software package (IBM Corp., Armonk, NY, USA). Kolmogorov–Smirnov tests were used to analyze the normality of data distribution. Continuous variables are described as median (25th–75th percentiles). Discrete data are summarized using descriptive statistics such as frequency and percentages. Comparisons of nonnormally distributed continuous variables between the groups were performed using the Mann–Whitney *U* test and Kruskal–Wallis one-way analysis of variance (ANOVA) and Dunn's post hoc test. Comparisons of categorical variables between the groups were performed using Pearson's chi-square, Fisher's exact chi-square, Yates's chi-square, and the Monte Carlo chi-square test. Sensitive teeth were divided into two groups according to the median (as ≤ 6 and > 6). Binary logistic regression analysis was performed to detect the risk factors and to derive an odds ratio with 95% confidence intervals of tooth sensitivity. Two-tailed $p < 0.05$ was considered statistically significant.

Results

The results of the present study are shown in Tables 1 and 2 and Figs. 1, 2, and 3. One thousand two hundred ten patients were examined during the study, and 124 were detected to have DH. The prevalence for self-reported hypersensitivity was found as 10.2%. Thirty-two of 124 patients (25.8%) were male and 92 (74.2%) were female, showing a male: female ratio of 1:2.9. The highest prevalence of DH was in the 31–40 years age group (26%). Housewives had the highest prevalence of DH (36.8%). The highest percentage prevalence was in high school education level (38%). Sharp pain (48.9%) and cold (97.1%) were the most reported types of pain and stimulus, respectively. On the other hand, when the frequency of hypersensitivity was questioned, "occasionally" had the highest prevalence (55.5%).

In respect to the results of the oral hygiene habits, a higher prevalence was found of patients (47.4%) using medium toothbrushes. Patients who brushed teeth twice per day (59.4%) and for 1–2 min (56.2%) had the highest prevalence. The circular method (33.8%) was the most reported method of toothbrushing.

When the questions of dietary habits were considered, the highest prevalence of consumption of fruit and fruit juice was once per day (36.3%). The most consumed fruit was apple (46.4%), followed by mandarin (36.7%), and orange (34%). The most consumed fruit juice was orange juice (12.5%). Once or twice per week consumption of carbonated beverages (27.2%) and herbal tea (11.9%) had the highest prevalence. The most consumed carbonated beverage and herbal tea were cola (35.8%) and green tea (8.8%), respectively. About 4% of patients with DH reported consuming vitamin C once or twice per week. Also, bruxism was detected in 57.4%. The rate of smoking was 26.2%, and those who consumed 1–2 cigarettes per week had the highest prevalence (7.4%).

Six hundred twelve teeth of 124 patients with DH were missing. Therefore, 2860 teeth of these patients were examined. The number of teeth that had clinical signs of DH was 840, showing an overall prevalence for clinically diagnosed DH in teeth of 29.4%. Nearly three-quarters (73.6%, 618/840) of these teeth responded to air and 42.6% (358/840) to tactile stimuli on the buccal surface. On the lingual surface, the rates of teeth that responded to air and tactile stimuli were 24.2% (203/840) and 28.3% (238/840), respectively. The buccal surface of the lower right central incisor showed the highest prevalence (29.1%) of DH with air and the highest prevalence (19.3%) of DH with tactile stimuli (Table 2). The buccal surface of the upper left canine had the highest prevalence (6.4%) of tooth wear at grade 1. The buccal surface of the upper left canine showed the highest prevalence (12.1%) with 1-mm gingival recession (Fig. 2). Also, the buccal surface of the upper left central and lateral incisor and the buccal surface of the lower right central incisor had the highest prevalence (17.7%) with 1-mm attachment loss (Fig. 3).

Regardless of air or tactile test stimulus, the buccal surface of 725 (86.3%) teeth and the lingual surface of 443 (52.7%) teeth showed DH (Fig. 1). The buccal surface of the lower right central incisor had the highest prevalence (5.7%). A significant difference was found between the buccal and lingual surfaces of the upper right central incisor and the upper right first premolar with air, and the upper left first premolar with tactile stimulus. The buccal surface of 130 (17.9%) teeth and the lingual surface of four (0.9%) teeth had tooth wear. The buccal surface of the upper right 1st premolar, upper left canine, lower right central incisor, and lower left 1st premolar (6.9%) had the highest prevalence. The buccal surface of 344 teeth (47.4%) and lingual surface of 132 teeth (29.8%) demonstrated gingival recession, and the buccal surface of lower right central incisors had the highest prevalence (5.7%) (Fig. 2). There was a significant difference between the buccal and lingual surfaces of the upper left canine and lower right lateral incisor. Also, the buccal surface of 574 teeth (79.1%) and the lingual surface of 358

Table 1 Distribution of DH and predisposing factors with demographic, stimuli, oral hygiene habits, dietary habits, bruxism or clenching habits, and smoke

Variables	*n* (%)	*n* (%)	*n* (%)	Median	25th/75th percentile	*p*
Examined patients $N = 1210$	**1210 (100)**	**Sensitive teeth**	**Nonsensitive teeth**			
Dentin hypersensitivity	**124 (10.2)**	**840**	**2020**			
Gender						
Female	92 (74.2)	645 (76.8)	1444 (71.5)	6.0	4.0/9.75	0.517
Male	32 (25.8)	195 (23.2)	576 (28.5)	5.0	4.0/8.0	0.517
Age						
18–20	19 (15,3)	95 (11.3)	339 (16.8)	4.0	2.0/5.0	0.073
21–30	30 (24.2)	218 (25.9)	447 (22.1)	6.0	4.0/8.25	0.073
31–40	34 (27.4)	219 (26.0)	600 (29.7)	5.0	3.0/10.0	0.073
41–50	23 (18.5)	156 (18.6)	355 (17.6)	7.0	4.0/10.0	0.073
51–60	13 (10.5)	104 (12.5)	205 (10.1)	7.0	4.5/11.0	0.073
61–70	5 (4)	48 (5.7)	74 (3.7)	9.0	7.5/12.0	0.073
>71	0	0	0	0	0	0
Occupation						
I: higher managerial and professional	1 (0.8)	2 (0.2)	23 (1.1)	-	-	-
II: lower managerial professional	11 (8.9)	72 (8.6)	190 (9.4)	4.0	4.0/6.75	0.468
IIIN: skilled nonmanual	10 (8.1)	71 (8.5)	138 (6.8)	7.5	3.75/9.5	0.468
IIIM: skilled manual	1 (0.8)	5 (0.6)	23 (1.1)	-	-	-
IV: partly skilled	4 (3.2)	28 (3.3)	82 (4.1)	7.0	4.0/9.0	0.468
V: unskilled, manual	22 (17.7)	144 (17.1)	364 (18.0)	5.0	3.0/9.5	0.468
VI: student	33 (26.6)	209 (24.9)	561 (27.8)	5.0	3.5/8.0	0.468
VII: housewife	42 (33.9)	309 (36.8)	639 (31.7)	7.0	4.0/10.25	0.468
Education level						
Literate	1 (0.8)	6 (0.7)	22 (1.1)	-	-	-
Primary school	23 (18.5)	188 (22.4)	343 (17.0)	8.0	5.0/11.5	0.172
Middle school	10 (8.1)	61(7.3)	164 (8.1)	6.5	2.5/9.5	0.172
High school	50 (40.3)	319 (38.0)	802 (39.7)	5.0	3.0/8.25	0.172
Undergraduate	39 (31.5)	264 (31.4)	666 (33.0)	5.5	4.0/8.0	0.172
Postgraduate	1 (0.8)	2 (0.2)	23 (1.1)	-	-	-
Type of hypersensitivity						
Sharp	61 (49.2)	410(48.9)	1039 (51.4)	6.0	4.0/9.0	0.720
Dull	49 (39.5)	337 (40.1)	699 (34.6)	6.0	3.5/9.5	0.720
Throbbing for variable periods	14 (11.3)	93 (11.0)	282 (14.0)	5.0	3.0/8.25	0.720
Stimuli trigger hypersensitivity						
Cold	120 (96.8)	816 (97.1)	1939 (96.0)	6.0	4.0/9.0	0.898
Heat	38 (30.6)	280 (33.3)	543 (26.9)	7.5	3.75/11.25	0.179
Sweet	49 (39.5)	393 (46.8)	645 (31.9)	7.0	4.0/11.5	0.018
Sour	23 (18.5)	153 (18.2)	391(19.4)	5.0	4.0/10.0	0.951
Brushing	35 (28.2)	294 (35.0)	498 (24.7)	7.0	5.0/11.0	0.007
Frequency of hypersensitivity						
Occasionally	79 (63.7)	466 (55.5)	1371 (67.9)	5.0	3.0/7.0	0.003
Often	28 (22.6)	218 (25.9)	473 (23.4)	7.5	5.0/10.5	0.003
All the time	17 (13.7)	156 (18.6)	176 (8.7)	8.0	5.0/13.0	0.003
Type of toothbrush						
Soft	45 (36.3)	291 (34.6)	748 (37.0)	5.0	4.0/8.0	0.197
Medium	53 (42.7)	398 (47.4)	783 (38.8)	7.0	4.0/11.0	0.197
Hard	6 (4.8)	26 (3.1)	120 (5.9)	4.0	2.5/6.0	0.197
Unknown	20 (16.1)	125 (14.9)	369 (18.3)	5.5	3.25/8.75	0.197

Table 1 (continued)

Variables	*n* (%)	*n* (%)	*n* (%)	Median	25th/75th percentile	*p*
Frequencies of toothbrushing						
Not toothbrushing	1 (0.8)	7 (0.8)	14 (0.7)	-	-	-
One time per a day	43 (34.7)	283 (33.7)	675 (33.4)	5.5	3.0/9.0	0.678
Twice per a day	73 (58.9)	499 (59.4)	1214 (60.1)	6.0	4.0/9.0	0.678
More than three times per a day	7 (5.6)	51 (6.1)	117 (5.8)	4.0	3.0/11.0	0.678
Duration of a toothbrush						
Not toothbrushing	1 (0.8)	7 (0.8)	14 (0.7)	-	-	-
Less than 1 min	29 (23.4)	208 (24.8)	494 (24.5)	6.5	4.0/10.25	0.539
1–2 min	72 (58.1)	472 (56.2)	1170 (57.9)	5.0	4.0/8.0	0.539
3–4 min	20 (16.1)	148 (17.7)	309 (15.3)	6.0	3.0/9.5	0.539
5 min	1 (0.8)	4 (0.4)	17 (0.8)	-	-	-
More than 5 min	1 (0.8)	1 (0.1)	16 (0.8)	-	-	-
Toothbrushing with excessive force						
Not toothbrushing	1 (0.8)	7 (0.8)	14 (0.7)	-	-	-
Yes	46 (37.1)	311 (37.0)	860 (42.6)	6.0	3.0/9.0	0.942
No	77 (62.1)	522 (62.2)	1146 (56.7)	5.0	4.0/9.0	0.942
Methods of toothbrushing						
Not toothbrushing	1 (0.8)	7 (0.8)	14 (0.7)	-	-	-
Horizontally	7 (5.6)	36 (4.3)	141(7.0)	6.0	3.25/7.0	0.099
Horizontally and vertically	39 (31.5)	253 (30.1)	720 (35.6)	5.0	3.0/8.0	0.099
Vertically	12 (9.7)	115 (13.7)	149 (7.4)	11.0	6.25/12.0	0.099
Circular	42 (33,9)	284 (33.8)	641(31.7)	5.5	4.0/9.0	0.099
Randomly	23 (18.5)	145 (17.3)	355 (17.6)	6.0	3.0/9.0	0.099
Consumption frequency of fruit						
Never	9 (7.3)	78 (9.3)	120 (5.9)	12.0	2.0/15.0	0.778
One time per day	48 (38.7)	305 (36.3)	748 (37.0)	5.5	3.25/9.0	0.778
Twice or three times per day	9 (7.3)	84 (10.0)	118 (5.9)	7.0	4.5/14.5	0.778
More than four times per day	4 (3.2)	25 (3.0)	76 (3.8)	6.5	2.0/10.25	0.778
One time or twice per week	47 (37.9)	291 (34.6)	843 (41.7)	6.0	4.0/8.0	0.778
One time or twice per month	7 (5.6)	57 (6.8)	115 (5.7)	5.0	4.0/16.0	0.778
Consumption frequency of fruit juice						
Never	79 (63.7)	524 (62.4)	1295 (64.1)	6.0	4.0/9.0	0.760
One time per a day	7 (5.6)	53 (6.3)	102 (5.0)	8.0	3.5/10.75	0.760
Twice or three times per a day	1 (0.8)	10 (1.2)	6 (0.3)	-	-	-
More than four times per a day	0	0	0	0	0	0
One time or twice per a week	17 (13.7)	110 (13.1)	278 (13.8)	5.0	3.0/8.5	0.760
One time or twice per a month	20 (16.1)	143 (17.0)	339 (16.8)	6.0	4.25/7.75	0.760
Consumption frequency of carbonated beverage						
Never	61 (49.2)	454 (54.0)	972 (48.1)	7.0	4.0/10.0	0.106
One time per a day	7 (5.6)	44 (5.2)	104 (5.1)	7.0	2.0/9.0	0.106
Twice or three times per a day	4 (3.2)	21 (2.5)	71 (3.5)	3.5	1.5/10.75	0.106
More than four times per a day	0	0	0	0	0	0
One time or twice per a week	33 (26.6)	228 (27.2)	511(25.3)	5.0	3.5/9.0	0.106
One time or twice per a month	19 (15.3)	93 (11.1)	362 (18.0)	4.0	2.0/9.0	0.106
Consumption frequency of herbal tea						
Never	94 (75.8)	618 (73.5)	1596 (79.0)	5.0	3.75/8.25	0.139
One time per a day	6 (4.8)	59 (7.0)	45 (2.2)	10.0	6.5/12.75	0.139
Twice or three times per a day	1 (0.8)	4 (0.5)	16 (0.8)	-	-	-
More than four times per a day	1 (0.8)	14 (1.7)	8 (0.4)	-	-	-
One time or twice per a week	15 (12.1)	100 (11.9)	213 (10.6)	6.0	4.0/10.0	0.139

Table 1 (continued)

Variables	*n* (%)	*n* (%)	*n* (%)	Median	25th/75th percentile	*p*
One time or twice per a month	7 (5.6)	45 (5.4)	142 (7.0)	7.0	4.0/9.0	0.139
Consumption frequency of vitamin C						
Never	118 (95.2)	787 (93.7)	1942 (96.1)	5.50	4.0/9.0	0.222
One time per a day	0	0	0	0	0	0
Twice or three times per a day	0	0	0	0	0	0
More than four times per a day	0	0	0	0	0	0
One time or twice per a week	3 (2.4)	33 (3.9)	29(1.5)	12.0	6.0/	0.222
One time or twice per a month	3 (2.4)	20 (2.3)	49 (2.4)	6.0	4.0/	0.222
Bruxism						
Present	65 (52.4)	482 (57.4)	1040 (51.5)	7.0	4.5/10.0	0.018
Absent	59 (47.6)	358 (42.6)	980 (48.5)	5.0	3.0/10.0	0.018
Frequency of smoking						
Never	89 (71.8)	620 (73.8)	1385 (68.6)	6.0	4.0/9.0	0.695
1–2 per a day	3 (2.4)	10 (1.2)	73 (3.6)	3.0	3.0/	0.695
2–10 per a day	6 (4.8)	46 (5.5)	94 (4.6)	6.5	4.75/12.5	0.695
10 per a day	7 (5.6)	44 (5.2)	111 (5.5)	6.0	4.0/7.0	0.695
20 per a day	7 (5.6)	40 (4.8)	127 (6.3)	5.0	4.0/9.0	0.695
More than 20 per a day	2 (1.6)	18 (2.1)	38 (1.9)	9.0	3.0/	0.695
1–2 per a week	10 (8.1)	62 (7.4)	192 (9.5)	6.5	2.0/9.25	0.695

teeth (80.8%) showed attachment loss. The buccal surface of the lower right central incisor had the highest prevalence (5%) (Fig. 3). A significant difference was detected between the buccal and lingual surfaces of the upper right central incisor, and the upper right and left 1st premolar.

A statistically significant association was found between DH and tooth wear. A statistically significant association was detected between tooth wear and age and stimuli that triggered DH by brushing ($p=0.002$). A statistically significant association was determined between gingival recession and age ($p=0.021$), education level ($p=0.001$), type of toothbrush ($p=0.024$), and frequencies of toothbrushing ($p=0.048$). Also, a statistically significant association was found between attachment loss and type of DH ($p=0.007$), stimuli that trigger DH by heat ($p=0.036$) and sweet ($p=0.013$), methods of toothbrushing ($p=0.009$), and toothbrushing with excessive force ($p=0.030$). Finally, a significant association was found between the type of toothbrush and DH with a tactile stimulus ($p=0.008$).

Discussion

This study found that the prevalence of hypersensitivity was 10.2% with the patients' "self-reporting" sensitivity. On the other hand, clinical examination of teeth gave a prevalence for dentin hypersensitivity of 29.4%. The review found the prevalence range to be as low as 1.3% and as high as 92.1%, concluding that the best estimate of DH was about 11.5%, and the average from all studies was 33.5%, which is concordant with our result [8]. In accordance with our finding, other studies have also reported a difference between the prevalence of self-reported sensitivity by patients and that found in clinical examinations [22, 25, 27, 31, 42]. In these studies, the prevalence of DH with self-reporting was between 25 and 49.7%. Also, the prevalence of DH with clinical examinations was between 4.1 and 34.5%. However, it was suggested that self-reported DH probably overestimated the prevalence in comparison with clinical exams [22, 25, 27, 31, 42]. In contrast to these suggestions, the prevalence of DH with clinical examinations was higher than in self-reported sensitivity in our study. Consistent with this finding, the reasons for this difference were explained by some factors such as the overall mean pain score being in the light range, implying that pain had no impact on the patients' everyday life. In addition, two different pain tests (air and tactile) were performed. More extensive stimulation may have elicited sensations previously unknown to patients and may have elicited pain symptoms, such as direct stimulation of pain sites and open or closed dentinal tubules, and so initiated DH [32, 50].

In this study, although there was no significant difference between males and females, females had three times more sensitive teeth than males. In agreement with our finding, other studies reported higher prevalences of DH in females than in males [4, 12, 23, 24, 27–29]. It was explained that this phenomenon may reflect the difference between men and women in the awareness of the importance of oral

Table 2 Extent of dentine hypersensitivity (DH) by tooth included diagnose type, surface, and tooth wear (distribution in %)

Tooth type	Buccal surface (n)			Lingual surface (*n*)		
	Diagnose type		**Tooth wear**	**Diagnose type**		**Tooth wear**
	Air	**Tactile**		**Air**	**Tactile**	
Upper right						
Central incisor	31 (25)	15 (12.1)	6 (4.8)	19 (15.3)	16 (12.9)	1 (0.8)
Lateral incisor	29 (23.4)	14 (11.3)	2 (1.6)	11 (8.9)	11 (8.9)	-
Canin	28 (22.6)	14 (11.3)	7 (5.6)	11 (8.9)	12 (9.7)	-
1st premolar	30 (24.2)	16 (12.9)	9 (7.2)	6 (4.8)	11 (8.9)	-
2nd premolar	23 (18.5)	16 (12.9)	6 (4.8)	4 (3.2)	6 (4.8)	-
1st molar	12 (9.7)	6 (4.8)	3 (2.4)	5 (4)	2 (1.6)	1 (0.8)
2nd molar	10 (8)	6 (4.8)	-	5 (4)	2 (1.6)	-
Upper left						
Central incisor	33 (26.6)	16 (12.9)	8 (6.4)	21 (16.9)	14 (11.3)	-
Lateral incisor	28 (22.6)	19 (15.3)	3 (2.4)	17 (13.7)	12 (9.7)	-
Canin	29 (23.4)	15 (12.1)	9 (7.2)	12 (9.7)	11 (8.9)	1 (0.8)
1st premolar	28 (22.6)	13 (10.5)	7 (5.6)	7 (5.6)	10 (8.1)	-
2nd premolar	25 (20.1)	15 (12.1)	7 (5.6)	12 (9.7)	4 (3.2)	-
1st molar	9 (7.2)	8 (6.4)	-	6 (4.8)	3 (2.4)	-
2nd molar	6 (4.8)	4 (3.2)	1 (0.8)	5 (4)	4 (3.2)	-
Lower right						
Central incisor	36 (29.1)	24 (19.3)	9 (7.2)	28 (22.6)	11 (8.9)	1 (0.8)
Lateral incisor	35 (28.1)	16 (12.9)	5 (4)	17 (13.7)	11 (8.9)	-
Canin	28 (22.6)	14 (11.3)	2 (1.6)	15 (12.1)	10 (8.1)	-
1st premolar	21 (16.9)	13 (10.5)	6 (4.8)	11 (8.9)	13 (10.5)	-
2nd premolar	17 (13.7)	14 (11.3)	5 (4)	8 (6.4)	5 (4)	-
1st molar	3 (2.4)	1 (0.8)	-	4 (3.2)	2 (1.6)	-
2nd molar	3 (2.4)	2 (1.6)	2 (1.6)	4 (3.2)	2 (1.6)	-
Lower left						
Central incisor	35 (28.3)	21 (16.9)	7 (5.6)	27 (21.8)	14 (11.3)	-
Lateral incisor	29 (23.3)	17 (13.7)	3 (2.4)	20 (16.1)	16 (12.9)	-
Canin	30 (24.1)	16 (12.9)	5 (4)	16 (12.9)	7 (5.6)	-
1st premolar	27 (21.7)	17 (13.7)	9 (7.2)	14 (11.3)	13 (10.5)	-
2nd premolar	21 (16.9)	15 (12.1)	7 (5.6)	9 (7.2)	8 (6.4)	-
1st molar	5 (4)	5 (4)	2 (1.6)	4 (3.2)	2 (1.6)	-
2nd molar	7 (5.6)	6 (4.8)	-	3 (2.4)	5 (4)	-

health, pain response to stimulus, pain anticipation, difference in diet [4, 20], and higher attendance at dental clinics [51] but might not show a valid relationship between sex and DH [12].

The age groups 31–40 years (26%) and 21–30 years (25.9%) showed the highest prevalence of DH although there was no significant difference between age groups. In contrast to our finding, several studies found a high prevalence of DH in the 60–69 years [11, 13], 50–59 years [22, 23, 25, 27], 41–50 years [52], and 40–49 years age groups [17, 21]. In agreement with our results, other studies found a high prevalence of DH in the 35–49 years [24], 36–45 years [4], 30–39 years [22, 31, 34], and 20–30 years age groups [44] and the third/fourth decade [28]. The age compositions of the study populations may explain the discrepancies in DH distribution by age in different studies [4, 21, 43]. Also, the peak values found in patients aged approximately 40 years with DH might be due to the high rate of exposed root surfaces at that age. In seniors, the lower number could be related to the reduced number of teeth and the occlusion of the tubules that naturally occur with aging, whereas the number of retained teeth increases in younger adults. This leads to an evident increase in the number of teeth and individuals at risk for exposed cervical dentin and causes DH to appear in a senior population. [36]. However, in our study, the highest number of gingival recessions was observed in the 41–50 years age group, followed by the 31–40 years age group. Occlusion

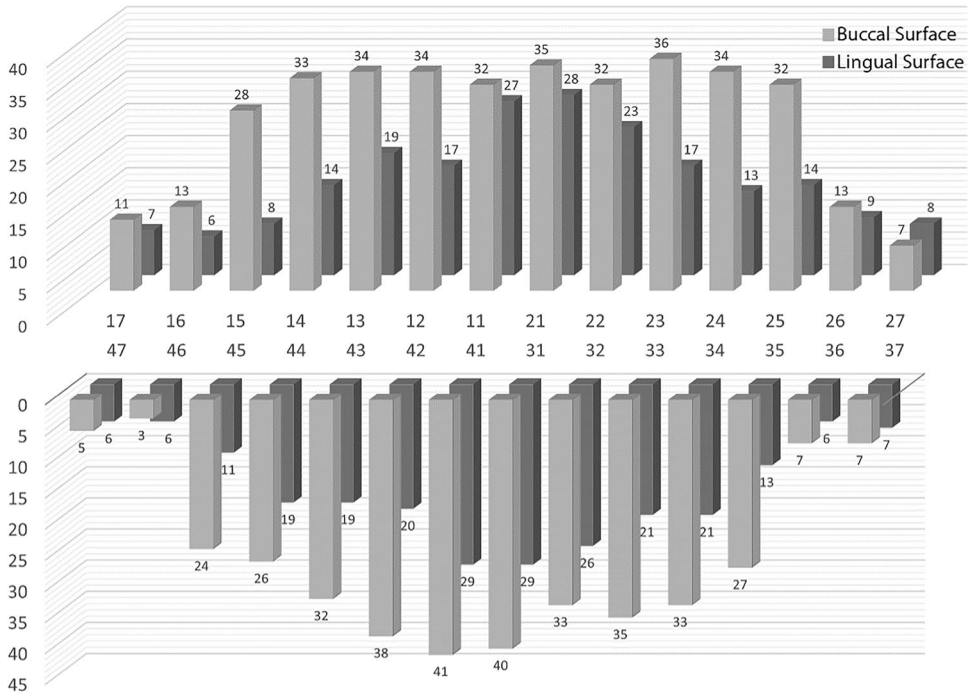

Fig. 1 Distribution of dentin hypersensitivity according to the tooth type and buccal and lingual surfaces

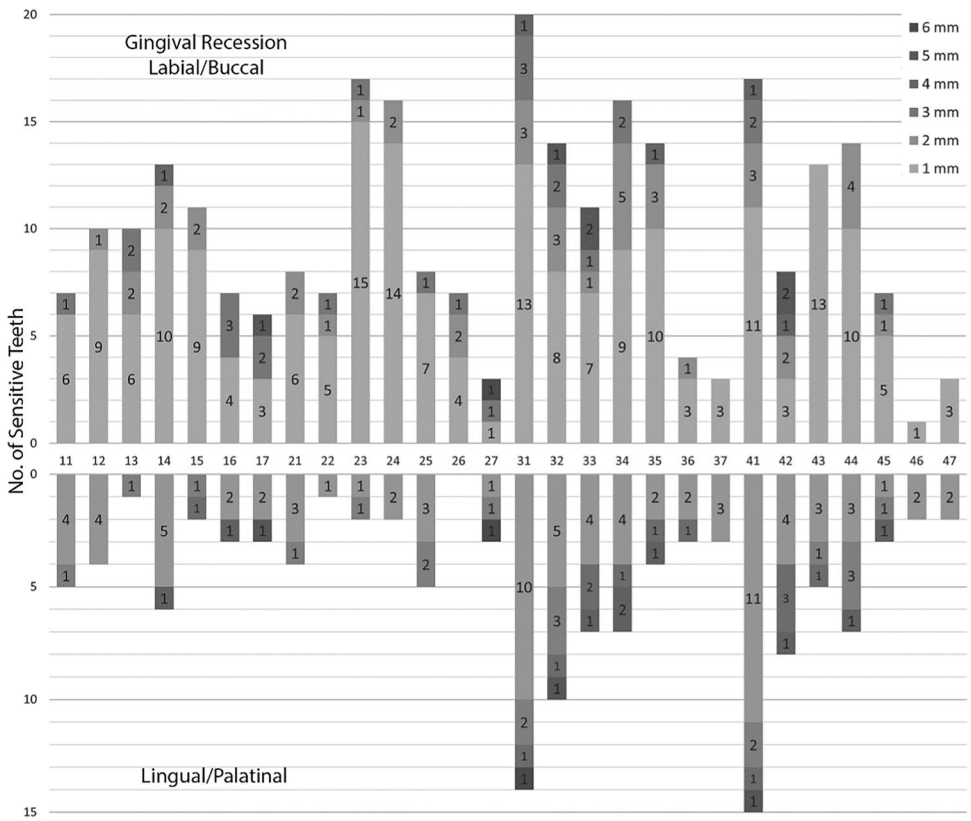

Fig. 2 Distribution of gingival recession according to the tooth type and buccal and lingual surfaces

of dentin tubules and the increase in dentin thickness with age may be possible causes for less sensitivity in the 41–50 years age group than in the 31–40 years age group.

Housewives showed the highest DH prevalence rates in the present study. This may be related to sex (female), which showed a much higher rate of DH in the present study. In

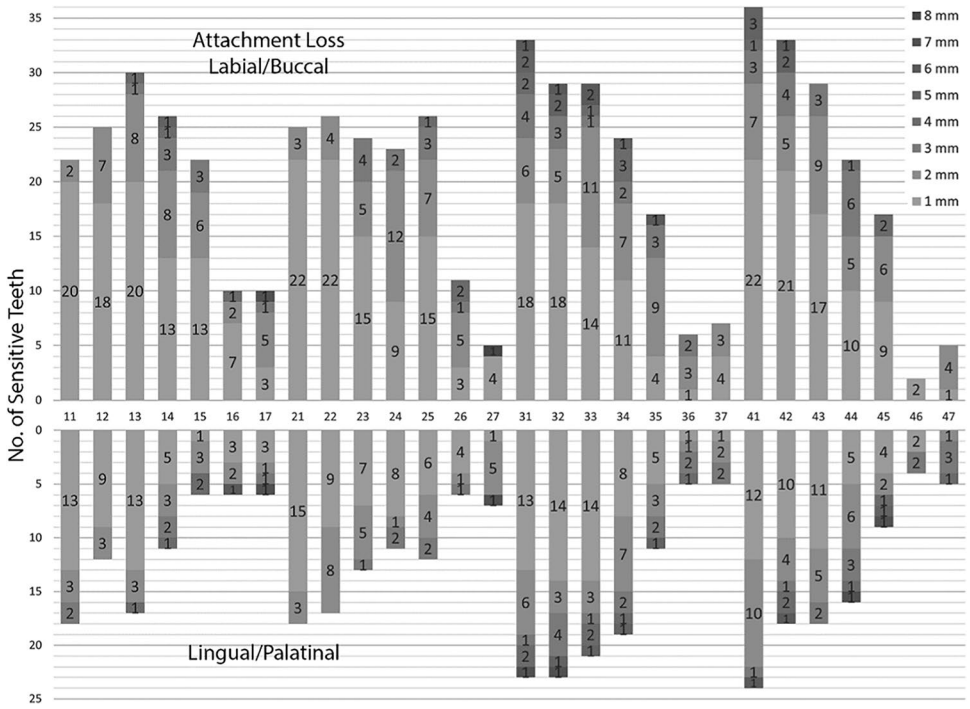

Fig. 3 Distribution of attachment loss according to the tooth type and buccal and lingual surfaces

contrast to our finding, Rees and Addy [31] showed that most patients with sensitivity (74%) fell into the first three groups (I, II, and IIIN). It was also shown that DH arose more frequently in higher social groups, which brush their teeth more attentively [34, 53]. On the other hand, Ramlogan et al. [13] found the highest percentages of mean sensitive teeth in class II managerial (40.2%), as well as the unemployed (41.9%) and retired (41.7%) groups, but the number of patients was small in each of these groups. West et al. [16] observed the highest prevalence of DH in managers (46.4%), unemployed (46.3%), and housewives (45.7%). In our study, the prevalence of DH was higher in the higher education groups such as high school and undergraduates, which is in agreement with other studies [23]. This may be due to their high awareness of oral health. On the other hand, another study found that people with low education levels had more teeth with DH [22]. The fact that the results obtained from the studies show that there is no direct relationship between socioeconomic status, education level, and dentin hypersensitivity supports the idea that these contradictory results can be explained by different sociocultural and lifestyles between different countries [16, 24].

In our study, the cold was the most common stimuli that triggered hypersensitivity. Concordant with our results, many studies reported cold as the most common stimuli that triggered hypersensitivity [13, 18, 22, 29, 31, 34, 35, 44, 52]. It was explained that cold caused fluid flow away from the pulp, generating a more rapid and greater pulp nerve response than other stimuli, which caused an inward flow [39]. Moreover, "occasionally" was the most prevalent type of DH frequency. This result is in agreement with other studies' findings [18, 28].

In respect to oral hygiene habits, a greater amount of dentin hypersensitivity was found in patients using medium brushes and those brushing twice per day for 1–2 min. Also, the type of toothbrush showed a significant association with DH with tactile stimulus. The majority of patients or teeth with DH were observed to brush using the circular method. However, the prevalence of DH was lower (37%) in those who brushed with excessive force than those who did not (62.2%). In our study, a significant association was found between gingival recession and type of toothbrush and frequencies of toothbrushing. Gingival recession is thought to result in exposed cervical dentin, open dentin tubules, and painful sensations to thermal, tactile, or other stimuli [4, 36]. Congruent with our finding, other studies reported a higher prevalence of DH with medium brushes [12, 13, 38], and a significant association was found between the type of toothbrush and DH [13, 38]. Conversely, it was shown that the prevalence of DH was more common in patients who used a soft toothbrush [18, 29, 43, 54]. In addition, a higher prevalence was found in patients who brushed for more than 2 min [38], twice per day [12, 24, 38], three times per day [16], or never brushed their teeth [55]. In accordance with our finding, the highest prevalence of DH was found in the circular toothbrushing method [24]. However, other studies have found brushing methods such as vertical [16], several directions [18], and scrubbing [13] at the highest frequency, and a significant association was reported with the vertical or horizontal direction [18]. Supporting our findings, it

has been reported that the percentage of patients with DH who brushed teeth aggressively was lower than those who did not [19]. By contrast, it was reported that the percentage of patients with DH who used excessive force during toothbrushing was higher than those who did not, and toothbrushing with excessive force might carry more risk for DH [29]. To explain the different findings, it can be thought that patients may use toothpastes with different relative dentin abrasion (RDA) values, patients with sensitivity may have previously been advised to brush with soft bristles and with less force [38], and toothbrushes may have different bristle diameter and number of bristles per cluster, as well as different bristle hardness, which may affect the results. In a study in which all the properties of the tested soft and medium–hard toothbrushes were the same, it was explained that soft bristles could deflect too much, especially due to high brushing force, and thus cause less abrasive particle entrainment on the dentin surface compared with medium bristles and that deflected bristles could hold more abrasive particles and act as a barrier between the particles and the dentin surface [56].

Regarding dietary habits, those who consumed fruit once per day showed the highest prevalence of DH. Also, there was only a significant relationship between the frequency of fruit consumption and DH with tactile stimulus. The highest DH rate was found in those who did not consume fruit juice, herbal tea, carbonated beverage, and vitamin C, and their consumption had no significant effect on DH prevalence. One explanation of this is that contact time between the tooth and the acid may be a more important risk factor for DH compared with the frequency of dietary acid intake. It was stated that increased contact time with dietary acids and sipping swishing or holding drinks in the mouth before swallowing should be addressed as an etiologic factor in DH. In our study, the dietary habits of the patients were questioned only in terms of intake frequency [38]. Per our finding, DH was more common among patients consuming fruit once per day between meals [38]. One study reported the highest prevalence of DH in Arab patients who consumed fruit, fruit and vegetable juice, isotonic and soft drinks once per week/month, and never [26]. Other studies found the highest prevalence of DH in those who consumed fruit, isotonic and soft drinks often, and those who did not consume fruit/vegetable juice [16, 39] or those who consumed ≥ 3 dietary acids between meals daily and those who drank ≥ 2 acidic drinks between meals [38]. Also, it was reported that people who consumed vitamin C often had a higher percentage of DH [39]. A study showed that there was a significant relation between acidic dietary intake and the elicited DH, with fresh fruit and isotonic/energy drinks [16]. On the other hand, other studies found no relation between hypersensitivity and acidic foods and fruit juices [11, 26], and it was reported that acidic fruits and carbonated drinks were not observed as risk factors [11]. These contradictory results could be ascribed to the multifactorial etiology of DH and the unique features of the studied populations in which the contribution of oral health and dietary habits, as well as sociodemographic factors, play key roles [26]. Questionnaires provide an estimate of dietary behavior [57]. Also, there is no standardized, definitive method in the literature to properly evaluate an acid diet [10, 57]. There may also be a clinical suspicion that diets have changed over time. For these reasons, a study that monitors patients over time and records their diet may be needed to determine whether increased intake of acidic foods and beverages has an impact on the prevalence of DS [35].

In our study, regarding the tooth surface, the buccal surfaces (86.3%) of teeth showed a higher prevalence of DH compared with the lingual surface (52.7%). The tooth surface with the highest percentage of DH was the buccal surface of the lower right central incisor, and the tooth group was the buccal surface of the lower right incisors. Also, the most affected teeth by DH were incisors followed by premolars; molars were the least sensitive teeth. There were more maxillary teeth with DH than mandibular teeth. This is a different distribution than in previous studies, which showed that the most commonly affected teeth were the premolars [10, 17, 18, 20, 21, 23, 24, 27]. Correspondingly, in some previous studies, the tooth groups most affected by DH teeth were incisors and premolars [4, 32, 42, 43, 52]. Also, the highest numbers of teeth with DS were the lower anterior teeth for both the buccal and lingual/palatal aspects [13] or labial/buccal cervical surface [27, 36]. It was explained that patients would also be more likely to retain lower incisor teeth longer due to their crucial esthetic position, even when they were severely compromised. Therefore, their risk of developing DH would be higher following gingival recession [52]. Considering the intraoral distribution of dentin sensitivity, the lower enamel thickness of the incisors, and the position of the premolars in the dental arch, overzealous brushing of these areas for esthetic concerns and more brushing of the buccal surfaces make these areas more prone to gingival recession and hard tissue loss, which are factors directly related to dentin sensitivity [23, 32, 36, 43].

In the present study, 15.8% of sensitive teeth had a loss of cervical tooth structure, and a significant correlation was observed between tooth wear and DH. In support of this finding, it was reported that 23.4% of sensitive teeth showed a loss of cervical tooth structure [52]. Also, in our study, it was shown that there was a significant relationship between tooth wear and toothbrushing stimuli. Tooth wear has been recognized as one of the main etiologic factors for DH, as it causes the dentinal tubules to open and enlarge, as well as promotes the loss of tooth structure [9]. In our study, the patients with bruxism had a higher percentage of sensitive teeth, and there was a significant association between

bruxism and DH. This result is harmonious with other studies [29, 43, 45, 55]. Bruxism and parafunctional habits are possible risk factors for non-carious cervical lesions [58]. Regarding parafunctional habits, occlusal parafunction is more likely to favor the dental substance loss in the cervical region than physiological processes because the force magnitudes during bruxism are much greater than loads of normal functional activity [10]. This could explain the greater risk for DH found in this study for subjects with bruxism because non-carious cervical lesions are also frequently associated with DH [29].

In the present study, the buccal surfaces (40.9%) of sensitive teeth showed a higher prevalence of gingival recession compared with the lingual surface (15.7%), which is in accordance with previous studies' results [27, 52]. Also, the prevalence of sensitive teeth with loss of attachment (81.5%) was more than twice that of sensitive teeth with gingival recession (36.8%). In agreement with this finding, it was reported that the amount of loss of attachment in teeth with DH was higher than that of gingival recession [25, 27]. It was explained that attachment loss always occurred before gingival recession due to anatomic factors exposing the enamel–cementum junction, which is prone to creating DH [22]. Also, it was stated that attachment loss arose before the gingival recession in the initial stage of periodontal disease. The positive correlation between gingival recession and dentin hypersensitivity can be explained by the theory that root exposure makes the tissue more vulnerable to the effects of hypersensitivity risk factors [10]. Consistent with our findings, gingival recession and loss of attachment were observed mainly in incisors [23], and the majority of gingival recession was in the range of 1–3 mm [20, 21, 34, 55]. In our study, there was a significant relation between gingival recession and the type of toothbrush and frequencies of toothbrushing. The most gingival recession was observed in those who used medium brushes and brushed twice per day. It was reported that gingival recession was significantly related to brushing once daily, horizontal toothbrushing, and the use of a medium–hardness bristle toothbrush [4] or toothbrush texture hardness [13]. Consistent with previous studies, in the present study, nonsmokers showed a higher percentage of DH, and no significant relationship was found between the frequency of smoking and DH [12, 13, 22, 25, 52]. However, it was observed that smokers showed a higher percentage of DH than nonsmokers, and a significant association between smoking and DH was found [16, 31]. It was presumed that smoking might not be the direct influential factor on DH but might affect it by exacerbating periodontal attachment loss [22].

In our study, there was a significant association between the diagnosis type and DH. The highest prevalence of DH was found with air and tactile stimulus, followed by air stimulus, which is consistent with the finding of a previous study [44]. Per our result, the DH prevalence to air stimulus was found higher than DH prevalence to tactile stimulus [4, 9, 18, 44]. The higher number of air-sensitive teeth is similar to the findings of other studies [9, 18, 23, 37, 44]. It can usually be associated with the sensitivity of only a small area of the lesion. The touch of the dental probe stimulates a limited area of exposed sensitive dentin, and tender points may not be stimulated. Air, on the other hand, can activate the entire sensitive area and more closely resemble a real situation than a tactile stimulus [9, 18, 23, 37].

Conclusions

The prevalence for self-reported hypersensitivity was found as 10.2%, and clinical examination of teeth gave an overall prevalence for DH of 29.4% in Turkish patients. Patient-related factors such as females, the 31–40 years age group, housewives, and high education groups had a higher risk for sensitive teeth. The cold was the most common stimuli that triggered hypersensitivity. The majority of patients had experienced hypersensitivity symptoms for more than 1 year and occasionally. Patients who used medium brushes and brushed twice per day for 1–2 min with the circular method have a greater risk of DH. Smoking and the consumption of fruit juice, carbonated beverage, herbal tea, and vitamin C have no risk for DH. Incisor and then premolar teeth as tooth type, buccal surfaces as tooth surface, gingival recession, and attachment loss on the buccal surface of teeth had a higher risk for DH. Also, loss of attachment had a higher risk than gingival recession. Bruxism was another risk for HD. Air and tactile stimulus caused more sensitivity than air stimulus.

Author contribution Conceptualization, methodology, and writing — original draft: Mustafa Demirci. Material preparation and data collection and analysis: Ferda Karabay and Meriç Berkman. Methodology, review, and editing: Safa Tuncer and Neslihan Tekçe. Project administration: Mustafa Demirci and İlknur Özcan. Statistical evaluation: Canan Baydemir. All authors read and approved the final manuscript.

Declarations

Ethics approval The study was approved by the Clinical Research Ethics Committee of the Faculty of Dentistry, Istanbul University, with protocol 2016/49. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare no competing interests.

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