European Journal of Orthodontics, 2018, 444–450
doi:10.1093/ejo/cjx083
Advance Access publication 14 November 2017

OXFORD

Original article

Tooth wear and gingival recession in 210 orthodontically treated patients: a retrospective cohort study

Marco Mijuskovic[1], Meret C. Gebistorf[1], Nikolaos Pandis[1,2], Anne M. Renkema[3] and Piotr S. Fudalej[1,4]

[1]Department of Orthodontics and Dentofacial Orthopedics,University of Berne, Switzerland, [2]Private Practice, Corfu, Greece, [3]Department of Orthodontics and Craniofacial Biology, Radboud Universitiy, Nijmegen, Netherlands, [4]Department of Orthodontics, Institute of Dentistry and Oral Sciences, Faculty of Medicine and Dentistry, Palacky University Olomouc, Czech Republic

Correspondence to: Piotr S. Fudalej, Department of Orthodontics and Dentofacial Orthopedics, University of Berne, Freiburgstrasse 7, 3010 Bern, Switzerland. E-mail: piotr.fudalej@zmk.unibe.ch

Summary

Aim: To assess the association between tooth wear (TW) and gingival recession (GR).
Materials and Methods: Two hundred and ten orthodontically treated participants (100 males) were evaluated. GR and TW were rated independently by four raters on plaster models at four time points: before treatment (T_1), mean age 13.8 years (SD = 3.7); after treatment (T_2), mean age 16.7 years (SD = 3.9); 3 years after treatment (T_3), mean age 19.7 years (SD = 4.2); and 7 years after treatment (T_4), mean age 23.9 years (SD = 4.8). Univariable and mulitvariable random effects logistic regression analyses were performed with scores for GR as dependent variables and with TW, age, gender, dental segments (maxillary and mandibular anterior and posterior segments), time points, and Angle classification as independent variables. Method reliability was assessed with kappa statistics.
Results: Mandibular incisors, mandibular and maxillary first premolars and maxillary first molars were most vulnerable to GR. The prevalence of GR increased during the observation period. At T_1 20.5% participants had one or more recession sites, at T_4 85.7 % of the participants had at least one GR. There was evidence of association between moderate/severe TW and GR—for a tooth with moderate/severe wear, the odds of recession were 23% higher compared to a tooth with no/mild wear (odds ratio 1.23; 95% CI: 1.08–1.40; *P* = 0.002). Age, dental segment, and time were also significant recession predictors, whereas gender was not.
Conclusions: There is evidence that moderate/severe TW is associated with the presence of gingival recession. Clinical significance of this can be limited.

Introduction

Tooth wear (TW), a loss of calcified tooth substance caused by chemical and/or mechanical factors, is frequently seen in deciduous and permanent dentition (1). Prevalence data show that mild and moderate TW is a common condition in adults, while extreme TW is relatively rare (2).

The relationship between TW and pathological changes in the region of cemento–enamel junction (CEJ)—development of gingival recession (GR) and non-carious cervical lesions (NCCLs)—has been studied over recent years. The GR and NCCL are different phenomena—GR is an apical migration of the marginal gingiva past the CEJ (3), whereas NCCL is a loss of hard dental tissue near the CEJ. However, the frequent co-occurrence of GR and NCCL suggests that they could share some etiologic factors (4). To our knowledge, most research has focused on NCCLs. Two systematic reviews (5, 6) found no evidence of association between NCCL and functioning of occlusion. However, the included studies in both reviews were of low quality (small cross-sectional prospective cohort with short follow up periods) (5).

The relationship between TW and GR has rarely been investigated (7,8). Kundapur et al. (7) analysed cross-sectionally the association of GR in the region of mandibular incisors and signs of occlusal trauma such as presence of fremitus (i.e. occlusal trauma that occurs when teeth contact in centric relation), wear facets, and tooth mobility in a group of 300 patients attending the Department of Periodontics, Manipal College of Dental Sciences, Manipal, India. Authors cautiously implied a relationship between occlusal trauma (fremitus and TW) and GR. Krishna Prasad et al. (8) examined cross-sectionally 60 out of 600 dental students of the A. B. Shetty Memorial Institute of Dental Sciences, Deralakatte, Karnataka, India, who had GR or gingival clefts. Subsequently the authors evaluated occlusal conditions—amount of TW, type of occlusion, and mandibular movements—and related them to gingival conditions. In conclusion, Krishna Prasad and co-workers (8) stated that GR was present in 85% participants in the region of the mandibular incisors when there was an absence of anterior disclusion in maximum intercuspation. Interferences in the form of protrusive and laterotrusive contacts were also associated with GR. However, a high risk of bias, lack of assessment of the method error, and cross-sectional design of both studies preclude solid conclusion regarding the association between occlusal factors and GR.

Given the limited evidence in this area, the aim of this study was to evaluate the association between TW and the development of GR in a large cohort of participants followed for approximately 10 years. Our hypothesis was that the development of GR was associated with TW.

Materials and methods

In this retrospective cohort study, participants were followed for approximately 10 years. The STROBE guidelines for reporting of observational studies were used to report this study (9).

Participants

The post-treatment archive housed at the Department of Orthodontics and Craniofacial Biology, the Radboud University Nijmegen Medical Centre, Nijmegen, The Netherlands was searched to identify eligible participants meeting the following criteria: 1. good quality pre-treatment (T_1), post-treatment (T_2), 3 years after treatment (T_3), and 7 years after treatment (T_4) plaster casts of 2. non-syndromic patients (e.g. without orofacial clefts), 3. treated with fixed orthodontic appliances, 4. had a retention phase with bonded lingual retainer, and 5. no orthodontic retreatment during the observation period. All participants had a lingual retainer either bonded only to the mandibular canines or bonded to all six mandibular anterior teeth during the entire post-treatment period.

Exclusion criteria were: 1. combined orthodontic / orthognathic surgery treatment, and 2. periodontal treatment after orthodontic therapy.

Demographic data such as patients' gender and age were obtained from the clinical charts and pre-treatment Angle classification was determined on the initial plaster models.

Measurements

Two types of evaluations were performed: first, assessment of the amount of TW and the second, scoring of the presence of labial/buccal GR of all teeth except wisdom teeth (primary outcome). Four examiners scored independently the models: MM and MG rated TW, while PF and AMR rated GR. TW was scored by both MM and MG on all models (n = 840) of 210 patients, whereas GR was scored by PF on all models of 210 patients (n = 840) and by AMR on all models of 20 randomly selected patients (n = 80). Both variables were graded at all time points, i.e. T_1, T_2, T_3, and T_4.

The amount of occlusal or incisal TW was graded for each permanent tooth from second to second molar in both dental arches at T_1, T_2, T_3, and T_4 according to the scale of Carlsson et al. (10) and Bauer et al. (11):

- score 0: enamel shows neither wear facets nor reduction of crown length;
- score 1: marked wear facets, but no noticeable reduction of crown length;
- score 2: distinct wear facets in combination with slight crown length reduction;
- score 3: extensive wear facets (i.e at least 2/3 of incisal edge missing) and marked reduction of crown length.

For the statistical analysis, the 4-point TW scale was converted into a binary scale—scores 0 and 1 were defined as "0", i.e. no or mild TW and scores 2 and 3 were defined as "1", i.e. moderate or severe TW.

For GR, an *Yes/No* scoring was implemented and validated as in our previous study (12): the presence of labial/buccal recession site was scored as *Yes*, if the cemento–enamel junction was visible during visual inspection of the model or the CEJ exposure was highly probable; otherwise, the score was *No*. The recession was graded at T_1, T_2, T_3, and T_4. Potential confounding variables such as dental plaque, gingival pocket probing depth, tooth brushing habits, and smoking were unknown and not considered in the analysis. All data were collected in an Excel worksheet.

Examiners calibration and method reliability

Assessment of TW

There were four calibration sessions between MM and MG. During the 1st session, the observers discussed the scale on three plaster models demonstrating TW of each grade. Possible problems of the scale were discussed. During the next three calibration sessions 20 dental models, not included later in the study, were graded separately by MM and MG. After each session, the differences in the scoring were discussed and a consensus was reached. The calibration sessions took place within 2 weeks. After an additional week, the two examiners started rating TW independently. The rating was accomplished within 5 weeks. The scores of TW for all 210 patients were used to calculate inter-rater reliability. After more than 1 month, both examiners scored 80 models again to assess intra-rater agreement. During assessment of TW, investigators were not blinded to the presence of GR.

Assessment of GR

There were no calibration exercises between PF and AMR because both examiners collaborated closely in several previous investigations, and it was decided that the calibration session could have been omitted. After more than 1 month, PF re-evaluated 60 models to assess intra-rater agreement. During the assessment of GR, investigators were not blinded to the presence of TW. However, the assessment of GR was carried out long before the current study was planned.

Assessment of detection bias

In order to detect bias in recording TW when assessor was able to see GR, and vice versa, models of 60 patients taken from a different sample were evaluated in four sessions: 1. assessor MM evaluated TW when labial surfaces of crowns were covered with aluminium foil; 2. assessor PF evaluated GR when regions with wear facets were covered with aluminium foil; 3. assessor MM evaluated TW when labial surfaces of crowns were fully exposed; and 4. assessor PF evaluated GR when wear facets were fully exposed.

Statistical analysis

Descriptive statistics including the frequency of TW and GR sites were calculated per 1. tooth, 2. patient, and 3. time point. Method reliability and detection bias were assessed with the kappa statistic. Univariable and multivariable random effects logistic regression was implemented in order to evaluate potential associations between the presence of GR and degree of TW, gender, age, dental segment, time point and the Angle classification. All analyses were performed using Stata 14.1 statistical software (Statacorp, College Station, TX, USA).

Results

Sample

Of the 500 potentially eligible participants, 210 were randomly selected and confirmed eligible and were included in the study. The mean age at T_1 was 13.8 years (SD = 3.7, range: 8.5–32.6), at T_2 was 16.7 years (SD = 3.9, range: 10.5–36), at T_3 was 19.7 years (SD = 4.2, range: 13.1–40.9), and at T_4 was 23.9 years (SD = 4.8, range: 16.7–46.8). The proportion of males was 47.6% (n = 100). The Angle class distribution was as follows: class I—34.6% (n = 73), class II—63.8% (n = 134), and class III—1.6% (n = 3).

Inter- and intra-observer agreement

The results of the assessment of the reliability of methods are shown in Table 1. Overall, intra- and inter-rater agreement for grading TW was good to very good according to Bland and Altman (13)—the kappas ranged from 0.746 (95% CI: 0.674–0.819) for examiner MG, rating of maxillary molars, to 0.967 (95% CI: 0.938–0.996) for examiner MG, rating of mandibular canines. The kappa values for scoring recession sites were lower and ranged from 0.487 (95% CI: 0.426–0.548) for inter-examiner (PF vs. AMR) agreement, rating of maxillary premolars, to 0.887 (95% CI: 0.813–0.960) for inter-examiner (PF vs. AMR) agreement, rating of maxillary molars.

Evaluation of the detection bias showed that the agreement in assessment of TW in individual teeth ranged from 57.6% to 91.1% (kappa from 0.3 to 0.85) and in assessment of GR in individual teeth ranged from 98.3% to 100% (kappa from 0.66 to 1).

Tooth wear

The distribution of TW at different time points is presented in Figure 1 and Table 2. Maxillary and mandibular anterior teeth (incisors and canines) and first molars were most vulnerable to TW. The prevalence of TW increased during the observation period—at T_1, 58.6% participants had no/mild TW and only 4.8% participants had multiple moderate/severe TW (7 or more teeth involved); at T_4, 95.7% participants had moderate/severe TW and 68.1% participants had multiple moderate/severe TW (seven or more teeth involved).

Multivariable random effects logistic regression modelling (Table 3) showed that age (OR: 1.06, 95% CI: 1.04–1.09, $P \leq 0.001$) and time points (OR T_2: 3.13, 95% CI: 2.27–4.32, $P \leq 0.001$; OR T_3: 6.91, 95% CI: 4.95–9.63, $P \leq 0.001$; and OR T_4: 11.82, 95% CI: 8.09–17.27, $P \leq 0.001$ for T_2, T_3, and T_4, respectively, in relation to T_1) were associated with moderate/severe TW.

The mandibular anterior segment had higher odds for developing moderate/severe TW in comparison to the maxillary posterior segment which was the referent segment (OR: 5.58, 95% CI: 5.13–6.08, $P \leq 0.001$). Gender was not associated with the development of moderate/severe TW. There was weak evidence of an association between Angle class II malocclusion and TW (OR: 1.28, 95% CI: 0.99–1.67, $P = 0.06$).

Gingival recession and its association with tooth wear

The distribution of GR at different time points is presented in Figure 2 and Table 3. Mandibular incisors, mandibular and maxillary first premolars, and maxillary first molars were most vulnerable to GR. The prevalence of GR increased during the observation period—at T_1 20.5% participants had one or more recession sites and only 1% of the participants had multiple GR (seven or more sites); at T_4 85.7 % of the participants had GR and 35.2% participants had multiple GR sites (seven or more).

Multivariable random effects logistic regression models (Table 4) showed that age (OR: 1.14, 95% CI: 1.11–1.17, $P \leq 0.001$) and time points (OR T_2: 2.57, 95% CI: 1.71–3.87, $P \leq 0.001$; OR T_3: 6.06, 95% CI: 4.04–9.09, $P \leq 0.001$; OR T_4: 6.62, 95% CI: 4.43–10.82, $P \leq 0.001$ for T_2, T_3, and T_4, respectively, in relation to T_1) were associated with moderate/severe TW. The mandibular anterior segment had higher odds for developing GR in comparison to reference segment (OR: 2.77, 95% CI: 2.38–3.21, $P \leq 0.001$), which was the mandibular posterior segment. Angle class III malocclusion was associated with GR (OR: 2.98, 95% CI: 1.28–6.90, $P = 0.011$). Gender was not associated with the development of moderate/severe TW.

Table 1. Reliability of assessment of tooth wear and gingival recession with kappa statistics (95% confidence interval in brackets).

		Incisors	Canines	Premolars	Molars
Tooth wear					
Rater 1 vs. 2	Maxilla	0.864 (0.831–0.897)	0.904 (0.867–0.941)	0.930 (0.909–0.951)	0.798 (0.748–0.848)
	Mandible	0.854 (0.817–0.890)	0.884 (0.839–0.928)	0.943 (0.923–0.963)	0.782 (0.733–0.831)
Rater 1	Maxilla	0.878 (0.837–0.918)	0.926 (0.881–0.971)	0.915 (0.884–0.946)	0.746 (0.674–0.819)
	Mandible	0.878 (0.835–0.920)	0.967 (0.938–0.996)	0.950 (0.921–0.978)	0.889 (0.838–0.940)
Rater 2	Maxilla	0.854 (0.802–0.905)	0.884 (0.829–0.939)	0.927 (0.898–0.956)	0.814 (0.752–0.875)
	Mandible	0.922 (0.886–0.959)	0.931 (0.882–0.981)	0.958 (0.936–0.980)	0.829 (0.771–0.887)
Recession					
Rater 1 vs. 2	Maxilla	0.676 (0.547–0.806)	0.616 (0.497–0.735)	0.487 (0.426–0.548)	0.664 (0.539–0.789)
	Mandible	0.608 (0.535–0.681)	0.621 (0.464–0.777)	0.508 (0.432–0.584)	0.701 (0.553–0.850)
Rater 1	Maxilla	0.887 (0.813–0.960)	0.754 (0.658–0.850)	0.836 (0.784–0.888)	0.807 (0.712–0.902)
	Mandible	0.743 (0.683–0.804)	0.772 (0.653–0.892)	0.819 (0.752–0.886)	0.842 (0.734–0.950)

In the multivariable regression model, moderate/severe TW was associated with the development of GR (OR: 1.23 95% CI: 1.08–1.40, P = 0.002)—a tooth with moderate/severe TW had 23% higher odds for developing GR compared to a tooth with no/mild TW (Figure 3).

Discussion

The determination of possible associations between TW and GR could help in the treatment of both phenomena. For example, therapy of GR without addressing occlusal problems could be less successful than treatment of GR performed along with occlusal adjustment. Two studies from India investigated the short term effect of occlusal factors on the development of GR (7, 8) and both implied that TW could lead to GR. The low methodological quality of both publications call in question their conclusion. Therefore the present study aimed to evaluate the association of TW and GR in a large cohort followed for approximately 10 years.

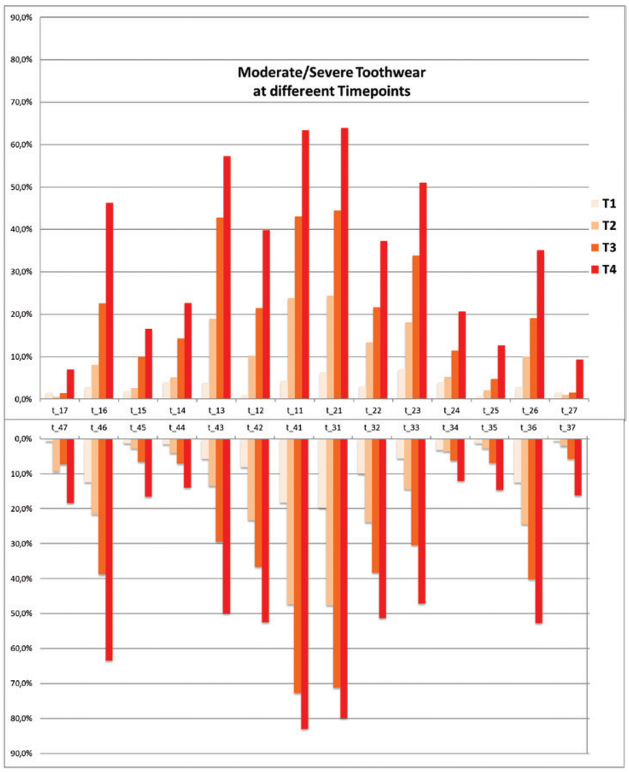

Figure 1. Prevalance of moderate/severe tooth wear in different teeth and different time points.

Our results demonstrate an association between TW and GR. Overall, the teeth with moderate or severe TW have 23% higher odds for developing GR than the teeth with no or mild TW. A comparison of the distribution of moderate/severe TW and GR in the dental arches (Figure 3) shows that the relationship between the occurrence of TW and GR is different for various teeth. In general, most teeth show a higher prevalence of TW than of GR. However, for some teeth the high prevalence of moderate/severe TW is associated with the high prevalence of GR (e.g. mandibular central incisors, maxillary first molars), whereas for other teeth, there seems to be no such association (e.g. the high frequency of TW in maxillary central incisors is accompanied by the low frequency of GR). This can be due to the influence of other factors associated with the development of TW and/or GR, which were not analysed in the current investigation. For example, tooth brushing could have affected a distribution of the GR only, modifying this way a TW/GR relationship.

An association between TW and GR found in this study ‘does not mean’ a cause-and-effect relationship because causality is difficult to determine in observational studies such as the current one. Theoretically, the association between TW and GR implies that TW predicts the development of GR or, reversely, GR predicts the development of TW. An assumption which variable (GR or TW) is the ‘exposure/predictor’ and which is the ‘outcome’ is made based on biological plausibility. Here, we assumed that TW was the ‘exposure’ and GR was the ‘outcome’ because existing knowledge supports this more than the alternative scheme—GR was the exposure and TW was the outcome. A possible mechanism by which factor(s) leading to TW promote(s) the development of GR is that occlusal trauma could ‘trigger’ the development of NCCLs. The NCCL could, in turn, create an environment conducive to the development of GR. Specifically, micro-fractures and ‘breaking away’ of the enamel in the region of the CEJ could establish an area of dental plaque accumulation and could facilitate the development of gingivitis. If this process occurs in an individual susceptible to GR, it can result in a localized GR. It should be noted, however, that an association between TW and NCCLs has not been unequivocally confirmed yet (5, 6).

We found that the prevalence of TW and GR was associated with age—the older the patient, the more TW and GR were present. Our findings are supported by results of the studies of Cunha-Cruz et al. (14) and Wetselaar et al. (2). Cunha-Cruz et al. (14) analysed TW in 1288 Americans aged 18–93 and found that the prevalence of wear facets in teeth increased with age. Comparable results were found in a sample of 1125 Dutch adults (2). Also the results of epidemiological investigations on GR (15, 16, 17) are in agreement with our

Table 2. Prevalance of tooth wear and gingival recession in the sample.

Number of sites with tooth wear or gingival recession	Number of patients (per cent) with moderate/severe **tooth wear** (combined scores 2 and 3) at different time points				Number of patients (per cent) with **gingival recession** at different time points			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
0	123 (58.6%)	54 (25.7%)	16 (7.6%)	9 (4.3%)	167 (79.5%)	115 (54.8%)	50 (23.8%)	30 (14.3%)
1 to 3	64 (30.5%)	74 (35.2%)	51 (24.3%)	17 (8.1%)	35 (16.7%)	67 (31.9%)	76 (36.2%)	62 (29.5%)
4 to 6	13 (6.2%)	45 21.4%)	49 (23.3%)	41 (19.5%)	6 (2.9%)	15 (7.1%)	43 (20.5%)	44 (21%)
7 or more	10 (4.8%)	37 (17.6%)	94 (44.8%)	143 (68.1%)	2 (1%)	13 (6.2%)	41 (19.5%)	74 (35.2%)

Table 3. Regression analysis estimating predictors of moderate/severe tooth wear.

Predictor	Univariable random effects logistic regression		Multivariable random effects logistic regression	
	OR (95% CIs)	*P* value	*OR (95% CIs)*	*P* value
Age (per unit)	1.18 (1.16–1.20)	< 0.001	1.06 (1.04–1.09)	< 0.001
Gender (female as reference)	1.10 (0.86–1.41)	0.470	1.13 (0.93–1.38)	0.220
Dental segment (maxillary posterior as reference)				
Maxillary anterior	2.57 (2.37–2.79)	< 0.001	2.63 (2.42–2.86)	< 0.001
Mandibular posterior	1.28 (1.19–1.38)	< 0.001	1.29 (1.2–1.4)	< 0.001
Mandibular anterior	5.43 (4.99–5.9)	< 0.001	5.58 (5.13–6.08)	< 0.001
Time point (T_1 as reference)				
T_2	3.65 (2.67–5.00)	< 0.001	3.13 (2.27–4.32)	< 0.001
T_3	9.74 (7.16–13.27)	< 0.001	6.91 (4.95–9.63)	< 0.001
T_4	21.16 (15.53–28.82)	< 0.001	11.82 (8.09–17.27)	< 0.001
Angle class (class I as reference)				
II	1.17 (0.93–1.46)	0.180	1.28 (0.99–1.67)	0.060
III	1.40 (0.57–3.47)	0.470	1.66 (0.60–4.60)	0.330

OR, odds ratio

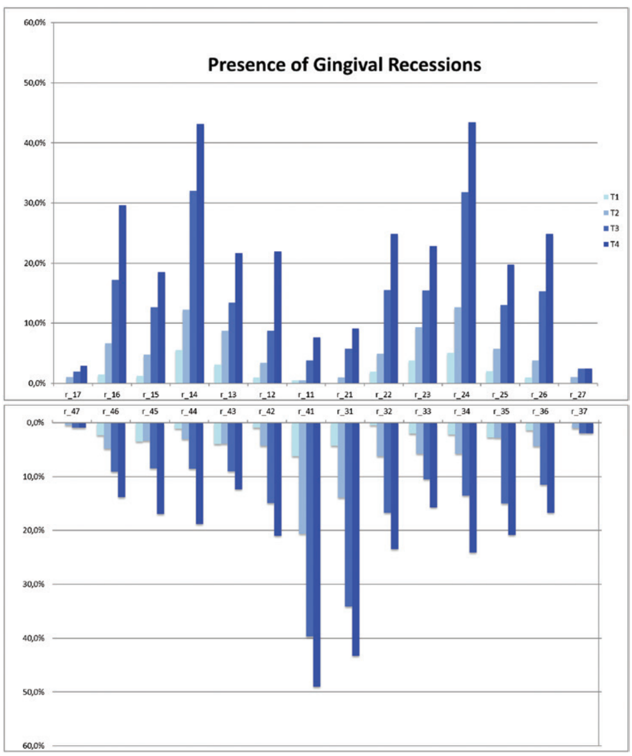

Figure 2. Prevalance of gingival recession in different teeth and different time points.

results—the natural history of the development of GR demonstrates that the age is a predictor of GR.

Previous studies demonstrated that the distribution of TW and GR in the dental arches is not uniform—different teeth have different susceptibility to TW (18, 19) and to GR (20, 21). Our results agree with these studies—we found the highest prevalence of TW in anterior segments, mandibular followed by maxillary. Posterior segments—mandibular and maxillary—had less TW than anterior segments. The highest prevalence of GR was in the mandibular anterior segment (similar to TW), followed by maxillary posterior and maxillary anterior segments. The mandibular posterior segment was the one with the lowest GR prevalence.

The number of recession sites found in this study was higher than that reported by Renkema et al. (22), despite the fact that samples comprised of participants from the same archive (Radboud University Nijmegen). For example, 14.3% patients had no recession at 23.9 years in our study, whereas Renkema et al. (22) reported that 65% patients at the age of 20.4 years were free of recession. Also, the prevalence of multiple recession sites was higher in the current study than that found by Renkema et al. (22). A possible explanation for this is a difference in methodology of scoring recession—Renkema et al. (22) scored recession as present only if CEJ was clearly exposed, whereas we scored recession as present also in situations when CEJ was not visible but its exposure was highly probable (e.g. co-occurrence of recession and NCCL with 'disappearance' of the CEJ line). Other studies (23, 24) found similar prevalence of recession as in our study.

We scored TW using the index of Carlsson et al. (10) and Bauer et al. (11), because it is simple and reproducible—high values of kappas for intra- and inter-rater agreement support our choice. Other indices for scoring TW have too many stages (25) or were developed for other purposes such as assessment of bruxism (26). Furthermore, many indices were created to investigate tooth erosion or the combination of erosion and attrition (27, 28, 29). Scoring erosion calls for the evaluation of dentin exposure, which was impossible on plaster casts.

Limitations

This study has limitations resulting from a retrospective design such as evaluation of plaster casts only, the lack of assessment of potential confounders such as other periodontal parameters, diet, hygiene habits, smoking, and piercing.

All participants were treated orthodontically and wore fixed retainers bonded to mandibular anterior teeth. Ideally, investigation of the relationship between TW and GR should be performed in orthodontically untreated subjects because orthodontic treatment 'per se' can promote the development of GR. However, the risk of GR associated with orthodontic treatment/retention was equal for all participants because all of them were treated orthodontically with similar methods. Furthermore, raters scoring TW were not

Table 4. Regression analysis estimating predictors of gingival recession.

Predictor	Univariable random effects logistic regression		Multivariable random effects logistic regression	
	OR (95% CIs)	*P* value	*OR* (95% CIs)	*P* value
Tooth wear score (combined scores 0 and 1 as reference)				
2 and 3	1.55 (1.37–1.75)	< 0.001	1.23 (1.08–1.40)	0.002
Age (per unit)	1.22 (1.19, 1.25)	< 0.001	1.14 (1.11–1.17)	< 0.001
Gender (female as reference)	0.99 (0.74, 1.33)	0.970	0.99 (0.74,1.33)	0.970
Dental segment (mandibular posterior as reference)				
Mandibular anterior	2.98 (2.59–3.44)	< 0.001	2.77 (2.38–3.21)	< 0.001
Maxillary posterior	2.02 (1.75–2.32)	< 0.001	2.01 (1.74–2.31)	< 0.001
Maxillary anterior	1.33 (1.14–1.55)	< 0.001	1.26 (1.08–1.48)	0.004
Time point (T_1 as reference)				
T_2	3.59 (2.35, 5.48)	< 0.001	2.57 (1.71–3.87)	< 0.001
T_3	13.08 (8.69, 19.69)	< 0.001	6.06 (4.04–9.09)	< 0.001
T_4	24.60 (16.36, 36.97)	< 0.001	6.62 (4.43–10.82)	< 0.001
Angle class (class I as reference)				
II	0.96 (0.71, 1.30)	0.810	1.02 (0.8–1.29)	0.910
III	6.39 (2.11, 19.40)	0.001	2.98 (1.28–6.90)	0.010

OR, odds ratio

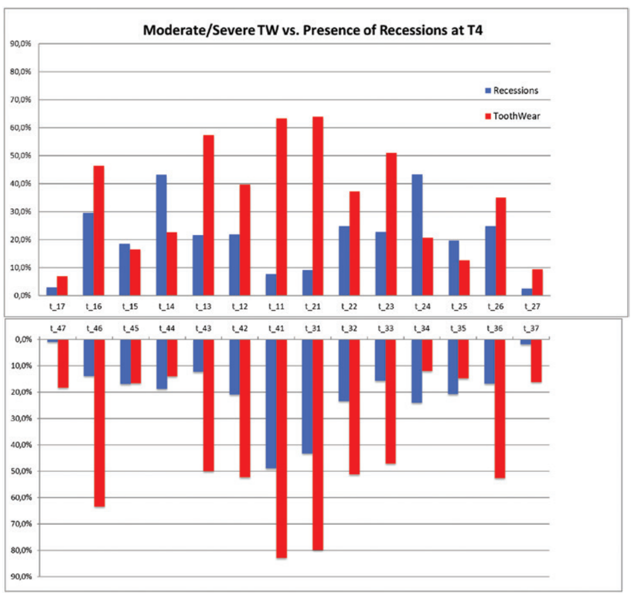

Figure 3. Moderate/severe tooth wear and gingival recession at the last assessment (T_4).

blinded to the presence/absence of GR. For logistical reasons, the evaluation of detection bias was carried out on a different sample. The results demonstrate good agreement.

Conclusion

Within the limitations of this study, there is evidence that moderate/severe TW is associated with the presence of GR.

Conflict of interest

None to declare.

References

1. Kreulen, C.M., Van 't Spijker, A., Rodriguez, J.M., Bronkhorst, E.M., Creugers, N.H. and Bartlett, D.W. (2010) Systematic review of the prevalence of tooth wear in children and adolescents. *Caries Research*, 44, 151–159.
2. Wetselaar, P., Vermaire, J.H., Visscher, C.M., Lobbezoo, F. and Schuller, A.A. (2016) The Prevalence of Tooth Wear in the Dutch Adult Population. *Caries Research*, 50, 543–550.
3. Wennström, J.L., Lindhe, J., Sinclair, F. and Thilander, B. (1987) Some periodontal tissue reactions to orthodontic tooth movement in monkeys. *Journal of Clinical Periodontology*, 14, 121–129.
4. Pini-Prato, G., Franceschi, D., Cairo, F., Nieri, M. and Rotundo, R. (2010) Classification of dental surface defects in areas of gingival recession. *Journal of Periodontology*, 81, 885–890.
5. Senna, P., Del Bel Cury, A. and Rösing, C. (2012) Non-carious cervical lesions and occlusion: a systematic review of clinical studies. *Journal of Oral Rehabilitation*, 39, 450–462.
6. Silva, A.G., Martins, C.C., Zina, L.G., Moreira, A.N., Paiva, S.M., Pordeus, I.A. and Magalhães, C.S. (2013) The association between occlusal factors and noncarious cervical lesions: a systematic review. *Journal of Dentistry*, 41, 9–16.
7. Kundapur, P.P., Bhat, K.M. and Bhat, G.S. (2006) Association of trauma from occlusion with localized gingival recession in mandibular anterior teeth. *Dental Research Journal*, 6, 71–74.
8. Prasad, D.K., Shetty, N.S. and Solomon, E.G.R. (2012) The influence of occlusal trauma on gingival recessions and gingival clefts. *Journal of Indian Prosthodontic Society*, 1, 7–12.
9. Vandenbroucke, J.P., von Elm, E., Altman, D.G., Gotzsche, P.C., Mulrow, C.D., Pocock, S.J., Poole, C., Schlesselman, J.J. and Egger, M. (2007) Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): Explanation and Elaboration. *PLos Medicine*, 4, 1628–1654.
10. Carlsson, G.E., Johansson, A. and Lundqvist, S. (1985) Occlusal wear. A follow-up study of 18 subjects with extensively worn dentitions. *Acta Odontologica Scandinavica*, 43, 83–90.
11. Bauer, W., van den Hoven, F. and Diedrich, P. (1997) Wear in the upper and lower incisors in relation to incisal and condylar guidance. *Journal of Orofacial Orthopedics*, 58, 306–319.
12. Renkema, A.M., Fudalej, P.S., Renkema, A., Bronkhorst, E. and Katsaros, C. (2013) Gingival recessions and the change of inclination of mandibular incisors during orthodontic treatment. *European Journal of Orthodontics*, 35, 249–255.
13. Bland, J.M. and Altman, D.G. (1986) Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet (London, England)*, 1, 307–310.
14. Cunha-Cruz, J., Pashova, H., Packard, J.D., Zhou, L. and Hilton, T.J.; for Northwest PRECEDENT. (2010) Tooth wear: prevalence and associated

factors in general practice patients. *Community Dentistry and Oral Epidemiology*, 38, 228–234.
15. Löe, H., Anerud, A. and Boysen, H. (1992) The natural history of periodontal disease in man: prevalence, severity, and extent of gingival recession. *Journal of Periodontology*, 63, 489–495.
16. Albandar, J.M. and Kingman, A. (1999) Gingival recession, gingival bleeding, and dental calculus in adults 30 years of age and older in the United States, 1988-1994. *Journal of Periodontology*, 70, 30–43.
17. Rios, F.S., Costa, R.S., Moura, M.S., Jardim, J.J., Maltz, M. and Haas, A.N. (2014) Estimates and multivariable risk assessment of gingival recession in the population of adults from Porto Alegre, Brazil. *Journal of Clinical Periodontology*, 41, 1098–1107.
18. Liu, B., Zhang, M., Chen, Y. and Yao, Y. (2014) Tooth wear in aging people: an investigation of the prevalence and the influential factors of incisal/occlusal tooth wear in northwest China. *BMC Oral Health*, 14, 65.
19. Schierz, O., Dommel, S., Hirsch, C. and Reissmann, D.R. (2014) Occlusal tooth wear in the general population of Germany: effects of age, sex, and location of teeth. *The Journal of Prosthetic Dentistry*, 112, 465–471.
20. Slutzkey, S. and Levin, L. (2008) Gingival recession in young adults: occurrence, severity, and relationship to past orthodontic treatment and oral piercing. *American Journal of Orthodontics and Dentofacial Orthopedics*, 134, 652–656.
21. Renkema, A.M., Fudalej, P.S., Renkema, A.A., Abbas, F., Bronkhorst, E. and Katsaros, C. (2013) Gingival labial recessions in orthodontically treated and untreated individuals: a case - control study. *Journal of Clinical Periodontology*, 40, 631–637.
22. Renkema, A.M., Fudalej, P.S., Renkema, A., Kiekens, R. and Katsaros, C. (2013) Development of labial gingival recessions in orthodontically treated patients. *American Journal of Orthodontics and Dentofacial Orthopedics*, 143, 206–212.
23. Thomson, W.M. (2002) Orthodontic treatment outcomes in the long term: findings from a longitudinal study of New Zealanders. *The Angle Orthodontist*, 72, 449–455.
24. Susin, C., Haas, A.N., Oppermann, R.V., Haugejorden, O. and Albandar, J.M. (2004) Gingival recession: epidemiology and risk indicators in a representative urban Brazilian population. *Journal of Periodontology*, 75, 1377–1386.
25. Hooper, S.M., Meredith, N. and Jagger, D.C. (2004) The development of a new index for measurement of incisal/occlusal tooth wear. *Journal of Oral Rehabilitation*, 31, 206–212.
26. Shetty, S., Pitti, V., Satish Babu, C.L., Surendra Kumar, G.P. and Deepthi, B.C. (2010) Bruxism: a literature review. *Journal of Indian Prosthodontic Society*, 10, 141–148.
27. Addy, M. and Shellis, R.P. (2006) Interaction between Attrition, Abrasion and Erosion in Tooth Wear. Dental Erosion, From Diagnosis to Therapy, Chapter 3, Editor Lussi, A. *Monographs in oral science* 20, 17–31.
28. Bartlett, D., Ganss, C. and Lussi, A. (2008) Basic Erosive Wear Examination (BEWE): A new scoring system for scientific and clinical needs. *Clinical Oral Investigations*, 12, 65–68.
29. Bardsley, P.F. (2008) The evolution of tooth wear indices. *Clinical Oral Investigations*, 12 (Suppl 1), S15–S19.