Prevalence and Associated Factors of Tooth Wear in Shanghai

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Objective: *To estimate the prevalence and distribution of tooth wear among groups of adolescents and adults in Shanghai, China through an epidemiological survey, and explore the associated factors.*

Methods: *Multistage, stratified, constant volume and cluster sampling methods were used in an epidemiological survey conducted in Shanghai in 2014. The basic erosive wear examination (BEWE) index was used to screen for tooth wear in different age groups: 12 years, 15 years, 18 to 35 years, 36 to 49 years and 50 to 74 years. A previously published questionnaire collected information including dietary habits, oral hygiene habits and general conditions.*

Results: *This survey reports the results for 1806 participants in Shanghai. The prevalence of tooth wear was 59.7% in adolescents (BEWE ≥ 1) and 93.1% in adults (BEWE ≥ 2). The prevalence and severity of disease increased with age ($P < 0.01$). The teeth most susceptible to wear were the central incisors and first molars. Multivariate analysis of covariance (ANCOVA) results showed that soft drinks, alcoholic drinks, pickled vegetables and hard food, gastroesophageal reflux disease (GERD), xerostomia and poor tooth brushing habits were statistically correlated with tooth wear in different age groups.*

Conclusion: *The prevalence of tooth wear appears to be high in adolescents and adults in Shanghai. Frequent consumption of soft or alcoholic drinks, GERD, xerostomia and poor tooth brushing habits were positively associated with tooth wear in different age groups.*

Key words: *adolescents, adults, basic erosive wear examination index, epidemiological survey, tooth wear*

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Tooth wear is a term that encompasses attrition, abrasion, abfraction and erosion[1,2]. Its aetiology has not been fully disclosed, but it is generally considered to be an undesirable condition due to multivariate chemical, biological and behavioural factors. The risk factors for tooth wear have been reported to be age and sex, frequent consumption of dietary acid, parafunctional behaviours and gastroesophageal reflux disease (GERD)[3]. Only few patients show one specific form of tooth wear; in most cases, a combination of erosion, attrition, abrasion and abfraction result in tooth wear[4]. For this reason, the term 'tooth wear' or 'erosive tooth wear' is preferred, to acknowledge that erosion is commonly part of the aetiology but may not be the only cause.

Tooth wear is an irreversible, multifactorial process that progresses when influenced by risk factors; as such, early diagnosis is important. Recent epidemiological

studies have shown that tooth wear becomes more common in both the primary and permanent dentition[3,5-9]. A broad range of prevalence of tooth wear, from 26.9% to 90.0%, has been reported in permanent dentition around the world[3,5-11]. This wide variation may be attributed to the distinctive diet and lifestyle of various populations and the application of various indexes used for evaluation.

The basic erosive wear examination (BEWE) index was proposed as a measure for grading the levels of tooth wear by Bartlett et al[12] in 2008. The BEWE was designed to provide a simple tool for use in general practice and to allow comparison to other more discriminative indices. It has been used in multiple general practice and epidemiological surveys and is considered reasonably accurate[8,11,13-17]. The BEWE is a convenient index, with sufficient sensitivity and specificity[18-20]. In 2013, it was used in a prevalence study of 3187 adults in Europe which found that 57.1% had clinically visible tooth wear[8].

Shanghai is a metropolitan city, with a population of over 24 million people, and is also known as the economic centre of China. No previous surveys have reported on the prevalence of tooth wear in adolescents and adults in Shanghai. Thus, this investigation aimed to measure the prevalence and severity of tooth wear among adolescents and adults in Shanghai, China, and to explore the associated risk indicators for tooth wear.

Materials and methods

This observational, cross-sectional survey applied multistage, stratified, constant volume and cluster sampling methods. The sample population was stratified by age, sex and district. Two districts were randomly selected from a list of all districts in Shanghai ordered by initial letter. A survey conducted in Europe found that prevalence of tooth wear was estimated to be 55%[8]. Thus, a group size of approximately 327 participants was proposed, along with the estimation of prevalence ($\alpha = 0.05$) and the acceptable margins of error ($d = 0.1P$) to decrease sampling error. The authors added a further 10% to the sample size to account for statistical errors. Three survey sites were randomly selected from each district included on the alphabetical list, including schools, neighbourhoods, factories and companies, and 60 participants were investigated in each site for the corresponding age group.

The 12- and 15-year-old participants were selected from schools, the participants aged 18 to 35 years and 36 to 49 years were chosen from local factories, companies and communities, and the participants aged 50 to 74 years were selected from local communities. Ethical approval for the study was obtained from the heads and instructors of each institution or communities. Written informed consent was obtained from each participant or their parent or guardian if they were under the age of 18. The study protocol was approved by the Research Ethics Committee of the Shanghai Ninth People's Hospital (No. 2014010).

The buccal cervical, facial/buccal, incisal/occlusal and palatal/lingual tooth surfaces of permanent dentition were scored on all teeth using the BEWE on an ordinal scale from 0 to 3 (0, no wear; 1, early surface loss; 2, surface loss < 50%; 3, surface loss > 50%) and awarded a depth score of 0 or 1 estimated from dentine exposure for each tooth (0, without dentine exposure; 1, with dentine exposure)[12]. A cumulative BEWE score was calculated for each sextant (teeth 14 to 17, 13 to 23, 24 to 27, 34 to 37, 33 to 43 and 44 to 47, according to FDI notation) of each participant, with the highest score recorded from each tooth surface in each sextant. Missing teeth, restored surfaces (over 50% of the surface), teeth with crowns, traumatic or carious surfaces, third molars and teeth or surfaces unable to be examined were not scored. For the 12- and 15-year-old age groups, at least one surface scored 1 or above (BEWE ≥ 1) was determined to be the result of tooth wear. For the adult groups, surfaces that scored BEWE ≥ 2 were thought to be suffering from tooth wear.

All examinations were conducted by a single trained examiner (TY). The participants were examined in a dental chair in the supine position. The teeth were dried using cotton wool rolls and a sterile disposable dental mirror was used for examination under good lighting. Prior to the main survey, the examiner was trained by an experienced dentist (DB), whose technique was recognised as the gold standard. To estimate the intraexaminer reliability, 5% of participants were re-examined during the examination. The kappa score for intraexaminer reliability was 0.87.

Prior to the clinical examination, each participant was asked to complete the questionnaire, with guidance available if they experienced any difficulties understanding. The questionnaire was based on calibrated questionnaires previously used to identify risk factors for tooth wear, including socioeconomic status, behavioural factors, dietary and eating habits (such as frequency of consumption of carbonated drinks, coffee, tea, wine and fruit juice), oral hygiene habits and general health status (including xerostomia, vomiting and medication)[10]. A pilot study was conducted to test and refine the questionnaire. The data were analysed using SPSS (version 20.0, IBM, Armonk, NY, USA).

Table 1 BEWE scores in the five age groups.

Age, y	n	BEWE = 0, n (%)	BEWE = 1, n (%)	BEWE = 2, n (%)	BEWE = 3, n (%)
12	360	164 (45.5)	181 (50.3)	15 (4.2)	0 (0.0)
15	362	127 (35.1)	213 (58.8)	21 (5.8)	1 (0.3)
18–35	363	7 (1.9)	55 (15.2)	267 (73.6)	34 (9.4)
36–49	360	0 (0.0)	5 (1.4)	201 (55.8)	154 (42.8)
50–74	361	0 (0.0)	8 (2.2)	121 (33.5)	232 (64.3)
Total	1806	298 (16.5)	463 (25.6)	625 (34.6)	421 (23.3)

Table 2 Mean cumulative BEWE score and prevalence of tooth wear and dentine exposure.

Age, y	n	Cumulative BEWE score (mean ± SD)	*P* value	Tooth wear, n (%)*	*P* value	Dentine exposure (depth = 1), n (%)	*P* value
12	360	1.10 ± 1.42		196 (54.44)		1 (0.28)	
15	362	1.50 ± 1.64		235 (64.92)		7 (1.93)	
18–35	363	8.36 ± 3.45		301 (82.92)		144 (39.67)	
36-49	360	11.43 ± 2.30	< 0.001†	355 (98.61)	< 0.001†	259 (71.94)	< 0.001†
50–74	361	12.12 ± 2.60		353 (97.78)		353 (97.78)	
Total	1806	6.90 ± 5.31		1440 (79.7)		764 (42.3)	

*BEWE ≥ 1 in the adolescent groups and BEWE ≥ 2 in the adult groups were included
†Difference in five age groups
SD, standard deviation.

They were analysed at the participant level, with the highest BEWE score recorded for any scorable tooth surface. Intraexaminer agreement was evaluated using Cohen's kappa. Descriptive analysis was conducted to describe the prevalence and distribution characteristics of tooth wear. Bivariate analyses (including Pearson correlation coefficient, chi-squared test, *t* test, analysis of covariance (ANCOVA), Mann-Whitney test and Kruskal-Wallis test) were applied to test possible associations between potential risk variables and tooth wear. Variables that were associated with tooth wear ($P < 0.20$) entered as candidate variables into a multivariate ANCOVA. The level of significance was set at 0.05. The 12- and 15-year-old participants were merged into one group for bivariate analyses and ANCOVA. The three adult groups were analysed separately.

Results

This study, conducted in 2014, reports on 1806 participants (903 men/boys and 903 women/girls) from Pudong new district and Xuhui district in Shanghai. There were 360 participants in the 12-year-old group, 362 in the 15-year-old group, 363 aged 18 to 35 years, 360 aged 36 to 49 years and 361 aged 50 to 74 years.

Signs of tooth wear on at least one surface (BEWE ≥ 1 in the adolescent groups and BEWE ≥ 2 in the adult groups) were evident in 1440 participants and the prevalence of tooth wear was 79.7% (59.7% in adolescents and 93.1% in adults). The prevalence of BEWE ≥ 1 for 12- and 15-year-olds was 54.4% and 64.9%, respectively, and that of BEWE ≥ 2 for the 18 to 35, 36 to 49 and 50 to 74 years groups was 82.9%, 98.6% and 97.8%, respectively. A total of 764 participants (42.3%) had tooth wear with exposed dentine. The cumulative BEWE score was 6.9 ± 5.3. The cumulative BEWE scores for each age group followed a normal distribution (Tables 1 and 2). The prevalence of tooth wear by sex for each age group is shown in Tables 3 and 4. Male participants were more susceptible to tooth wear than female participants in the 12- and 15-year-old groups ($P < 0.05$).

A total of 46,749 teeth (187,509 tooth surfaces) were scored and 13,290 teeth (16,377 tooth surfaces) were affected (BEWE ≥ 1 in the adolescent groups and BEWE ≥ 2 in the adult groups). The distribution of tooth wear and exposed dentine by teeth is shown in Tables 5 and 6 and Fig 1. The most frequently affected teeth were the central incisors and first molars, followed by the canines and lateral incisors. The mandibular central incisors were the most susceptible teeth. The most frequently affected surface was the incisal/occlusal surface (24.67%), followed by buccal cervical (4.97%), facial/buccal (2.96%) and palatal/lingual surfaces (2.30%) (Fig 2). The correlation between age and BEWE score in the adult groups is shown in Table 7. The cumulative BEWE score was clearly positively correlated with age in the groups of participants aged 18 to 35 and 36 to 49 years.

Table 3 Prevalence and cumulative BEWE score of tooth wear by sex in adolescents.

Age, y	Sex	n	BEWE (mean ± SD)	*P* value	BEWE ≥ 1, n (%)	*P* value	Depth = 1, n (%)	*P* value
12	Male	180	1.26 ± 1.43	< 0.001*, 0.031†	115(63.9)	0.004*, < 0.001†	1 (0.60)	0.069*, 0.317†
	Female	180	0.94 ± 1.40		81(45.0)		0 (0.00)	
	Subtotal	360	1.10 ± 1.42		196(54.4)		1 (0.28)	
15	Male	182	1.81 ± 1.84	< 0.001*, < 0.001†	130(71.4)	0.004*, 0.009†	6 (3.30)	0.069*, 0.121†
	Female	180	1.18 ± 1.33		105(58.3)		1 (0.60)	
	Subtotal	362	1.56 ± 1.59		235(64.9)		7 (1.93)	
Total		722	1.38 ± 1.55	NA	431(59.7)	NA	8 (1.10)	NA

*Difference between age groups.
†Difference between sexes.
NA, not applicable.

Table 4 Prevalence and cumulative BEWE score of tooth wear by sex in adults.

Age, y	Sex	n	BEWE (mean ± SD)	*P* value	BEWE ≥ 2, n (%)	*P* value	Depth = 1, n (%)	*P* value
18–35	Male	181	8.61 ± 3.11	< 0.001*, 0.083†	149 (82.3)	< 0.001*, 0.762†	80 (44.2)	< 0.001*, 0.079†
	Female	182	8.01 ± 3.47		152 (83.5)		64 (35.2)	
	Subtotal	363	8.36 ± 3.45		301 (82.9)		144 (39.7)	
36–49	Male	180	11.61 ± 2.35	< 0.001*, 0.124†	178 (98.9)	< 0.001*, 0.652†	136 (75.6)	< 0.001*, 0.127†
	Female	180	11.24 ± 2.23		177 (98.3)		123 (68.3)	
	Subtotal	360	11.43 ± 2.30		355 (98.6)		259 (71.9)	
50–74	Male	180	12.04 ± 2.69	< 0.001*, 0.573†	176 (97.8)	< 0.001*, 0.994†	176 (97.8)	< 0.001*, 0.994†
	Female	181	12.20 ± 2.51		177 (97.8)		177 (97.8)	
	Subtotal	361	12.12 ± 2.60		353 (97.8)		353 (97.8)	
Total		1084	10.63 ± 2.36	NA	1009 (93.1)	NA	756 (69.70)	NA

*Difference between age groups.
†Difference between sexes.

The questionnaire addressing eating habits, oral hygiene habits and general health status provided information about the associated risk factors. The ANCOVA was applied to investigate the relationship between the associated factors and the cumulative BEWE score. Tables 8 and 9 show the results of the multivariate ANCOVA. No associations were observed apart from those listed in Tables 8 and 9, with only the positive associations shown. In the adolescent groups, the cumulative BEWE score was statistically significantly related to frequency of consuming carbonated drinks, frequency of tooth brushing, frequency of changing toothbrush and GERD ($P < 0.05$), whereas in the group aged 18 to 35 years, the statistically significant associated variables were frequency of consuming alcoholic drinks and methods of tooth brushing ($P < 0.05$). In the group aged 36 to 49 years, the statistically significant associated variables were frequency of consuming pickled vegetables, frequency of consuming hard food and type of toothbrush ($P < 0.05$), and for the group aged 50 to 74 years it was xerostomia ($P < 0.05$).

Discussion

In this study, tooth wear was almost a universal experience for adolescents and adults, with the total score of BEWE ≥ 2 and 3 being recorded in 57.9% of participants across all age groups. This implies that tooth wear is common in Shanghai, and 42.3% of participants presented exposed dentine. This does not mean that restorative intervention is indicated for all high scores but implies tooth wear is common and may have economic implications for health care providers.

In this investigation, the term 'tooth wear' was applied to describe changes to teeth. Some researchers have used the term 'erosion' to describe defects of smooth surfaces and observed the impact of attrition on the occlusal surfaces. Without a thorough clinical history and special investigations to distinguish the aetiology of the wear on teeth, it is difficult to separate and determine the specific form of tooth wear. On the other hand, no attempt was made in this study to diagnose the special aetiology of tooth wear from the clinical appearance.

Table 5 Distribution of tooth wear and dentine exposure by teeth in all participants.

Tooth	17	16	15	14	13	12	11	21	22	23	24	25	26	27
Tooth wear* (%)	20.9	49.0	12.0	12.6	26.2	17.4	27.5	27.1	16.8	26.4	13.4	11.7	44.5	19.2
Dentine exposure† (%)	7.2	13.7	7.1	4.5	7.2	5.2	7.9	7.5	3.4	8.1	4.6	4.0	12.0	6.3
Tooth	47	46	45	44	43	42	41	31	32	33	34	35	36	37
Tooth wear* (%)	23.0	42.3	14.3	16.8	34.9	44.1	54.0	54.1	44.9	37.5	18.8	14.4	41.3	21.0
Dentine exposure† (%)	8.9	16.3	5.0	5.9	14.9	20.8	27.0	27.2	21.4	16.3	6.4	6.1	14.7	7.3

*BEWE ≥ 1 in the adolescent groups and BEWE ≥ 2 in the adult groups.
†Depth = 1 in all five age groups.

Table 6 Distribution of tooth wear (%) by teeth across all age groups (BEWE ≥ 1 in adolescent groups and BEWE ≥ 2 in adult groups).

Age, y	Tooth													
	17	16	15	14	13	12	11	21	22	23	24	25	26	27
12	0.4	16.0	1.2	1.4	8.5	9.4	15.9	15.9	9.2	8.0	1.1	1.2	12.6	0.0
15	0.6	29.1	2.5	2.0	8.0	11.4	20.0	19.5	9.7	8.1	2.0	1.1	26.2	0.6
18–35	16.4	47.6	5.9	5.6	27.3	6.1	20.0	19.8	6.4	26.9	6.2	5.4	42.3	12.9
36–49	36.5	79.6	18.8	17.1	39.9	23.6	34.5	36.2	24.1	39.5	19.2	18.8	80.4	35.5
50–75	56.7	86.5	37.4	43.1	50.2	39.5	50.3	51.7	38.3	52.7	43.3	38.4	84.0	54.7
Total	20.9	49.0	12.0	12.6	26.2	17.4	27.5	27.1	16.8	26.4	13.4	11.7	44.5	19.2
Age, y	**Tooth**													
	47	46	45	44	43	42	41	31	32	33	34	35	36	37
12	0.0	7.4	1.8	2.3	9.5	6.1	16.2	15.6	7.2	11.4	3.7	1.2	8.8	0.0
15	0.8	13.3	3.1	3.4	11.3	8.1	19.7	19.7	9.5	14.6	4.8	3.7	10.7	0.8
18–35	15.1	41.7	6.4	9.8	34.7	44.2	57.9	57.7	44.3	36.7	12.0	5.6	40.5	13.0
36–49	40.9	77.5	18.4	24.2	55.5	80.8	90.1	90.9	81.0	58.4	25.3	21.1	77.6	41.7
50–75	66.9	89.1	48.4	49.7	66.8	88.0	91.9	92.6	88.0	68.3	52.4	45.9	88.8	59.3
Total	23	42.3	14.3	16.8	34.9	44.1	54.0	54.1	44.9	37.5	18.8	14.4	41.3	21.0

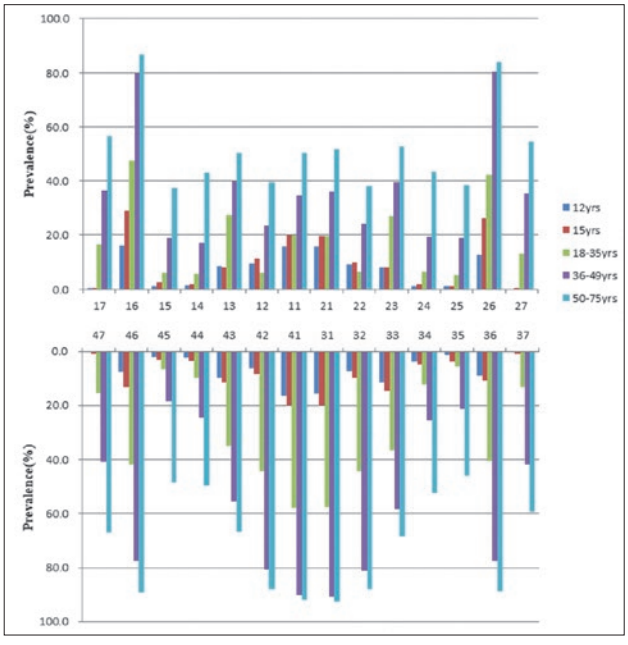

Fig 1 Distribution of tooth wear by teeth in all groups (BEWE ≥ 1 in the adolescent groups and BEWE ≥ 2 in the adult groups).

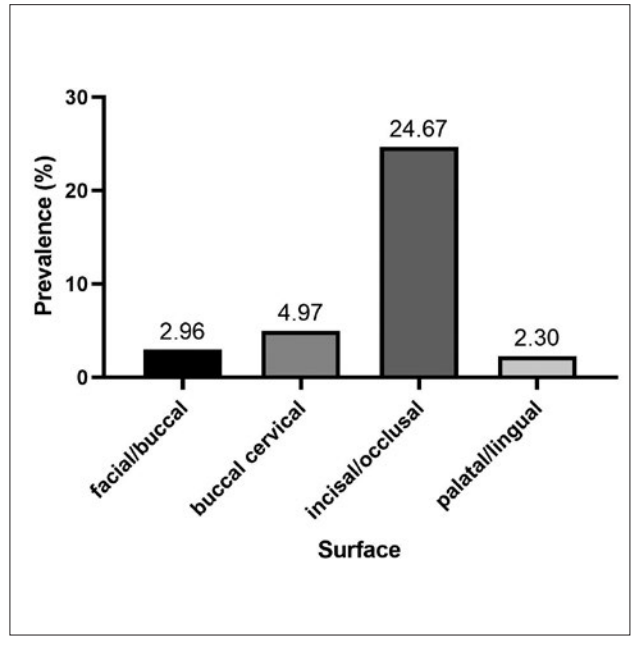

Fig 2 Distribution of tooth wear by tooth surface in all groups (BEWE ≥ 1 in the adolescent groups and BEWE ≥ 2 in the adult groups).

Table 7 Correlation between age and BEWE score.

Age, y	Age, y (mean ± SD)	BEWE score (mean ± SD)	Pearson
18–35	27.16 ± 3.80	8.31 ± 3.30	< 0.01
36–49	41.35 ± 4.73	11.43 ± 2.30	< 0.01
50–74	62.30 ± 6.15	12.12 ± 2.60	0.148

Table 8 Multivariate ANCOVA of cumulative BEWE scores in 12- and 15-year-old groups.

Variable		n (%)	Cumulative BEWE score (mean ± SD)	B	95% CI	*P* value
Frequency of tooth brushing	Twice or more daily	564 (78.1)	1.12 ± 1.48	NA	NA	NA
	Once or less daily	158 (21.9)	1.79 ± 1.66	0.593	[0.327–0.859]	< 0.001
Frequency of consumption of carbonated drinks	Never/rarely	342 (47.4)	1.03 ± 1.23	NA	NA	NA
	Sometimes	288 (39.9)	1.42 ± 1.63	0.348	[0.117–0.580]	0.003
	Once or more daily	92 (12.7)	1.91 ± 2.04	0.715	[0.368–1.063]	< 0.001
GERD	No	712 (98.6)	1.46 ± 0.55	NA	NA	NA
	Yes	10 (1.4)	4.11 ± 1.30	2.032	[1.063–3.000]	< 0.001
Frequency of changing toothbrush	< 3 months	369 (51.1)	1.12 ± 1.37	NA	NA	NA
	≥ 3 months	347 (48.1)	1.49 ± 1.69	0.318	[0.099–0.536]	0.011
Age		NA	NA	0.103	[0.040–0.166]	0.001

NA, not applicable. Cells marked with NA indicate the reference item.

Table 9 Multivariate ANCOVA of cumulative BEWE scores in adults.

Age, y	Variable		n (%)	Cumulative BEWE score (mean ± SD)	B	*95% CI*	*P value*
18–35	Methods of tooth brushing	Vertical	91 (25.1)	7.47 ± 3.24	NA	NA	NA
		Horizontal	67 (18.4)	8.31 ± 3.29	1.500	[0.544–2.456]	0.001
		Mixed	205 (56.5)	8.67 ± 3.29	1.620	[0.874–2.366]	< 0.001
	Frequency of consumption of alcoholic drinks	Never/rarely	311 (85.7)	8.08 ± 3.32	NA	NA	NA
		Once or more weekly	52 (14.3)	9.63 ± 2.90	1.372	[0.488–2.256]	0.002
	Age		NA	NA	0.304	[0.221–0.386]	< 0.001
36–49	Frequency of consumption of pickled vegetables	Never/rarely	300 (83.3)	11.22 ± 2.32	NA	NA	NA
		Sometimes	53 (14.7)	12.36 ± 1.83	1.016	[0.395–1.638]	0.001
		Once or more daily	7 (1.9)	13.00 ± 2.52	2.128	[0.526–3.730]	0.009
	Frequency of consumption of hard food	Never/rarely	190 (52.8)	11.21 ± 2.25	NA	NA	NA
		Sometimes/often	170 (47.2)	11.66 ± 2.33	0.495	[0.053–0.936]	0.028
	Type of toothbrush	Electric	30 (8.3)	10.10 ± 1.97	NA	NA	NA
		Manual	330 (91.7)	11.55 ± 2.29	1.192	[0.387–1.997]	0.004
	Age		NA	NA	0.139	[0.092–0.185]	< 0.001
50–74	Xerostomia	No/unsure	290 (80.3)	12.00 ± 2.49	NA	NA	NA
		Yes	71 (19.7)	12.63 ± 2.95	0.726	[0.061–1.391]	0.032

NA, not applicable. Cells marked with NA indicate the reference item.

In most reports using BEWE, participants with BEWE ≥ 2 (at least one surface scoring 2 or above) are identified as having tooth wear. In this study, however, only a few participants recorded a BEWE score of 2 or 3. Based on data from other studies, for example in Hong Kong, only a few children had teeth with a BEWE score of 2, and no children had a BEWE score of 3[21]. In the present study, BEWE ≥ 1 was used to indicate tooth wear in the 12- and 15-year-old groups. The results of this survey (36 participants received a BEWE score of 2 and only one received a score of 3) could suggest that BEWE ≥ 2 may not be suitable for adolescents. Muller-Bolla et al[13] used a total BEWE score ≥ 1 on permanent teeth to diagnose dental erosion in adolescents, which is similar to the methods used in this study. For adults, we used BEWE ≥ 2 to identify tooth wear like in other studies.

Compared to other studies, the prevalence of tooth wear in adolescents was higher in the present study. In 12-year-olds, it was 54.4%, which is higher than in

Brazil, Jordan and Hong Kong[5,7,21-23], but similar to studies conducted in Beijing, China (61.8%)[24] and in the UK (59.7%)[25]. Likewise, the prevalence among 15-year-old adolescents was 64.9%, which is higher than surveys conducted in Iceland and England[6,26], but similar to a study in Sudan (74%)[27] and lower than central China (89.4%)[23]. Variations in the data from different studies from different countries is not unusual as populations vary and so do their dietary habits, and differences arise between examiners' scoring, particularly in large studies. However, the data from this study suggest that tooth wear is common in 12- and 15-year-olds but not severe.

This investigation shows that the prevalence of tooth wear in the adult population was 93.1% (BEWE $\geq$ 2). This result is in the range previously reported by others[8,11,15,28,29]. It is higher than that reported in Europe using a similar protocol[8] and closer to that in 20-year-olds studied in Sweden[11].

In the present study, the central incisors and first molars were more susceptible to tooth wear than other teeth. This result is consistent with previous reports both in China and in other countries. Sun et al[30] reported that the incisors were affected predominantly in Beijing, China. In a report by Al-Dlaigan et al[31], the central incisors, lateral incisors and first molars showed a higher prevalence. The central incisors are the first permanent teeth to erupt and first to come into contact with acidic food or drink. The first molars also erupt at the same age and bear the largest occlusal force during mastication, which promotes the effect and process of tooth wear.

The incidence of tooth wear on the incisal/occlusal surface was highest (24.67%), as reported in other studies[30,32,33], and this is the main functional surface of the teeth to perform a masticatory function. The contact time with food is obviously longer, and the force during mastication is also greater on this surface than others; thus, the risk faced by the of incisal/occlusal surface is probably much higher. The prevalence on the buccal cervical surface (4.97%) was higher than that for the facial/buccal and palatal/lingual surfaces, which may be related to the anatomical characteristics of the buccal cervical surface and the stress concentration area of the cervical portion of the tooth[34]. Dentine can be exposed because of the thinner layer of enamel on the cervical portion. In addition, the anti-corrosion and anti-friction ability of dentine is weaker than that of enamel[35]. The loss of hard tissue is aggravated by the exposure of dentin, which puts the buccal cervical surface at increased risk.

The difference in prevalence between individuals and teeth may be attributed to three factors. First, previous studies used different indices and diagnostic criteria, which may have led to different results. Second, in the present study BEWE $\geq$ 1 was used as the sign of tooth wear in adolescents, which means early tooth wear was included and thus led to a higher detection rate. Finally, in the present study, the survey was conducted in Shanghai, a highly developed city where acidic food and soft drinks are easily available, as reported by Tao et al[36]. In the present study, consuming soft drinks and carbonated drinks was a statistically significantly associated risk factor for tooth wear in adolescents.

Tooth wear is a common clinical finding and can be cumulative with age. In the present study, the correlation between age and BEWE score was statistically significant. The life habits and medical history of the different age groups were also different. For example, the intake of carbonated drinks per week was significantly higher in adolescents than in the group aged 50 to 74 years. It is therefore more advantageous to explore the influence of related factors on different age groups by analysing each age group separately.

From the results of the present investigation, boys were more susceptible to tooth wear than girls in both adolescent groups, which supports the findings of Hou et al[24], Dugmore and Rock[25] and Abu-Ghazaleh et al[7]. This has been suggested to be related to the fact that boys are more likely to consume soft drinks than girls. In the present study, soft drink consumption was significantly higher in boys than girls ($P < 0.05$), whereas in the adult groups, no difference was found between the sexes. It is possible that the distribution of some risk factors was balanced in adults and further investigation is required to explore the reasons.

Soft drinks including fruit and vegetable juices, carbonated drinks and other acidic drinks have been proven to be a risk factor for dental erosion in both epidemiological and in vitro studies[37,38]. According to the results of the multivariate ANCOVA in the present study, consuming soft drinks once or more daily, especially carbonated drinks, significantly increased the risk of erosive tooth wear in the adolescent groups. Alcoholic drinks can have a lower pH value and lower calcium and phosphorus content, which might cause demineralisation of dental hard tissue[39]. It has also been reported that alcoholics often suffer from GERD[40], which also has a certain impact on the occurrence of tooth wear. In the present study, participants aged 18 to 35 years who drank once or more weekly were at higher risk compared with non-drinkers.

Among the participants aged 36 to 49 years, the cumulative BEWE score of those who regularly or sometimes consumed hard food and pickled vegetables

was significantly higher. Eating hard food (such as melon seeds and walnuts) could also cause abrasion of the incisal/occlusal surfaces, leading to tooth wear[34]. Pickled vegetables contain a large amount of lactic acid and have a lower pH value than normal vegetables, which may lead to tooth erosion. The relationship between pickled vegetables and tooth wear still requires further study.

GERD is defined as a condition in which the gastroduodenal content regularly reaches the oesophagus and may reach the oral cavity. Because the stomach content contains gastric acid, the pH value of which is much lower than that of saliva, when the content reaches the oral cavity, it interferes with the oral tissue. Although the association between GERD and erosive tooth wear was not clear, erosion seems to be more common and more severe in GERD patients than in healthy controls[41]. In the present study, the adolescents with GERD had a higher prevalence of erosive tooth wear and higher cumulative BEWE scores than those without, which confirms the findings of other authors[41,42].

In the groups aged 18 to 35 and 50 to 74 years, the cumulative BEWE score for participants with xerostomia was higher than that of the non-xerostomia group. Patients with xerostomia often suffer from reduced salivary secretion and dry mouth. Studies have shown that saliva plays an important role in adjusting pH, maintaining the stability of the oral environment, enhancing the ability of teeth to resist erosion and promoting remineralisation[43,44]. Thus, patients with xerostomia are at increased risk of tooth wear when their saliva secretion decreases.

In the present study, participants in the adolescent groups who brushed their teeth once or less daily received higher cumulative BEWE scores than those who brushed their teeth twice daily or more, and those who changed their toothbrush after more than 3 months had higher cumulative BEWE scores than those who changed theirs after less than 2 months of use. In the 18- to 35-year-old group, the risk of tooth wear was significantly higher in the horizontal toothbrushing group than in the vertical toothbrushing group, which was in line with the findings of Bartlett et al[8] and Sun et al[30]. In the 36- to 49-year-old group, however, participants who used a manual toothbrush received higher cumulative BEWE scores than those who used an electric toothbrush, contrary to the findings of Bartlett et al[8]. Further clinical and in vitro studies are required to elucidate the association between tooth wear and tooth brushing.

With the loss of hard tooth tissue, tooth wear may have an impact on aesthetics and the masticatory function. It may result in dentine hypersensitivity, pulp inflammation and even tooth fracture. Strategies need to be applied to prevent tooth wear so that the associated factors are manageable. Education in oral health and management (fluoridation measures, restoration and occlusal reconstruction) are necessary to reduce the risk of tooth wear and treat severe cases.

Conclusion

The present study showed that tooth wear in the Shanghai population is a problem that should be treated with concern. Frequent consumption of soft drinks, alcohol, pickled vegetables and hard food, GERD, xerostomia and poor tooth brushing habits were found to be positively associated with tooth wear in different age groups, which confirms the multifactorial aetiology of tooth wear.

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Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Tian YU performed the dental examination and analysis and prepared the manuscript; Dr Dan Ying TAO performed the arrangement and supervision of fieldworkers during the survey; Drs Hai Xia LU, Jia Lin ZHU and Chun Yu XIE performed and checked the data entry; Drs David Bartlett and Xi Ping FENG provided instruction, checked the analysis and revised the manuscript. All authors read and approved the final manuscript.

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