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ORIGINAL ARTICLE

Long-term effects of Class II orthodontic treatment on oral health

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Abstract

Aim To investigate the long-term (≥15 years) benefit of orthodontic Class II treatment (Tx) on oral health (OH).

Subjects and methods All patients (Department of Orthodontics, University of Giessen, Giessen, Germany) who underwent Class II correction (Herbst-multibracket Tx, end of active Tx ≥ 15 years ago) and agreed to participate in a recall (clinical examination, interview, impressions, and photographs) were included. Records after active Tx were used to assess the long-term OH effects. Data were compared to corresponding population-representative age-cohorts as well as to untreated Class I controls without orthodontic Tx need during adolescence.

Results Of 152 treated Class II patients, 75 could be located and agreed to participate at 33.7 ± 3.0 years of age (pre-Tx age: 14.0 ± 2.7 years). The majority (70.8%) were fully satisfied with their teeth and with their masticatory system. The Decayed, Missing, Filled Teeth Index (DMFT) was 7.1 ± 4.8 and, thus, almost identical to that of the untreated Class I controls (7.9 ± 3.6). In contrast, the DMFT in the population-representative age-cohort was 56% higher. The determined mean Community Periodontal Index (CPI) maximum score (1.6 ± 0.6) was also comparable to the untreated Class I controls (1.7 ± 0.9) but in the corresponding population-representative age-cohort it was 19–44% higher. The extent of lower incisor gingival recessions did not differ significantly between the treated Class II participants and the untreated Class I controls (0.1 ± 0.2 vs. 0.0 ± 0.1 mm).

Conclusion Patients with orthodontically treated severe Class II malocclusions had a lower risk for oral health impairment than the general population. The risk corresponded to that of untreated Class I controls (without orthodontic Tx need during adolescence).

Keywords Class II treatment · Oral health · Caries · Periodontal disease · Long-term

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Langfristige Effekte einer kieferorthopädischen Klasse-II-Behandlung auf die Mundgesundheit

Zusammenfassung

Ziel Untersucht werden sollten mögliche langfristige (≥15 Jahre) Effekte einer kieferorthopädischen Klasse-II-Behandlung auf die Mundgesundheit.

Material und Methode Alle Patienten (Abteilung für Kieferorthopädie, Justus-Liebig-Universität Gießen, Deutschland), bei welchen eine Klasse-II-Behandlung (Herbst-Multibracket-Apparatur, Ende der aktiven Behandlung vor ≥15 Jahren) durchgeführt worden war und die zu einer Nachuntersuchung (Befragung, klinische Untersuchung, Anfertigung von Studienmodellen und Fotos) bereit waren. Zur Beurteilung der Langzeiteffekte auf die Mundgesundheit wurden außerdem die Unterlagen von unmittelbar nach der Behandlung verwendet. Die Daten wurden mit denen korrespondierender bevölkerungsrepräsentativer Alterskohorten sowie unbehandelter Klasse-I-Kontrollen ohne kieferorthopädischen Behandlungsbedarf während der Adoleszenz verglichen.

Ergebnisse Von 152 Patienten konnten 72 lokalisiert werden, diese nahmen im Alter von 33,7 ± 3,0 Jahren an der Studie teil (Alter vor Behandlung: 14,0 ± 2,7). Die Mehrheit (70,8 %) gab an, mit ihren Zähnen und der Funktion des Kauorgans vollständig zufrieden zu sein. Der DMFT(„decayed, missing, filled teeth")-Index zeigte einen Wert von 7,1 ± 4,8 und war damit fast identisch mit dem der unbehandelten Kontrollen (7,9 ± 3,6). Im Gegensatz dazu zeigte die korrespondierende bevölkerungsrepräsentativer Alterskohorte (DMS[Deutsche Mundgesundheitsstudie] V) einen um 56 % höheren Wert. Der durchschnittliche Maximalwert des CPI („community periodontal index") zeigte bei den Teilnehmern einen Wert von 1,6 ± 0,6. Bei den unbehandelten Kontrollen war der Wert vergleichbar (1,7 ± 0,9), während er in der korrespondierenden bevölkerungsrepräsentativen Alterskohorte (DMS V) um 19–44 % höher war.

Das Ausmaß gingivaler Rezessionen an den unteren Schneidezähnen unterschied sich nicht systematisch zwischen den behandelten Klasse-II-Patienten und den unbehandelten Klasse-I-Kontrollen (0,1 ± 0,2 vs. 0,0 ± 0,1 mm).

Schlussfolgerung Patienten, die eine kieferorthopädische Behandlung bei ausgeprägter Klasse-II-Malokklusion erfahren hatten, zeigten ein geringeres Risiko für eine Beeinträchtigung der Mundgesundheit als die Allgemeinbevölkerung. Das Risiko entsprach dem von unbehandelten Klasse-I-Kontrollen (ohne kieferorthopädischen Behandlungsbedarf während der Adoleszenz).

Schlüsselwörter Klasse II Behandlung · Mundgesundheit · Karies · Parodontalerkrankung · Langzeiteffekt

Introduction

One of the most important aims of orthodontic treatment (Tx) is to create functional occlusal conditions which serve as a long-term preventive basis for excellent oral health (OH) and oral-health-related quality of life. Especially in recent years, both the public and the authorities have demanded proof for such a positive contributory effect of orthodontic interventions in terms of an improvement and of the long-term maintenance of OH, respectively.

To date, the benefit of orthodontic Tx on OH remains controversial. Unfortunately, systematic reviews have been unable to prove associations between crowding and the susceptibility to caries [23] or positive effects of orthodontic Tx on periodontal health [11]. On the other hand, a direct relationship between the presence of malocclusion and periodontal disease was concluded from a systematic review [10]. In addition, more tooth-related problems in life compared to individuals showing normal occlusion during childhood were found in a long-term observational study [58]. In addition, a long-term positive difference in self-rated dental appearance was seen between treated and untreated cohorts [59].

Why can't we scientifically prove, what we witness in daily practice? First of all, the level of OH is no doubt influenced by multiple factors and does not solely depend on the provision of an orthodontic Tx or its quality. In addition, the very long latency times of different exposures (years to decades) and the generally slow progression of the most common oral diseases like dental caries, periodontal diseases and mucosal disorders hamper the investigation of preventive orthodontic effects. Finally, from a research methodological point of view, the proof of a causal (preventive) effect of orthodontic Tx would require a randomized controlled trial (RCT) design with untreated controls, which given the long-term perspective would be impossible to conduct both from an ethical and financial/administrative point of view. Finally, malocclusion is not a uniform condition. Instead there is a large variety of different malocclusions with different degrees of severity and countless possibilities for combination in turn with different possible effects on OH. The latter has however not been taken into account in the aforementioned studies/reviews. Thus, if we focus on a very narrowly defined type of malocclusion, we might see effects.

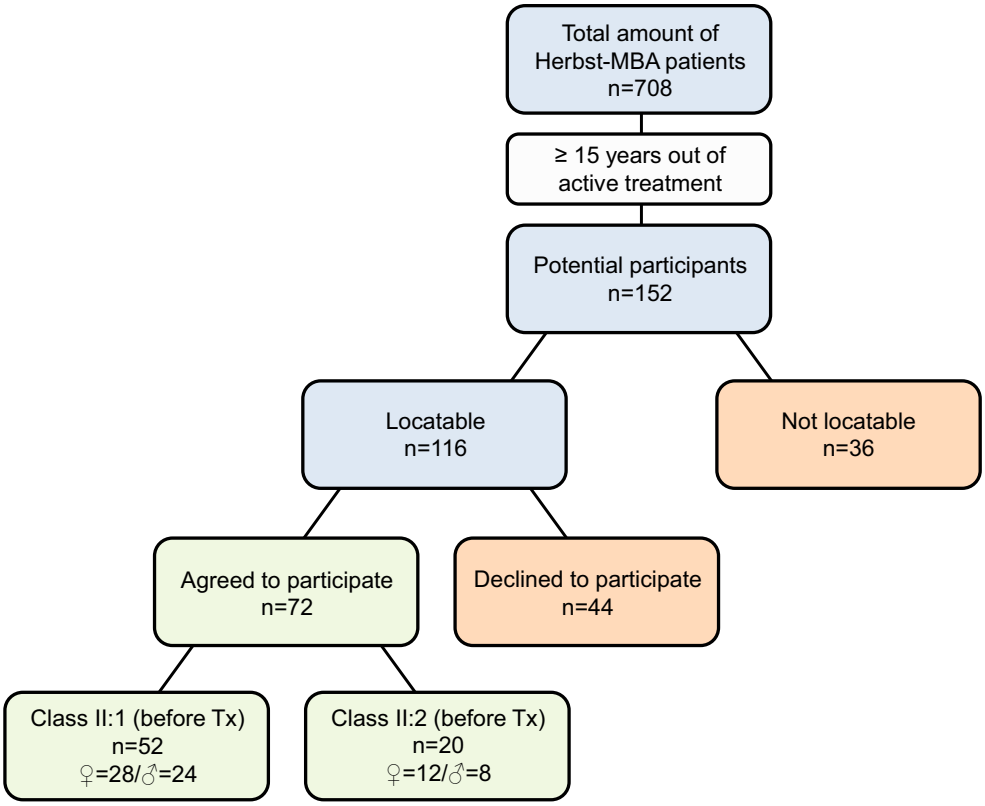

Fig. 1 Flow chart of the treated Class II participants and non-participants (the number of total Herbst-MBA patients—active Tx completed by 01 January 2015—as well as potential participants and the results of the recruitment process are given). *MBA* multibracket appliance, *Tx* treatment

Abb. 1 Flussdiagramm der behandelten Klasse-II-Teilnehmer und der Nichtteilnehmer (dargestellt ist die Gesamtanzahl der Herbst-MBA-Patienten [aktive Behandlung vor dem 1. Januar 2015 beendet] und der potenziellen Teilnehmer sowie die Resultate des Rekrutierungsprozesses). *MBA* „multibracket appliance“, *Tx* „treatment“

For Class II Tx in general, countless studies on the effectiveness of certain Tx procedures with respect to their corrective occlusal potential [18, 20, 31, 35, 41, 44, 62, 64] have been performed. These studies mainly concentrate on the active Tx period, while data on long-term effects or stability are scarce [7, 12, 35, 41, 45–47]. For long-term effects of Class II Tx on OH, respective data are rare and equivocal [49, 54, 55].

Aim

Therefore, it was the aim of the present investigation to assess the long-term OH effects of orthodontic Class II Tx.

Material and methods

After ethical approval (No. 146/13) and registration (WHO: ID DRKS00006354), the archive of the Department of Orthodontics at the University of Giessen, Giessen, Germany was screened for Class II patients who had been treated with a Herbst-multibracket appliance (MBA) and whose active Tx had been finished at least 15 years ago.

A total of 152 patients with a mean age of 14.0 years at the start of Herbst-MBA Tx fulfilled these criteria. All patients exhibited a severe Class II malocclusion before Tx—mean Class II molar relationship: 0.77 cusp widths; mean Peer Assessment Rating Index (PAR) [51]: 27.4 points. In all, 116 patients could be located using the address data from the period of active Tx as well as the internet and they were asked to participate in the investigation. While 80 patients were not interested or unable due to other reasons (Fig. 1), 72 patients agreed to take part in the study (group: “treated Class II participants”). Thus, with respect to the locatable patients, the participation rate was 62%.

The records (baseline data and general dental status) of the 80 patients who did not attend the recall (group: “non-participants”) were used for comparison (Table 1) and for preclusion of a selection bias.

After obtaining informed consent, an anamnesis and eventual complaints regarding the condition of their teeth, their occlusion, and/or the function of the masticatory system were enquired. In addition, a clinical examination of the oral cavity including the gums and the teeth was performed. Furthermore, impressions of the upper and lower arches as well as a full set of standardized intraoral photographs were taken.

To assess the changes regarding the dental status and gingival recessions that had occurred since the end of active Tx, panoramic radiographs, intraoral photographs, and study models from after active orthodontic Tx (T1) were

Table 1 Comparison of the treated Class II participants' and nonparticipants' data (the mean value [Mean], standard deviation [SD], and *p*-value [*p*] of the respective group difference are given for age, Peer Assessment Rating Index [PAR], MFT index, and magnitude of gingival recessions [teeth 32–42])

Tab. 1 Daten der behandelten Klasse-II-Patienten: Teilnehmer vs. Nichtteilnehmer (Mittelwert [„mean"], Standardabweichung [SD] und *p*-Wert [*p*] des entsprechenden Gruppenunterschiedes sind angegeben für Alter, PAR („peer assessment rating index"), MFT-Index und Ausmaß der gingivalen Rezessionen [Zähne 32–42])

			Treated Class II Participants (40♀:32♂) Mean ± SD	Nonparticipants (39♀:41♂) Mean ± SD	*p*
Age (years)		T1	15.4 ± 1.9	15.9 ± 3.2	0.216
PAR score (total)		T0	23.9 ± 9.2	30.4 ± 9.7	0.000
		T1	3.2 ± 2.0	7.5 ± 4.4	0.000
MFT		T1	3.1 ± 3.8	3.4 ± 3.5	0.499
Magnitude of gingival recessions (mm)	Mean (teeth 32–42)	T1	0.0 ± 0.0	0.1 ± 0.3	0.038
	Tooth 32		0.0 ± 0.0	0.1 ± 0.3	0.131
	Tooth 31		0.0 ± 0.1	0.1 ± 0.3	0.058
	Tooth 41		0.0 ± 0.1	0.1 ± 0.6	0.081
	Tooth 42		0.0 ± 0.0	0.0 ± 0.3	0.227

MFT missing, filled teeth index

used for evaluation and comparison to the current situation (T2).

In detail, the following parameters were used for the assessment of oral health:

- General dental status:
  Decayed, Missing, Filled Teeth Index (DMFT) [34] and MFT Index (DMFT-modification assessed from panoramic radiographs)
- Gingival health:
  Periodontal Screening Index (PSI/PSR Index) [36, 40], soft tissue abnormalities; in addition, the study models were assessed visually for the presence of gingival recessions on teeth 32–42, which were quantified in millimeters by measuring the labial crown height as distance from the center of the incisal edge to the lowest point of the vestibulogingival margin to the nearest 0.5 mm using a manual calliper.

At recall (T2), 42 of the 72 treated Class II participants (58.3%) wore no retainers at all. A total of 29 participants (40.3%) had a lower fixed canine-to-canine retainer (26 fixed on the canines only, 3 fixed on all teeth) which was combined with an upper fixed retainer in 5 participants. One participant (1.4%) wore an upper fixed retainer only.

Control group

A "double negative, normal" control group (Class I, no orthodontic Tx need) was used for comparison [24]. These untreated Class I controls ($n = 31$) took part in a longitudinal study on growth changes in the dental arches in Finland, which followed the patients from age 7 until 33 (32.9 ± 1.2). The records obtained at age 15 (T1) and age 33 (T2) were considered to correspond best to the treated Class II participants regarding age (Table 2).

Study models from both time points T1 and T2 existed and a panoramic radiograph from age 33 years (T2) were

Table 2 Sex, age (in years), and duration of the observation period T1–T2 (in years) of the treated Class II participants and the "normal" untreated Class I controls (the mean value [mean], standard deviation [SD], and *p*-value [*p*] of the respective group difference are given)

Tab. 2 Geschlecht, Alter (in Jahren) und Dauer des Beobachtungszeitraumes T1–T2 (in Jahren) der behandelten Klasse-II-Teilnehmer und der „normalen", unbehandelten Klasse-I-Kontrollen (angegeben sind Mittelwert [„mean"], Standardabweichung [SD] und *p*-Wert [*p*] des entsprechenden Gruppenunterschiedes)

	Treated Class II participants 40♀:32♂ Mean ± SD	"Normal" untreated Class I controls 17♀:14♂ Mean ± SD	*p*
Age (years)			
T1	15.4 ± 1.9	15.3 ± 0.6	0.329
T2	33.7 ± 3.0	32.9 ± 1.2	0.219
Observation period (years)			
T2–T1	18.3 ± 2.9	17.6 ± 1.2	0.877

Table 3 Parameters used for the assessment and comparison of oral health (dental status, gingival health) at T1/T2 and the mode of application in the treated Class II participants and the "normal" untreated Class I controls

Tab. 3 Variablen, die zur Ermittlung und zum Vergleich der Mundgesundheit (Zahnstatus, gingivale Gesundheit) zu T1/T2 bei den behandelten Klasse-II-Teilnehmern und den „normalen", unbehandelten Klasse-I-Kontrollen herangezogen wurden und Art der vorgenommenen Untersuchung

	Parameter	Treated Class II participants		"Normal" untreated Class I controls	
T1	Dental status	(D)MFT index	(Radiograph)	No data available	–
	Gingival health	Recessions teeth 32–42	(Study model)	Recessions teeth 32–42	(Study model)
T2	Dental status	DMFT index	(Clinical examination)	(D)MFT index	(Radiograph)
	Gingival health	PSI[a]	(Clinical examination)	CPI[b]	(Clinical examination)
		Recessions teeth 32–42	(Study model)	Recessions teeth 32–42	(Study model)

[a]*PSI* Periodontal Screening Index [40]
[b]*CPI* Community Periodontal Index [3]
(D)MFT (decayed), missing, filled teeth index

available for 28 of the 31 untreated Class I controls. Furthermore, data from a clinical inspection Community Periodontal Index (CPI) [3] and the anamnesis (eventual complaints regarding the condition of teeth, occlusion and/or function) from T2 were evaluated.

A detailed overview on the parameters used for the assessment and comparison of oral health is given in Table 3.

A remark on the assessment of gingival health: PSI [40] is the German version of PSR [36] and is very similar to CPI. Particularly the grades 0, 1, and 2 which are the most relevant in the current investigation can be considered equal. For ease of reading, only the term CPI will be used for all determined data in the respective tables and figures as well as for the description of the results and in the discussion.

Benchmark data

Epidemiological OH benchmark data from population-representative cross-sectional studies of different age cohorts (Tables 4 and 5; [4, 15–17, 27–30, 32, 42, 43, 48, 57]) were used to account for population-wide changes during the time interval of approximately 15 years between the T2 recall assessments in the treated Class II participants (2014/2015) and the untreated Class I controls (1998/1999).

In addition, the German Oral Health Studies (DMS I, III, IV, and V; Supplementary Table 1) [27–30] were used for comparison to rate the OH effects of orthodontic Tx. If not otherwise indicated, comparisons were performed exclusively with age-corresponding cohorts.

To minimize the error of the method, all measurements were performed twice (N. B.) and the mean value of both measurements was used for further calculations.

In addition to a descriptive statistical analysis, the Shapiro–Wilk and Kolmogorov–Smirnov tests were applied to assess the data regarding normal distribution. In case of normal distribution, the t-test or an ANOVA was used, depending on the number of groups to be compared. In case of nonnormal distribution, the Mann–Whitney U test or the Kruskal–Wallis test were applied, respectively. Due to the explorative study design, p-values ≤ 0.15 were considered to suggest a group difference. This procedure was chosen as explorative data analysis does not use a fixed threshold value of probability to search for "patterns" or "structure" in experimental data although robust inferential statistical procedures are utilized [60]. The 0.1–0.15 threshold was heuristically adapted from a selection process commonly used to screen for relevant factors in logistic regression and similar analytical procedures.

Results

Treated Class II participants vs. nonparticipants

The 72 treated Class II participants and the 80 nonparticipants did not differ significantly regarding age and MFT after Tx (Table 1). The mean value of the total PAR score was higher in the nonparticipants by 6.5 points before Tx ($p = 0.000$) and by 4.3 points after Tx ($p = 0.000$). Regarding the magnitude of gingival recessions on lower incisors, clinically irrelevant group differences ($p = 0.058$–0.277) were seen.

Treated Class II participants vs. untreated Class I controls

The 72 treated Class II participants (40 females, 32 males) had a mean age of 15.4 ± 1.9 years after Tx (T1) and 33.7 ± 3.0 years at recall (T2; Table 2). The mean post-Tx observation period was 18.3 ± 2.9 years. The untreated Class I controls (17 females, 14 males) had a mean age of 15.3 ± 0.6 years at T1 and 32.9 ± 1.2 years at T2 resulting in an observation period of 17.6 ± 1.2 years, which means good comparability to the treated Class II participants.

All treated Class II participants had undergone Herbst-MBA Tx due to a severe Class II malocclusion (mean pre-Tx PAR score: 23.9 ± 9.2) which was successfully treated (mean T1 PAR score: 3.2 ± 2.0). Slight changes had oc-

Table 4 General dental status: (D)MFT data of the treated Class II participants and the untreated Class I controls as well as comparative data from the literature
Tab. 4 Allgemeiner Zahnstatus: (D)MFT(„[decayed,]missing, filled teeth")-Werte der behandelten Klasse-II-Teilnehmer und der unbehandelten Klasse-I-Kontrollen sowie Vergleichsdaten aus der Literatur

Current investigation	Population	Year(s) of investigation	Type of evaluation	Location	*N* =	Mean age	Mean (D)MFT	(D)MFT = 0
–	Treated Class II participants	1988–2000 (T1)	Radiographic	DE	68	15.4	3.1 ± 3.8	34%
		2014–2015 (T2)	Clinical		72	33.7	7.1 ± 4.9	7%
–	Untreated Class I controls	1998–2002 (T2)	Radiographic	FI	28	32.9	7.9 ± 3.6	4%
Publication	*Year of publication*	*Year(s) of investigation*	*Type of evaluation*	*Location*	*N* =	*Age*	*(D)MFT*	*(D)MFT = 0*
DMS I [27]	1991	1989	Clinical	DE (West)	452	13–14	5.1	12%
					451	35–44	16.7	1%
DMS III [28]	1999	1997	Clinical	DE (West)	516	35–44	16.1 ± 5.7	1%
DMS IV [29]	2006	2005	Clinical	DE (West)	1012	15	1.7 ± 2.5	48%
					755	35–44	14.4 ± 5.8	1%
DMS IV [30]	2016	2014	Clinical	DE (West)	814	35–44	11.1 ± 5.6	3%
DAJ [16, 17]	2005	2004	Clinical	DE (Hessen)	1987	15	1.8	46%
	2010	2009			2656	15	1.1	62%
Splieth et al. [57]	2003	1997–2001	Clinical	DE	699	25–34	7.6	–
National Public Health Institute [43]	2008	2000	Clinical	FI	2148	30–44	11.3	–
National Institute for Health and Welfare [42]	2010	1985	Clinical	FI	>10,000	15	6.2	–
					>10,000	18	9.4	2%
		1994			>10,000	15	2.8	–
					>10,000	18	4.7	14%
		2000			>10,000	15	2.6	–
					>10,000	18	4.0	16%
		2003			>10,000	17	–	20%
Ankkuri and Ainamo [4]	1997	1991	Clinical	FI	4057	20.3	7.3 ± 5.1	7%
Peltola et al. [48]	2006	1982	Radiographic	FI	176	19.8	11.0 ± 4.2	0%
		2002			231	20.2	2.9 ± 3.2	28%
Kämppi et al. [32]	2013	2011	Clinical	FI	13,304	21–23	4.1 ± 4.2	21%
Crocombe et al. [15]	2009	2004–2006	Clinical	AUS	5505	16–19	–	24%
						20–34	–	4%
						35–49	–	0%

DE Germany, *FI* Finland, *AUS* Australia, *(D)MFT* (decayed) missing, filled teeth index, *DMS* Deutsche Mundgesundheitsstudie (German Oral Health Study)
– Data not available

Table 5 Gingival health: Community Periodontal Index (CPI) and gingival recession data of the treated Class II participants and the untreated Class I controls as well as comparative data from the literature

Tab. 5 Gingivale Gesundheit: Daten zum CPI („community periodontal index“) und zu Rezessionen bei den behandelten Klasse-II-Teilnehmern und den unbehandelten Klasse-I-Kontrollen ermittelte Werte sowie Vergleichsdaten aus der Literatur

	Population	Year(s) of investigation	Type of evaluation	Location	*N*=	Age	CPI				
							Maximum score				
							Mean	= 0	= 0,1,2	= 3	= 4
–	Treated Class II participants	2014–2015 (T2)	Clinical	DE	72	33.7	1.6 ± 0.6	4%	100%	0%	0%
–	Untreated Class I controls	1998–2002 (T2)	Clinical	FI	31	32.9	1.7 ± 0.9	16%	91%	6%	3%
Publication	*Year of publication*	*Year(s) of investigation*	*Type of evaluation*	*Location*	*N*=	*Age*	*CPI*				
							Maximum score				
							Mean	*= 0*	*= 0,1,2*	*= 3*	*= 4*
DMS I [27]	1991	1989	Clinical	DE (West)	451	35–44	2.5	6%	45%	40%	15%
DMS III [28]	1999	1997	Clinical	DE (West)	509	35–44	2.0	18%	62%	29%	9%
DMS IV [29]	2006	2005	Clinical	DE (West)	740	35–44	2.8 ± 0.9	0%	28%	53%	19%
DMS V [30]	2016	2014	Clinical	DE (West)	806	35–44	1.9–2.3[a]	–	39%	51%	10%

DE Germany, *FI* Finland, *DMS* Deutsche Mundgesundheitsstudie (German Oral Health Study)
[a]Exact value not known; best and worse possible value calculated

Table 6 Mean magnitude of gingival recessions on lower incisors. Results of study model assessment in mm are given for each of the teeth 32–42 as well as mean (teeth 32–42). The data is shown for the treated Class II participants and the untreated Class I controls. In addition the group difference (*p*-value) is given where applicable

Tab. 6 Durchschnittliches Ausmaß gingivaler Rezessionen an den unteren Inzisiven. Die Ergebnisse der Modellauswertung sind sowohl für jeden der Zähne 32–42 einzeln als auch als Mittelwert (Zähne 32–42) in mm dargestellt. Neben den Daten der behandelten Klasse-II-Teilnehmer und der unbehandelten Klasse-I-Kontrollen ist – sofern zutreffend – der Gruppenunterschied (*p*-Wert) angegeben

			Tooth 32	*p*	Tooth 31	*p*	Tooth 41	*p*	Tooth 42	*p*	Mean (teeth 32–42)	*p*
T1	Treated Class II participants	*n* = 70	0.0 ± 0.1	0.136	0.0 ± 0.1	0.288	0.0 ± 0.1	0.392	0.0 ± 0.0	0.145	0.0 ± 0.0	0.585
	Untreated Class I controls	*n* = 31	0.0 ± 0.1		0.0 ± 0.0		0.0 ± 0.0		0.0 ± 0.1		0.0 ± 0.0	
T2	Treated Class II participants	*n* = 72	0.1 ± 0.2	0.469	0.1 ± 0.4	0.267	0.2 ± 0.5	0.903	0.0 ± 0.1	0.845	0.1 ± 0.2	0.193
	Untreated Class I controls	*n* = 31	0.0 ± 0.1		0.0 ± 0.1		0.1 ± 0.4		0.0 ± 0.1		0.0 ± 0.1	

curred until the recall investigation (mean T2 PAR score: 7.5 ± 5.1). At age 15 (T1) the untreated Class I controls exhibited a mean PAR score of 8.7 ± 3.7 which remained stable (8.8 ± 3.3) until age 33 (T2). The mean T2 PAR score in the untreated Class I controls did not differ significantly ($p = 0.196$) from the treated Class II participants. More detailed data on the changes in occlusion and alignment have been published in two separate articles [8, 9].

Looking at the degree of patient satisfaction at recall, the majority of the treated Class II participants (70.8%) was fully satisfied with the condition and appearance of their teeth as well as masticatory system function at T2, 27.8% were conditionally satisfied, and 1.4% ($n = 1$) were unsatisfied. For the untreated Class I controls, a smaller percentage of subjects (48.3%) could be categorized as fully satisfied, while 12.9% were categorized as conditionally satisfied and 38.8% as unsatisfied.

In addition to the detailed findings described below, the clinical examination of the oral cavity and the gums in the treated Class II participants revealed minor anomalies in some patients: signs of local/superficial gingival inflammation ($n = 16$), signs of pathology/purulence ($n = 2$), atypical structure of the mucosa ($n = 6$), cervical root/dentine exposure/tooth brushing defects ($n = 2$).

The general dental status (Table 3) showed a mean MFT score of 3.1 ± 3.8 immediately post-Tx (T1—radiologic evaluation) in the treated Class II participants. For the untreated Class I controls, no T1 data were available. At recall (T2), the treated Class II participants exhibited a mean DMFT score of 7.1 ± 4.8 (clinical evaluation), while the DMFT score of the corresponding population-representative age-cohort (DMS V 2016) [30] is 56% higher (11.1). The MFT score of the untreated Class I control group from about 15 years earlier was 7.9 ± 3.6 (radiologic evaluation), while the epidemiological age and year-corresponding Finnish control data [43] show a value which is 43% higher.

Looking at periodontal health (Fig. 2, Table 5), the mean CPI maximum scores at recall (T2) were 1.6 ± 0.6 in the treated Class II participants and 1.7 ± 0.9 in the untreated Class I controls ($p = 0.479$). The average value for the respective corresponding population-representative age-cohort (DMS V) [30] is not available, but according to the published prevalences of the CPI maximum scores it ranges between 1.9 (best possible scenario) and 2.3 (worst possible scenario); in the previous epidemiologic evaluation (DMS IV) [29] an average value of 2.8 ± 0.9 was seen. While 100% of the treated Class II participants exhibited a maximum score of 0, 1, or 2, this was true for 91% of the untreated Class I controls but only 39% of the epidemiological age-cohort (DMS V) [30].

The mean extent of gingival recessions (on teeth 32/31/41/42) measured on the study models at T2 was 0.1 ± 0.2 in the treated Class II participants and 0.0 ± 0.1 in the untreated Class I controls ($p = 0.193$). In both groups, the respective value had been 0.0 ± 0.0 at T1 (Table 6). Comparable population benchmark data are lacking.

Evaluating the long-term influence of lower fixed retention, no significant group differences (with/without bonded retainer, controls) were seen for DMFT, CPI or lower incisor gingival recessions (Table 7).

Discussion

The evidence supporting claims of significant dental health improvement following orthodontic Tx are tenuous [6]. The current investigation is the first to assess the long-term effects of orthodontic Tx on OH specifically in Class II patients. Before discussing the results in detail it seems important to reflect about what OH actually implies and what kind of findings might realistically be expected in patients many years after orthodontic Tx.

Undoubtedly, OH is a multifactorial condition with continuous development. While the definition by the WHO (OH is a state of being free from chronic mouth and facial pain, oral and throat cancer, oral sores, birth defects such as cleft lip and palate, periodontal (gum) disease, tooth decay and tooth loss, and other diseases and disorders that affect the oral cavity) is very comprehensive. The predominant factors which could potentially be influenced by orthodontic Tx procedures are tooth decay/tooth loss, periodontal disease, and mouth/facial pain. So, in former orthodontic patients it would certainly be favorable to see good OH in terms of low DMFT scores, healthy periodontium, and no report of OH-related pain.

Ideally an untreated Class II sample should have been used for comparison. However, such a sample unfortunately does not exist. Nevertheless, it might be discussable whether the treated Class II participants should be compared with untreated Class I controls. However, the treated Class II participants were Class I after Tx, and thus possibly predisposed to similar long-term OH effects as the control group. In addition, untreated Class I controls without orthodontic Tx need at adolescence and with no orthodontic intervention represent a "natural" gold standard and therefore a more realistic control group than a sample with ideal occlusal characteristics (PAR score 0) which does not resemble the natural aging process of the human dentition [24, 26].

In terms of methodology, the lack of fully comparable data in terms of dental health must be considered as a limitation. While DMFT data from clinical assessment exist for the treated Class II participants at T2, the respective T1 data had to be determined from radiographs. Also the untreated Class I controls' data from T2 were based on a radiologic

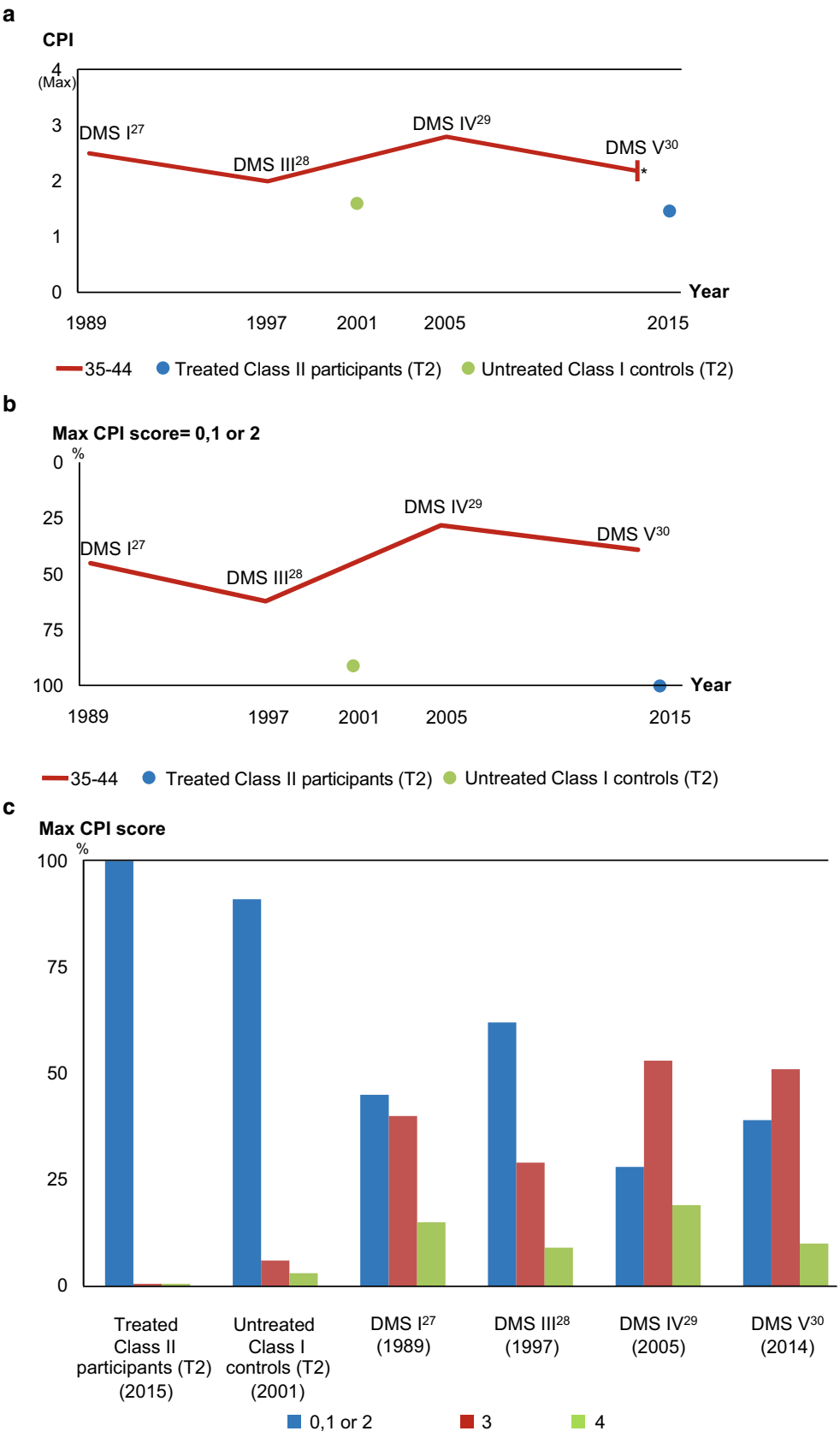

Fig. 2 Chart exhibiting the Community Periodontal Index (CPI) data (**a** mean score, **b** percentage exhibiting a maximum score of 0, 1, or 2, **c** distribution of maximum scores 0–4 in %) of the treated Class II participants and the untreated Class I controls at T2. In addition, the development of the CPI scores of the population in Germany (West) from the 1980s until today in the same age group is shown (data in the figure are allocated to the respective years of investigation). The names of the respective references are used as in Table 5 (*Exact value not known; best and worst possible value calculated)

Abb. 2 CPI(„community periodontal index“)-Daten (**a** Mittelwert, **b** Prozentsatz, der einen Maximalwert von 0, 1 oder 2 aufweist, **c** Verteilung der Maximalwerte 0–4 in %) der behandelten Klasse-II-Teilnehmer und der unbehandelten Klasse I-Kontrollen zu T2. Ferner ist die Entwicklung der CPI-Werte der Bevölkerung Deutschlands (West) von den 1980ern bis heute in der gleichen Altersgruppe dargestellt (abgebildete Daten sind den entsprechenden Untersuchungsjahren zugeordnet). Die Namen der entsprechenden Referenzen werden wie in Tab. 5 verwendet (* exakter Wert unbekannt, es wurden der jeweils best- und schlechtmöglichste Wert berechnet)

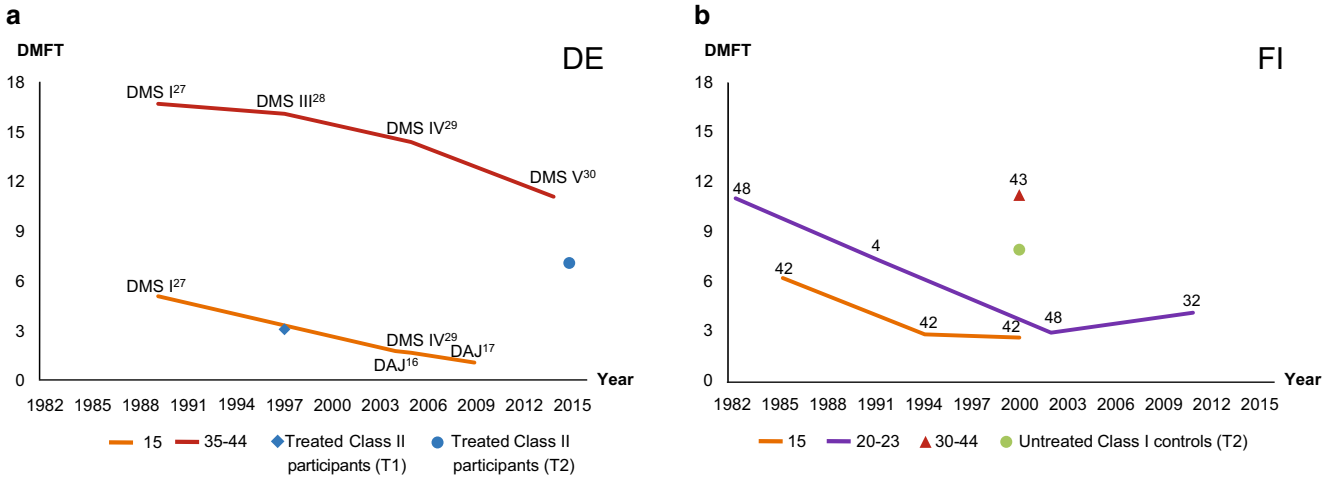

Fig. 3 Chart exhibiting the development of the mean (D)MFT ([decayed,]missing, filled teeth) scores of the population in **a** Germany (West) and **b** Finland from the 1980s until today in different age groups. In addition, the respective values of the treated Class II participants at T1 and T2 as well as of the untreated Class I controls (T2) are given (data in the figure are allocated to the respective years of investigation). For (**a**), the names of the respective references are used as in Table 4; for (**b**), the reference numbers are given

Abb. 3 Entwicklung des mittleren (D)MFT(„[decayed,]missing, filled teeth")-Wertes in der Bevölkerung **a** Deutschlands (West) und **b** Finnlands von den 1980er-Jahren bis heute in verschiedenen Altersgruppen. Ferner sind die entsprechenden Daten der behandelten Klasse-II-Teilnehmer zu T1 und T2 sowie der unbehandelten Klasse-I-Kontrollen (T2) dargestellt (abgebildete Daten sind den entsprechenden Untersuchungsjahren zugeordnet). Zu (**a**): Die Namen der entsprechenden Referenzen werden wie in Tab. 4 verwendet. Zu (**b**): Die Nummern der Referenzen sind angegeben

evaluation. Therefore, the respective score (MFT) might be slightly underrated in these cases. In addition, one might criticise that in terms of gingival recessions, only the lower anterior teeth 32–42 were considered. However, it has been shown that gingival recessions are not a relevant issue on any other teeth than lower incisors after Herbst-MBA Tx [53, 54]. The prevalence of gingival recessions with a magnitude of >1 mm was found to be ≤2.8% when considering all teeth after a retention period of 32 months [53].

When comparing the data of the treated Class II participants to those of the nonparticipants, both groups were similar in terms of age (T0, T1), MFT (T1), and gingival recessions (T1). Therefore, it can be assumed that no relevant selection bias exists.

The degree of satisfaction with the condition and appearance of the teeth and with masticatory system function can be considered as rather high among the treated Class II participants (about 70% fully satisfied, about 1% unsatisfied). In the untreated Class I controls less subjects were fully satisfied (about 48%) and more were unsatisfied (about 38%). However, evaluating these numbers, it has to be remembered that these controls filled out a questionnaire in a completely different setting. Nevertheless, the difference might be due to a higher degree of tooth—especially incisor—malalignment as neither orthodontic Tx nor retention had been performed in the untreated Class I controls. This is in concordance with the results of an investigation on subjective orthodontic Tx need where a significant association with perceived visible dental irregularity was seen [61]. According to a study from Finland [33], orthodontically treated subjects were also significantly more likely to be satisfied when compared to untreated subjects. The respective study comprised 281 subjects of which ≥89% were satisfied with the dental appearance/function of their occlusion. On the contrary, an investigation performed in Canada [50] determined 70% of 2184 participants to be satisfied with dental appearance, but found no relation to previous orthodontic Tx. Finally, a Brazilian study [38] found long-term (≥5 years) patient satisfaction to be slightly associated with the stability of orthodontic Tx result. However, when rating these numbers, it should also be considered that satisfied patients are more likely to participate in patient satisfaction surveys [39].

Looking at OH and especially the dental status, both the treated Class II participants and the untreated Class I controls exhibited similar (D)MFT scores at T2. For both groups, these values were distinctly higher (43–56%) in their corresponding population-representative age-cohorts. Furthermore, the treated Class II participants had been "fully normal" at T1 exhibiting similar values as the corresponding population-representative age-cohort at age 15 (Fig. 3a, b). How can this effect be explained? In the literature, straight teeth are described to retain less plaque than irregular teeth [1, 2]; however, no significant difference regarding the incidence of caries between well-aligned and irregular teeth was found [2]. This was confirmed by a systematic review which did not find any high-quality study resolving an association between the presence of crowding

Table 7 (D)MFT, CPI, and mean gingival recessions (teeth 32–42) after long-term observation (T2) in the treated Class II participants with ($n=29$) or without ($n=43$) a bonded lower canine-to-canine retainer at T2 as well as the untreated Class I controls. The mean value (mean), standard deviation (SD), median (Med) and p-value (p) of the respective group difference are given

Tab. 7 (D)MFT („[decayed,]missing, filled teeth"), CPI („community periodontal index") und durchschnittliche gingivale Rezessionen (Zähne 32–42) nach Langzeitbeobachtung (T2) (Die Daten der behandelten Klasse-II-Teilnehmer mit ($n=29$) oder ohne ($n=43$) festsitzenden Cuspidretainer im Unterkiefer zum Zeitpunkt T2 sowie der unbehandelten Klasse-I-Kontrollen sind dargestellt. Mittelwert („mean"), Standardabweichung (SD), Median (Med) und p-Wert (p) des entsprechenden Gruppenunterschiedes sind angegeben)

	Treated Class II participants						Untreated Class I controls		
	Bonded lower retainer at T2			No retainer at T2					
	Mean	SD	Med	Mean	SD	Med	Mean	SD	Med
(D)MFT	5.9	4.7	7.0	7.9	4.9	7.0	7.9	3.6	8.0
	$p=0.210$								
CPI	1.6	0.6	2.0	1.6	0.5	2.0	1.7	0.9	2.0
	$p=0.090$								
Mean gingival recessions (teeth 32–42; mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	$p=0.227$								

(D)MFT (decayed) missing, filled teeth index, *CPI* Community Periodontal Index

and the susceptibility to caries in case of good oral hygiene [23]. A similar conclusion was derived from a study which reassessed adolescents 20 years after an initial examination [25] and where no relationship was found between malocclusion and caries prevalence. So, the reason seems to be a different or an additional one. If we consider possible similarities between the treated Class II participants and the untreated Class I controls, both groups experienced an intensive attendance and/or Tx by the dental/orthodontic profession for quite an extensive period during adolescence, during which they were repeatedly motivated (kind of Hawthorne effect) to maintain good oral hygiene and health. So, by undergoing orthodontic Tx children might learn to appreciate the value of good oral hygiene, which is supported by the literature, as orthodontically treated children have been shown to present with lower plaque scores [19, 21] and caries [14]. This might be the major difference compared to the corresponding population-representative age-cohorts. In addition, a study from Sweden observed that alignment of the teeth seemed to have a positive psychological effect, motivating the patients and giving them greater dental awareness [22].

A similar explanation might account for the observations on periodontal health. Both the treated Class II participants and the untreated Class I controls exhibited similar and distinctly better CPI findings than the corresponding population-representative age-cohort for Germany (no data available for Finland). No other explanation than a difference in awareness due to constant motivation can be assumed.

Looking at the literature comparing the periodontal status of orthodontically treated and untreated patients, one investigation could not detect a significant difference for any periodontal variable at least 10 years after orthodontic Tx [49], while a similar long-term investigation revealed comparable results but found the orthodontic group to exhibit a greater prevalence of mild to moderate periodontal disease (by means of a tissue-destruction index) in the maxillary posterior and mandibular anterior regions than the untreated controls [55].

The mean magnitude of gingival recessions on the lower incisors was 0.1 ± 0.2 mm in the treated Class II participants and 0.0 ± 0.1 in the untreated Class I controls. The slightly larger value in the treated Class II participants might be due to the orthodontic Tx having induced proclination of the lower incisors. A three-dimensional radiographic evaluation determined alveolar bone loss on the buccal surface of the lower incisors after Herbst Tx by ≤ 0.2 mm and therefore without any clinical significance [56]. An investigation on long-term changes (32 years) after Herbst Tx only, revealed the occurrence of single gingival recessions during the long-term observation, but the authors attributed this finding to other factors like mechanical trauma from tooth brushing or gingival features rather than tooth inclination changes during and after Tx [37, 46].

The influence of lower bonded retainers on OH in the treated Class II participants was of no clinical relevance, which is in concordance with the literature [5, 13, 63], even if this issue remains controversial [52].

Finally, judging both dental and periodontal health one should keep in mind that a certain percentage of the population-representative age-cohorts underwent orthodontic Tx as well (40–60% according to DMS I, III, and IV) [27–29]. In other words, the differences for DMFT and CPI can be expected to be even larger when compared to an orthodontically untreated population.

Conclusion

Patients with orthodontically treated severe Class II malocclusions had a lower risk for oral health impairment than the general population. The risk corresponded to that of un-

treated Class I controls (without orthodontic Tx need during adolescence).

Compliance with ethical guidelines

Conflict of interest N. Bock, M. Saffar, H. Hudel, M. Evälahti, K. Heikinheimo, D. Rice and S. Ruf declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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