ACTA ODONTOLOGICA SCANDINAVICA
2022, VOL. 80, NO. 1, 65–73
https://doi.org/10.1080/00016357.2021.1937698

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ORIGINAL ARTICLE

Malocclusion and oral health-related quality of life among young Danish adults. Is there a difference between subjects who received orthodontic treatment during adolescence and subjects without treatment need? A cross-sectional study

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ABSTRACT

Objectives: To evaluate and compare malocclusion traits and oral health-related quality of life (OHRQoL) between untreated young adults assessed to have no orthodontic treatment need during childhood, and young adults treated orthodontically during childhood. In addition, to investigate the relationship between malocclusion and OHRQoL.

Materials and methods: One hundred undergraduate students were screened for eligibility. Subjects had intraoral scans and completed OHIP-14 questionnaires. Angle molar relationship, overjet, overbite, arch length and width, Little's Irregularity Index (LII), Peer Assessment Rating (PAR) index and Dental Aesthetic Index (DAI) scores were assessed. Unpaired t-tests were used to compare outcomes between treated and untreated subjects. Multiple regression analyses were conducted to model the relationship between OHIP-14 and several prognostics simultaneously.

Results: Ninety-six subjects were included (mean age ± SD = 23.7 ± 1.8 years): 41 treated and 55 untreated. The untreated subjects had significantly higher LII ($p = .02$), PAR ($p = .01$), DAI ($p < .01$) and overbite ($p = .03$). The treated subjects had significantly larger inter-canine and inter-premolar distances. No relationship was found between OHIP-14 and LII, PAR, DAI, age, gender and presence/absence of previous orthodontic treatment. However, the DAI score was significantly correlated with the OHIP-14 functional limitation domain.

Conclusions: Untreated subjects had significantly higher LII, PAR and DAI scores than the treated subjects. DAI score was significantly correlated with the OHIP-14 functional limitation domain.

ARTICLE HISTORY
Received 24 February 2021
Revised 4 May 2021
Accepted 25 May 2021

KEYWORDS
Orthodontics; malocclusion; oral health-related quality of life (OHRQoL); OHIP-14; orthodontic treatment need

Introduction

Denmark offers free orthodontic treatment (OT) to 25–33% of children and adolescents through highly developed public dental services (PDS) up to the age of 18 years [1]. Access to OT by PDS is given provided that the malocclusion implies a foreseeable or extant risk of physical damage or psychosocial strain [1]. Children and adolescents without functional needs are not offered treatment by PDS. Helm and co-workers investigated malocclusion in Denmark among school children [2] in the 1980s. Presently, however, there are no reports on malocclusion and OHRQoL in young Danish adults.

Despite the general belief that OT improves patients' oral function, appearance and social well-being, several researchers have failed to demonstrate any significant relationship between OT of malocclusion and OHRQoL [3,4]. On the contrary, other researchers have found that malocclusion had a significant negative impact on OHRQoL and that OT improved OHRQoL [5,6]. According to a recent systematic review [7], OHRQoL improves moderately after undergoing OT during childhood or adolescence, particularly in the dimensions of emotional and social well-being. However, the evidence level is low to moderate. One of the most widely used tools to measure OHRQoL is the Oral Health Impact Profile (OHIP) owing to its good psychometric properties [8].

Given the coverage of OT by PDS in Denmark, the severity of malocclusion among adolescents towards the middle of their teens is low; as malocclusion is either corrected by OT, or it is not severe enough to be treated. But how is the situation ten years later? OT can relapse [9] and occlusion changes throughout life, even in untreated subjects [10]. The plausible question is whether OT results are maintained from adolescence to adulthood. At the same time, how is the occlusion of children without OTN evolving throughout early adulthood? Finally, are both treated and untreated young adults equal in terms of OHRQoL? These questions remain unanswered so far and constitute the background for the present article.

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Supplemental data for this article can be accessed here.

The present cross-sectional study aimed to evaluate and compare the malocclusion traits and OHRQoL between untreated young adults assessed to have no OTN during childhood, and young adults treated orthodontically during their childhood, in Denmark. In addition, the study aimed to investigate the relationship between malocclusion and OHRQoL.

Materials and methods

This cross-sectional study was conducted at Aarhus University, Department of Dentistry and Oral Health, Section of Orthodontics. Approval was obtained from the Health Research Ethics Committee, Central Jutland, Denmark (case no. 1-10-72-225-18). Data collection and management were performed using the Research Electronic Data Capture (REDCap) tool hosted at Aarhus University [11].

Sample size calculation

A sample size calculation was performed using the program ClinCalc© (ClinCalc LLC 2020), based on the total PAR score. The standard deviation of the total PAR score was estimated as 7 points [12]. To demonstrate a mean difference of 5 points in total PAR score between treated and untreated subjects, a sample including 31 treated and 31 untreated subjects was needed to reject the null hypothesis that the population means of the treated and untreated subjects were equal ($\alpha = 0.05$ and $1\text{-}\beta = 0.8$). Assuming that at least 30% of randomly selected subjects would have been orthodontically treated, it was decided to enroll 100 subjects.

Participants

The sample consisted of 100 Danish undergraduate students. The inclusion criteria were: healthy subjects, over 18 years of age. Subjects undergoing OT as a 'first-time' treatment at the time of screening were excluded. Two operators approached students in a random order according to their availability. After obtaining their informed consent, the subjects were screened for eligibility by completing a self-administered digital questionnaire to gather socio-demographic information (gender, date of birth), general health and information establishing whether they had had OT in the past, or had an ongoing OT at the time of the study. In addition, subjects who reported an OT in the past were asked to specify their age at OT start and if they had received any re-treatment.

Digital models

Subjects had intraoral scans (Trios 3, 3Shape, Copenhagen, Denmark). The stereolithographic files were transferred into the Ortho Analyzer software (3Shape, Copenhagen, Denmark), and the following variables were assessed by one operator (AG):

1. Malocclusion parameters: Angle molar relationship, overjet, overbite, transverse relationship (crossbite, scissor bite or edge-to-edge), arch length and width (Figure 1), Little's Irregularity Index (LII) [13], Peer Assessment Rating Index (PAR) [14], Dental Aesthetic Index (DAI) [15], presence of missing teeth and presence of suspected unexpected post-treatment changes (defined as torque and/or rotational movements in the anterior region in the presence of a fixed retainer, and unrelated to the initial malocclusion [16]).
2. Presence or absence of fixed retainers.

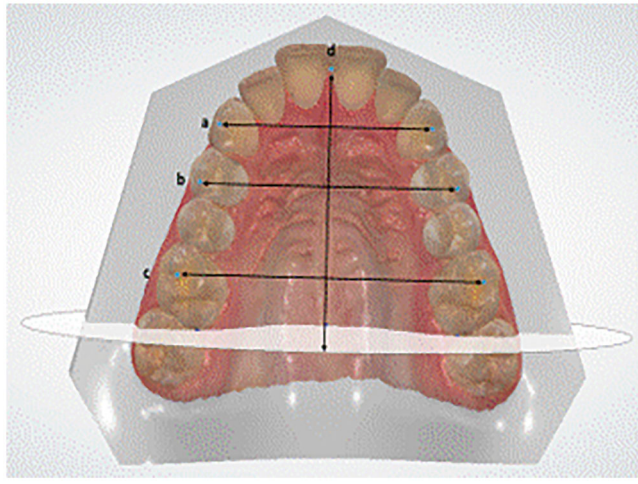

Figure 1. Intra-arch measurements. (a) Inter-canine distance: distance between the cusp tips of fully erupted canines in the same arch. (b) Inter-premolar distance: distance between the buccal cusp tips of the right and left first premolars. If the first premolars were missing, the second premolars were used instead. (c) Inter-molar: distance between the mesiobuccal cusp tips of the right and left first permanent molars. If the first permanent molar had been extracted, the second permanent molar was used instead. (d) Arch length: distance from the contact point of the central incisors to a frontal plane through the most posterior aspect of the first molars.

Reproducibility

All measurements were repeated for 24 digital model sets at a 2-week interval by the same operator (AG), as well as by another operator (SG).

OHRQoL questionnaires

All subjects completed the Oral Health Impact Profile-14 (OHIP-14) questionnaire (referring to impacts during the last 12 months) [17]. The weighted total OHIP-14 score was calculated, as well as the negative impacts. The OHIP-14 (Supplementary Table 1) consists of 14 items (7 domains) scored on a Likert scale ranging from 0 to 4 (0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, 4 = often). The response score for each item was multiplied by its weight and summed to produce sub-scale scores. The weighted total OHIP-14 score was calculated by summing the weighted score of each subscale (weighted-standardized method). To calculate the negative impact, responses with 'often' or 'fairly often' for the treated and untreated subjects were calculated using the simple count method.

Test re-test reliability

Fifty-seven subjects completed the OHIP-14 questionnaire again at a two-week interval.

Statistics

Statistical analyses were done using Stata Statistical Software (16. College Station, StataCorp, TX, USA). Information about gender, age, OT history and malocclusion was analyzed with descriptive statistics. Chi-square tests were used to analyze gender differences and Angle molar relationships. As normality of the data was confirmed, unpaired sample *t*-tests were computed to compare the parameters between treated and untreated subjects, and between subjects with and without fixed retainers within the treated subjects. Multiple regression analyses were conducted to model the relationship between the total OHIP-14 and several prognostics simultaneously (LII, PAR, DAI, age, gender, presence/absence of previous orthodontic treatment), as well as the relationship between DAI and the OHIP-14 domains. In addition, Spearman's correlation was used to assess the stability in the pattern of response of the test re-test. Reproducibility of the digital model analyses was measured using intra-class correlation coefficients (ICC) computed using the 'two-way mixed effects model', with two raters ($k = 2$). A p value of $<.05$ was set for statistical significance.

Results

Participants

Out of the 100 recruited subjects, a total of 96 (mean age ± SD = 23.7 ± 1.8 years) were included. Four subjects were excluded; two had reported an ongoing OT at the time of recruitment and another two had medical problems. Based on the data regarding OT history, the sample was divided into two groups; treated ($n = 41$) and untreated ($n = 55$). Females were more prevalent than males in both groups (81 females: 15 males), however, no difference in gender distribution within each group was observed (Chi^2 test = 0.82, $p = 0.36$). In addition, OT was reported to have been initiated at an average age of 12 years; i.e. an average span of ten years before the present study was conducted. Five treated subjects reported to have had orthodontic re-treatment in private practice within a range of 2–10 years after their initial OT because of relapse of spacing ($n = 1$) or crowding ($n = 4$).

Table 1. Angle molar relationship in the treated and untreated groups.

	Class I % (n=)	Class II* % (n=)	Class III* % (n=)	Total % (n=)
Treated group	51 ($n = 21$)	39 ($n = 16$)	10 ($n = 4$)	100 ($n = 41$)
Untreated group	51 ($n = 28$)	42 ($n = 23$)	7 ($n = 4$)	100 ($n = 55$)
Total	51 ($n = 49$)	41 ($n = 39$)	8 ($n = 8$)	100 ($n = 96$)

*Class II subdivisions were considered as Class II and Class III subdivisions were considered as Class III.
Chi^2=0.22, p=.90.

Digital models

The distribution of Class I, II and III molar relationships was not significantly different in the treated and untreated subjects (Table 1, Chi^2=0.22, $p = .90$). Overjet was not significantly different between the treated and untreated subjects, whereas overbite was significantly smaller in the treated subjects (Table 2). Treated subjects had significantly larger inter-canine and inter-premolar distances than untreated subjects. By contrast, inter-molar distances and arch lengths were not significantly different between the treated and untreated subjects. Regarding the transverse relationships, treated and untreated subjects showed a low frequency of crossbite of one or more teeth (4 treated subjects and 8 untreated subjects), one treated subject had one tooth in scissor bite, two untreated cases had edge-to-edge relations and one subject in each group had a combination of edge-to-edge relation and a crossbite of at least one tooth.

LII was significantly higher in the untreated subjects (Table 2). The treated subjects showed good-to-acceptable LII scores; none had 'very severe' irregularity (Figure 2). Only 22% of the untreated subjects had 'minimal' (1–3 mm) irregularity, whereas this percentage was doubled for the treated subjects (49%). A 'very severe' irregularity was observed in the untreated subjects (9%) only. Among the treated subjects, 28 had fixed retainers (in the upper or lower arch, or in

Table 2. Digital model analyses, for the total sample and for the treated and untreated groups.

Analyses	Total sample				Treated group				Untreated group				p-Value (Unpaired sample t-test)
	Mean	SD	95% CI		Mean	SD	95% CI		Mean	SD	95% CI		
Overjet (mm)	3.0	1.1	2.7	3.2	2.8	0.8	2.5	3.1	3.1	1.3	2.7	3.4	.24
Overbite (mm)	3.4	1.7	3.0	3.7	2.9	1.6	2.5	3.4	3.7	1.7	3.3	4.2	*.03
Upper inter-canine distance (mm)	33.4	2.6	32.9	33.9	34.1	2.2	33.4	34.8	32.9	2.7	32.1	33.6	*.02
Lower inter-canine distance (mm)	25.9	2.2	25.4	26.3	26.5	2.3	25.8	27.2	25.4	2.1	24.8	25.9	*.01
Upper inter-premolar distance (mm)	40.4	2.8	39.8	41.0	41.4	2.7	40.5	42.2	39.7	2.7	38.9	40.4	**<.01
Lower inter-premolar distance (mm)	33.8	2.6	33.3	34.3	34.5	2.5	33.7	35.3	33.3	2.5	32.6	34.0	*.02
Upper inter-molar distance (mm)	50.7	3.1	50.1	51.3	50.9	3.2	49.9	51.9	50.5	3.1	49.7	51.4	.54
Lower inter-molar distance (mm)	44.5	2.9	43.9	45.1	44.8	2.9	43.9	45.7	44.3	2.8	43.5	45.1	.38
Upper arch length (mm)	37.1	2.6	6.6	37.6	37.3	2.9	36.4	38.2	36.9	2.4	36.3	37.6	.48
Lower arch length (mm)	32.8	2.6	32.3	33.3	33.1	2.5	32.3	33.9	32.6	2.7	31.9	33.3	.35
LII (mm)	5.5	2.6	5.0	6.0	4.4	2.1	3.7	5.0	6.3	2.7	5.6	7.1	**<.01
Total PAR score (points)	12.6	9.4	10.7	14.4	9.7	6.4	7.6	11.7	14.7	10.6	11.8	17.6	*.01
DAI (points)	26.9	5.8	25.7	28.1	25.3	5.3	23.6	27.0	28.1	5.9	26.5	29.7	*.02

*$p < .05$.
**$p < .01$.

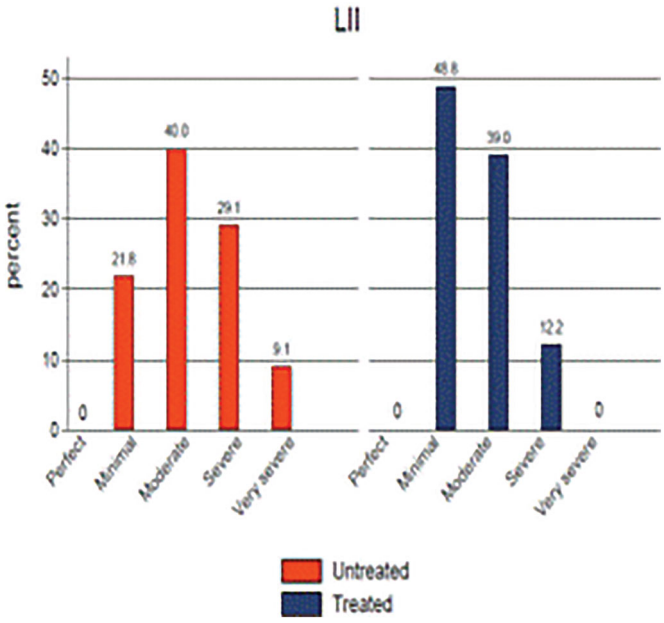

Figure 2. LII for the untreated and treated subjects. LII irregularity criteria according to the measured tooth displacement in mm. Perfect 0; minimal 1–3; moderate 4–6; severe 7–9; very severe 10.

both arches), whereas 13 subjects had no fixed retainers. Treated subjects who had fixed retainers showed a significantly lower LII (mean = 3.9, 95% CI = 3.2–4.6) than treated subjects without fixed retainers (mean = 5.3, 95% CI = 4.0–6.5) (p=.045) (Figure 3).

The PAR index was significantly higher in the untreated subjects (Table 2). The upper and lower anterior displacements (PAR components) were significantly higher in the untreated subjects (Table 3). No significant difference was observed in the mean PAR scores of the treated subjects with or without fixed retainers (p=.63).

The DAI was significantly higher in the untreated subjects (Table 2) and showed no difference between the genders (Chi^2=0.85, p=.84). 'No treatment need' (DAI grade 1) was the most prevalent grade among the total sample as well as among the treated subjects (Figure 4). No difference in DAI was observed among treated subjects with or without a fixed retainer (p=.37). Among the treated subjects, 37% of the subjects fell into the treatment need categories (DAI grades 2–4; grade 2: 22%; grade 3: 7.3%; grade 4: 7.3%) in contrast to the untreated subjects where almost double the subjects (i.e. 64%) were in the treatment need categories (grade 2: 30.9%; grade 3: 21.8%; grade 4: 10.9%).

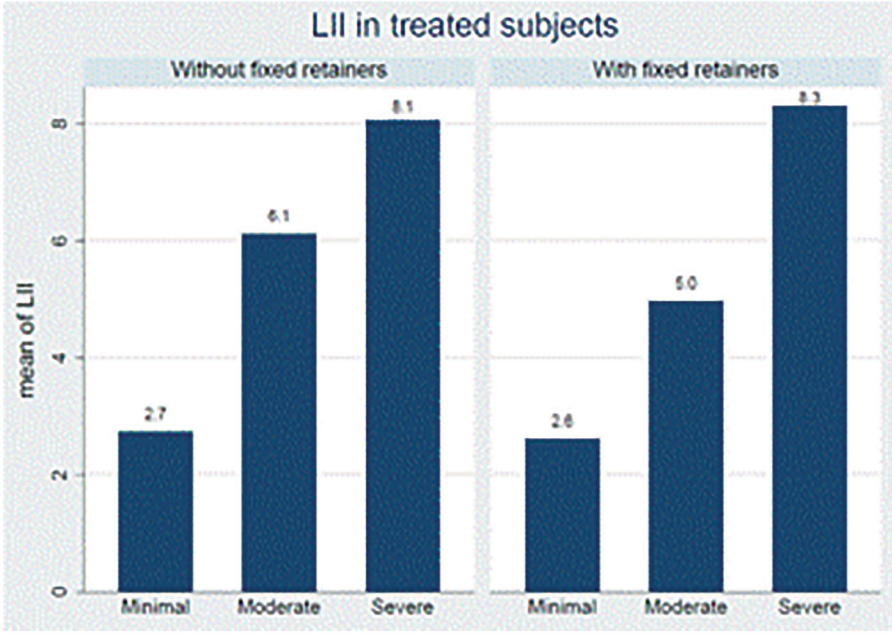

Figure 3. Mean LII (in each grade) in treated subjects with and without fixed retainers.

Table 3. PAR index components. Total sample, treated and untreated groups.

	Total sample (n = 96)		Treated group (n = 41)		Untreated group (n = 55)		p Value
Weighted PAR components	Mean (SD)	95% CI	Mean (SD)	95% CI	Mean (SD)	95% CI	(unpaired t-test)
Upper anterior segment	2.4 (2.4)	1.9–2.9	1.6 (1.3)	1.2–2.0	3.0 (2.9)	2.2–3.7	**<.01
Lower anterior segment	2.6 (2.3)	2.1–3.1	1.6 (1.8)	1.0–2.1	3.4 (2.4)	2.7–4.0	**<.01
Sagittal	0.9 (1.2)	0.6–1.1	0.7 (1.1)	0.4–1.1	1.0 (1.3)	0.6–1.3	.38
Vertical	0	–	0	–	0	–	–
Transverse	0.3 (1.0)	0.1–0.5	0.3 (0.9)	0.5–0.6	0.3 (1.0)	0.1–0.6	.98
Overjet	3.6 (4.6)	2.7–4.5	2.6 (3.0)	0.5–1.7	4.4 (5.3)	2.9–5.8	.07
Overbite	1.4 (1.7)	1.0–1.7	1.3 (1.8)	0.7–1.9	1.4 (1.6)	1.0–1.9	.70
Centerline	1.3 (2.4)	0.8–1.8	1.5 (2.3)	0.7–2.2	1.2 (2.4)	0.6–1.9	.64

**p<.01.

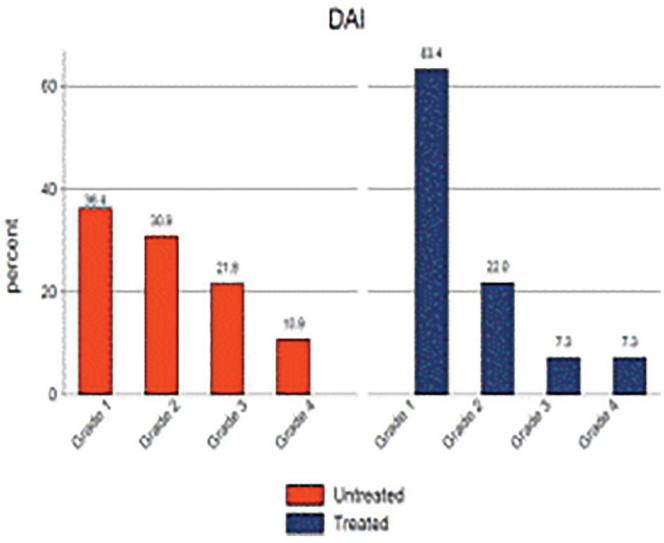

Figure 4. DAI for the untreated and treated subjects.

Eleven percent of the subjects had missing teeth (Table 4). Two subjects (out of 24 treated subjects, with a lower fixed multistranded retainer: 8%) presented suspected unexpected post-treatment changes in the form of torque movements in the lower arch (Figure 5).

OHRQoL questionnaires

All subjects answered the 14 items of the OHIP-14, with a mean total score of 2.1 ± 2.4 points (95% confidence interval (CI)=1.7–2.7) and with no significant differences between the treated and untreated subjects (mean difference = 0.3 ± 0.5 points, p=.55) (Figure 6). From the 1,344 responses, the most frequent answer was 'Never' (80.9%). The psychological discomfort (D3) represented the highest means (1.00 for the treated subjects and 0.8 for the untreated subjects). The total negative impacts of OHIP-14 for the treated and untreated subjects was 22 and 19 points, respectively. Responses with

Table 4. Distribution of the frequency of cases with missing permanent teeth (excluding third molars) in the upper and lower arches: agenesis, orthodontic extractions, or other extractions.

	Untreated group		Treated group	
	Number of cases		Number of cases	
Status	Upper arch	Lower arch	Upper arch	Lower arch
Orthodontic extractions				
2 Premolars			2	
4 Premolars			1	
Missing teeth*		2	1	
Unilateral or bilateral agenesis of second premolars**		1	2	1
Bilateral agenesis of lateral incisors	1		1	

*Unclear diagnosis, as the permanent teeth were missing: predicted to be either extracted, rare agenesis (other than premolars) or impaction cases.
**Assumed to be agenesis as the primary teeth were retained.

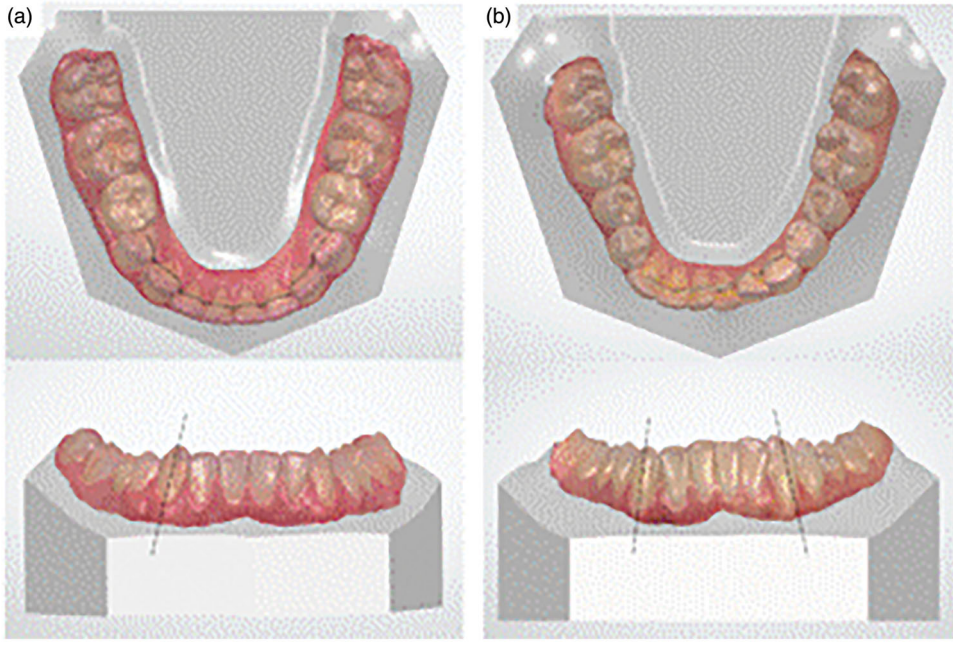

Figure 5. Suspected unexpected post-treatment changes. (a). Unexpected post-treatment change is suspected on tooth 43 (lingual crown torque), relapse of rotation is suspected on teeth 44 and 34; female; 21 years old (10 years after orthodontic treatment). (b) Unexpected post-treatment change is suspected on teeth 43 (labial crown torque) and 33 (lingual crown torque), relapse of crowding is suspected on all four incisors; probably due to local debondings; female; 24 years old (eight years after orthodontic treatment).

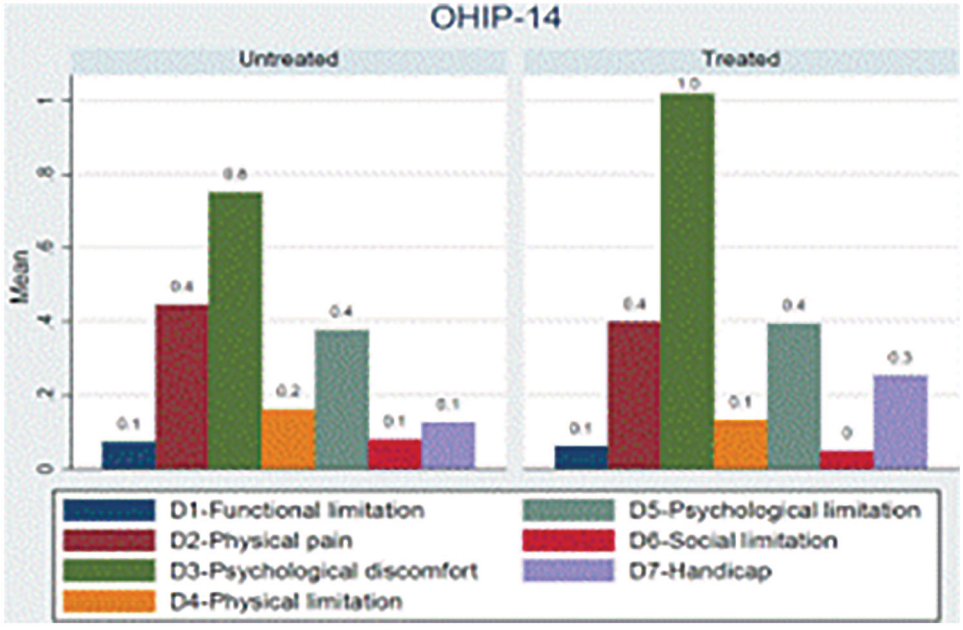

Figure 6. OHIP-14 scores per domain for the untreated and treated subjects.

'often' for the treated and untreated subjects were 12 and 10, respectively, and for 'fairly often' 6 and 13, respectively. Five questions were free of any negative impact; Q1, Q2, Q7, Q12, and Q14 (Supplementary Table 1). The linear models showed no relationship between total OHIP-14 and LII, PAR, DAI, age, gender or presence/absence of previous orthodontic treatment. However, the DAI score was significantly correlated with the OHIP-14 functional limitation domain (D1), an increase of 1 unit in OHIP-14 D1 correlating with an increase of 6.5 units in DAI score (p=.049, 95% CI = 0.03–12.96).

Reproducibility

The test re-test reliability of the OHIP-14 questionnaire ($n = 57$) showed a strong positive correlation within the groups (r_s=0.81; p<.001, r_s=0.93; p<.001 for the treated and untreated subjects, respectively). The intra- and inter-rater reproducibility of digital model measurements were excellent (Supplementary Table 2).

Discussion

The present study was designed to provide knowledge about malocclusion traits and OHRQoL in untreated young adults assessed to have no OTN during childhood, and in young adults treated orthodontically during childhood/adolescence. In addition, the study aimed to investigate the relationship between malocclusion and OHRQoL. Malocclusion and its relation to OHRQoL among young Danish adults has not previously been reported in the literature.

In the Netherlands, 39% of adolescents and young adults were assessed to have an OTN [18]. In the present study, 41 out of 96 subjects had been treated which is consistent with the fact that, in Denmark, 25–33% of the children and adolescents [1] receive free OT by the PDS up to the age of 18 years, provided that the malocclusion implies a foreseeable or extant risk of physical damage or psychosocial strain [1]. The treated subjects in this study had OT in one of the several PDS clinics in Jutland.

The prevalence of malocclusion falls in the 39–93% range depending on ethnic group, age and method of registration [19]. In early childhood, the most prevalent malocclusions are anterior open bite and posterior crossbite; whereas in school children, crowding and displacement of teeth are more common [20–22]. In Denmark, the prevalence of malocclusion in school children (9–15 years old) was recorded for the first time in 1965–1966 in an area North of Copenhagen where OT was rare and no PDS was available. Extreme overjet and deep bite were more prevalent among boys, whereas crossbite was more prevalent among girls. An association was observed between unilateral crossbite and displacement of the mandibular midline. Along the course of development, a decrease in the frequency of distal molar occlusion was observed. By 1982, PDS were implemented in that area, as a consequence, a decrease in the prevalence of distal molar occlusion, extreme overjet, crossbite, deep bite and scissor bite was noted, which reflected a treatment priority for Class II malocclusions [2].

In a systematic review [23], Class I was reported to be the most prevalent molar relationship worldwide in mixed and permanent dentitions, followed by Class II and lastly by Class III. However, Class II was more prevalent among Caucasians of Northern European descent (25% of Danish children), whereas Angle Class III was more prevalent among Asians (3–5% in Japan) [24]. In the present study, the prevalence of Class I was highest (51%), followed by Class II (41%), and lastly by Class III (8%), which is consistent with other studies [23]. Yet, there were no significant differences between treated and untreated subjects, which is consistent with the

findings by Jonsson et al. [25], where the prevalence of malocclusion among Icelandic adults was similar in treated and untreated subjects and a lower prevalence of overjet and a higher prevalence of molar crossbite was observed in the treated subjects. This is in contrast to the present study where the overjet was normal in both treated and untreated subjects, and the overbite was significantly lower in the treated subjects. This finding may suggest that malocclusions with highly increased overjet were treated during childhood or adolescence, supporting the findings of Helm et al. [2].

In the present study, untreated subjects, although they were assessed as 'not in OTN' during childhood, had significantly higher LII, PAR and DAI scores than their orthodontically treated peers, approximatively ten years post-treatment. The DAI detected a 64% OTN (DAI grades 2–4, Figure 4) in the untreated subjects, which is slightly higher than the typical OTN among Danish adolescents (range: 45–61%) [26]. This finding was unexpected, as all the subjects in the present cross-sectional study had been screened for malocclusion during childhood. Although the untreated subjects of this sample had been categorized as 'not in OTN' during childhood, their LII, PAR and DAI upon adulthood were significantly higher than those recorded in the orthodontically treated subjects. The present findings might suggest that the treated subjects, which had been selected for OT due to a higher degree of malocclusion than the untreated subjects, ultimately ended up with a significantly better occlusion than the untreated subjects in the long run, or that the untreated subjects developed a malocclusion after having been screened during childhood. Surprisingly, on the one hand, the molar relationships and overjet were not significantly different in the treated vs the untreated subjects. On the other hand, the PAR index was significantly lower in the treated than in the untreated subjects.

Regarding the larger arch width in the treated subjects compared to the untreated subjects, it may be assumed that this resulted from OT using fixed appliances with wide preformed arches, especially as the frequency of OT with premolar extractions was very low in this sample ($n = 3$). Assuming that the subjects were treated during adolescence, this might suggest that the expansion remained for a decade following OT.

In the present study, neither of the treated or untreated subjects had a perfect lower mandibular alignment. Almost 50% of the treated subjects had mild crowding, which is considered good in the long-term as OT occurred an average span of ten years before the present study was conducted, and some of the treated subjects were without fixed retainers. Hence, it may be hypothesized that the mild anterior crowding was due to the continuous processes of craniofacial growth and development, and to the dimensional dental changes that occur throughout life as part of regular 'maturation' as a consequence of ageing [27]. Indeed, mandibular crowding occurs in treated as well as untreated subjects as a consequence of physiologic tooth movement [10], which drives subjects to request re-treatment. In the present study, 12% of the treated subjects had undergone re-treatment in the past years due to relapse of spacing or crowding.

In the present study, fixed retention was observed in 28 out of the 41 treated subjects. In the Netherlands, orthodontists more commonly use fixed retainers than removable retainers [28]. Since this is a cross-sectional study with a one-time point reference, the original malocclusion was unknown, and it is hard to speculate as to what may have occurred after debonding. Still, the LII was significantly better in the treated subjects with fixed retainers than in subjects without fixed retainers, which runs contrary to the findings of Schutz-Fransson et al. [29]. Conversely, PAR scores were not significantly different in treated subjects with or without fixed retainers. This might be related to the scoring of the anterior displacement component of the PAR index: scoring is not based on the absolute value of the measured displacement but, instead, the measured value in millimetres falls into a range which is then given a score (e.g. a displacement measured anywhere between 0 and 1 mm is given a score of 0 points, whereas a displacement of 1.1-2 mm is given a score of 1 point). In contrast, the LII sums the absolute values. Nevertheless, in the absence of a lower fixed retainer, the region most affected by relapse is indeed the mandibular anterior region, which is evaluated by the LII, whereas the PAR index evaluates several different components.

In a survey of retention procedures, all Dutch orthodontists were aware of the phenomenon of 'active retainer', and 44% believed that the problem was caused by the properties of round multistranded wires [30]. In the present study, two cases were suspected to present unexpected post-treatment changes consisting of torque effects in the lower arch due to the presence of fixed retainers, as reported in the literature [31,32]. However, this is only a hypothesis as the initial malocclusion was unknown because of the cross-sectional design of this study.

The Danish criteria for defining OTN depend on a professionally defined need rather than a subjectively perceived need. As the ultimate goal of a health service is to meet public needs, objective measures may be supplemented by self-perceived OHRQoL [33]. The present study did not identify any correlation between total OHIP-14 and LII, PAR, DAI, age, gender or presence/absence of previous orthodontic treatment. However, the DAI score was significantly correlated with the OHIP-14 functional limitation domain. Evidence of the physical, psychological and social consequences of malocclusion and its associated treatment as regards to OHRQoL remains conflicting, the strength of evidence is relatively low and standardized methods to enhance comparability are needed [34,35]. The present findings partially support the results of Taylor et al. [4], stating that no significant relationship exists between OT of malocclusion and OHRQoL, if considering the total OHIP-14 score. However, the correlation observed between the DAI score and the OHIP-14 functional domain is in contradiction with Taylor et al. [4]. Given that over half of the untreated subjects were classified as in treatment need according to the DAI score, the correlation of the DAI score with functional limitation suggests that some of the untreated subjects

might have benefitted from an orthodontic treatment. However, though the results of this study might indicate that the criteria used to offer OT should be revised, studies on larger samples should be implemented before conclusions can be drawn in terms of implications for the Danish public health services.

There are some limitations in the present study: Most notably, this is a cross-sectional study assessing a one-time point rather than long-term dental changes in treated and untreated subjects. Furthermore, the sample size was calculated based on malocclusion traits, and not on OHRQoL features, which could result in an undersized sample in order to identify correlations between malocclusion and OHRQoL.

Conclusions

- Despite not being judged in need of OTN during childhood, upon adulthood, untreated Danes had a significantly higher OTN (DAI) than Danes treated during adolescence. Among the treated subjects, 37% fell into the OTN categories (DAI grades 2–4) in contrast to the untreated subjects where 64% had a treatment need.
- Untreated young Danish adults had a significantly higher deviation from normal occlusion (PAR) and anterior mandibular crowding (LII) than young Danish adults treated during adolescence.
- The prevalence of Angle Class I, II and III molar relationships was similar among young Danish adults whether they had been treated during adolescence or not. Class I occlusion was the most prevalent molar relationship; 51% (Class II; 41%, and Class III; 8%). Overjet was normal in both the treated and untreated subjects.
- Approximately ten years post-treatment, treated subjects had significantly larger inter-canine and inter-premolar distances than untreated young adults.
- No relationship was observed between total OHIP-14 and malocclusion traits (LII, PAR, DAI), age, gender or presence/absence of previous orthodontic treatment. However, the DAI score was significantly correlated with OHIP-14 functional limitation domain.

Acknowledgements

The authors would like to express their gratitude to Sarah Josefine Engberg, Martin Sørensen, Amalie Qvist & Aleksander Qvist (undergraduate dental students, Department of Dentistry and Oral Health, Aarhus, Denmark) for their assistance in recruiting and scanning the undergraduate students and to Sandro Leidi for statistical support.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the [Aarhus University Forskingsfond (AUFF)] under Grant [number 2432].

Author contributions

AG implemented the research under the supervision of MAC and PMC. MAC conceived the idea and initial study design and obtained the funding. AG developed the study design, added the concept of OHRQoL and the use of the DAI, wrote the study protocol, digitized the questionnaire and data collection forms and conducted the statistical analyses. AG wrote the manuscript in consultation of MAC and PMC. AG and SG collected the data and performed dental measurements. All authors read and approved the final manuscript.

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Data availability statement

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

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