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ORIGINAL ARTICLE

Impact of specific orthodontic parameters on the oral health-related quality of life in children and adolescents

A prospective interdisciplinary, multicentre, cohort study

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Abstract

Purpose The aim of the present study was to analyse the impact of specific orthodontic findings on oral health-related quality of life (OHRQoL) when taking into consideration age and psychological factors in children and adolescents.

Methods In all, 250 children and adolescents with an indication for orthodontic diagnostics were recruited using a multicentre study design. Using validated and internationally acknowledged questionnaires, we assessed OHRQoL, health-related quality of life (HRQoL), self-esteem and behavioural problems. We also examined a selection of specific orthodontic findings using photos, model casts and cephalometric analyses, and investigated the impact of these parameters on OHRQoL using simple linear regression analyses. Thereafter, we added all the significant specific orthodontic and psychological parameters to a multiple linear regression model using a stepwise forwards selection procedure.

Results We were able to identify different specific orthodontic findings that have a significant impact on OHRQoL. These were the type of lip closure, the position of the chin, the Little-index of the upper jaw, the overjet, the overbite and the ANB angle. Moreover, we were able to demonstrate that psychological and some specific orthodontic parameters have a significant impact on OHRQoL.

Conclusion Specific orthodontic findings have a significant impact on patients' perceived OHRQoL. Further longitudinal studies are required to investigate whether the treatment and correction of these malocclusions also improve the OHRQoL of children and adolescents.

Keywords Self esteem · Behavioural problems · COHIP-G19 · Orthodontics · Malocclusion

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Auswirkungen spezifischer kieferorthopädischer Parameter auf die mundgesundheitsbezogene Lebensqualität von Kindern und Jugendlichen

Eine prospektive, interdisziplinäre und multizentrische Kohortenstudie

Zusammenfassung

Ziel Ziel der vorliegenden Studie war es, die Auswirkungen spezifischer kieferorthopädischer Parameter auf die mundgesundheitsbezogene Lebensqualität unter Berücksichtigung demographischer und psychologischer Einflussfaktoren zu untersuchen.

Methodik Mittels multizentrischer Patientenakquise wurden 250 Patienten mit Indikation für eine kieferorthopädische Befundung in die Studie eingeschlossen. Mithilfe validierter und international anerkannter Fragebogeninstrumente wurden die mundgesundheitsbezogene Lebensqualität (MLQ), die gesundheitsbezogene Lebensqualität (GLQ), das Selbstwertgefühl und Verhaltensauffälligkeiten der Patienten ermittelt. Als kieferorthopädische Parameter wurden Befunde aus der Photostat-Untersuchung, Modellanalyse und Fernröntgenseitenanalyse einbezogen und mittels linearer Regressionsanalysen auf signifikante Zusammenhänge mit der MLQ untersucht. In einem zweiten Schritt wurde durch schrittweise Aufnahme aller signifikanten kieferorthopädischen und psychologischen Parameter ein multiples lineares Regressionsmodell aufgestellt.

Ergebnisse Für folgende kieferorthopädische Parameter konnte ein signifikanter Zusammenhang mit der MLQ nachgewiesen werden: Lippenschluss, Profiltyp, Little-Index für den Oberkiefer, Overjet, Overbite und ANB-Winkel. Zudem konnte gezeigt werden, dass sowohl psychologische als auch spezifische kieferorthopädische Parameter gemeinsam einen signifikanten Einfluss auf die MLQ haben.

Zusammenfassung Spezifische kieferorthopädische Parameter haben einen signifikanten Einfluss auf die vom Patienten empfundene MLQ. Mittels weiterer Studien bleibt zu klären, ob durch die Korrektur von Zahn- und Kieferfehlstellungen die MLQ der Patienten verbessert werden kann.

Schlüsselwörter Selbstwertgefühl · Verhaltensauffälligkeiten · COHIP-G19 · Kieferorthopädie · Zahn- und Kieferfehlstellungen

Introduction

Over the last few decades, the patient's subjective perception of his/her dental health status has become more important in dentistry [8, 9]. The concept of oral health-related quality of life (OHRQoL) was introduced to quantify this patient-determined health status. This is a patient-reported assessment that uses questionnaires to measure the impact of the orofacial system on quality of life [13]. By linking dental health to quality of life, OHRQoL constitutes a multidimensional construct that includes physical, emotional, mental, social and behavioural components of well-being and function [18].

The impact of oral conditions such as caries or malocclusions on OHRQoL, as well as the effect of dental and orthodontic therapies, respectively, has already been investigated by various studies [4, 6, 7, 14, 15, 21]. Kragt et al. published a meta-analysis demonstrating a negative correlation between OHRQoL and malocclusions [13]. However, this meta-analysis also noted that many potential influencing factors, such as sex, socioeconomic status (SES) or self-esteem, have not been taken into consideration in the majority of investigations. It is for that reason that we previously conducted a prospective interdisciplinary, multicentre, cohort study to investigate the correlation between OHRQoL and orthodontic treatment need of children and adolescents where demographic and psychological factors were taken into account [14]. Our results showed that orthodontic treatment need is significantly correlated with OHRQoL, but also with several demographic and psychological factors like age, health-related quality of life (HRQoL), self-esteem and behavioural problems. In contrast, other factors like sex, body mass index (BMI) or SES did not have any impact on OHRQoL in the course of this investigation. As this previous orthodontic evaluation was based on commonly used indices of orthodontic treatment need such as IOTN (Index of Orthodontic Treatment Needs) and DAI (Dental Aesthetic Index), we were unable to identify specific orthodontic findings that directly affect OHRQoL.

In continuation of our earlier investigation, the aims of the present study were to (1) identify specific orthodontic parameters that influence OHRQoL and (2) interpret these variables when taking into consideration age and psychological factors.

Patients and methods

Patients

A total of 250 patients were recruited for this investigation according to the sample size calculation performed by the

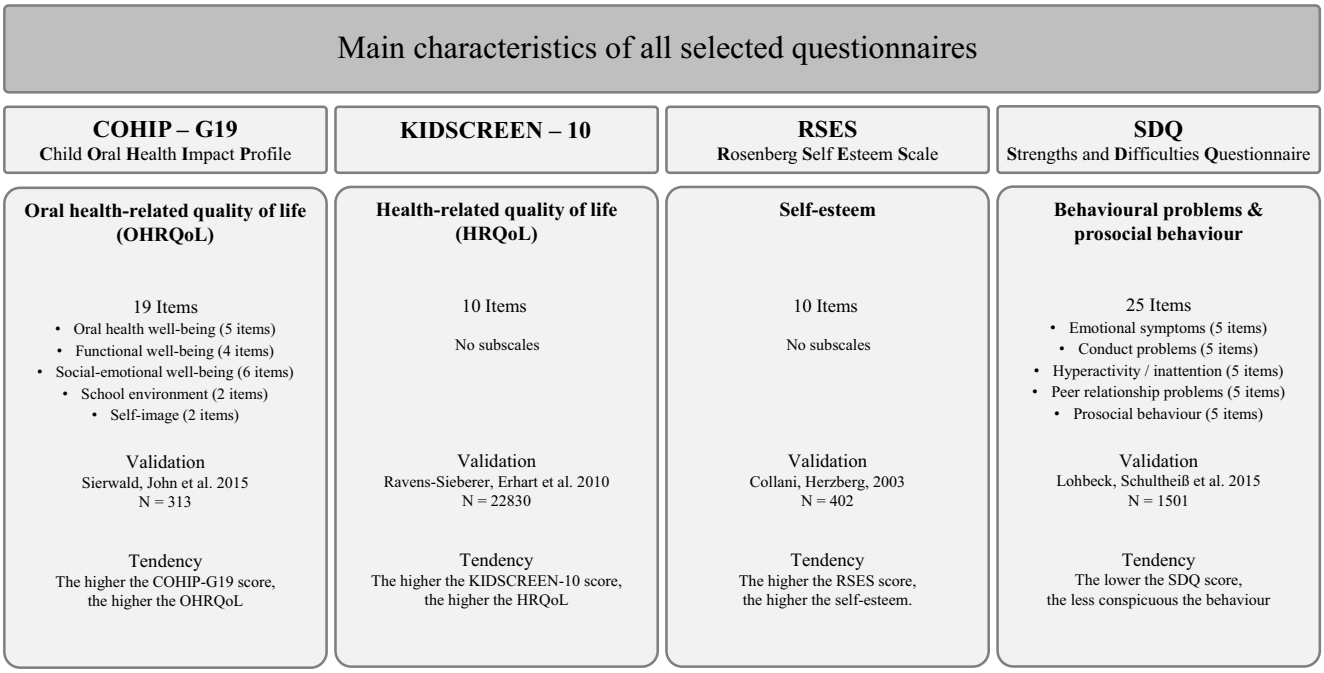

Fig. 1 Overview of the main characteristics of all selected questionnaires
Abb. 1 Übersicht über die Hauptmerkmale der ausgewählten Fragebogeninstrumente

Institute of Clinical Epidemiology and Biometry of the University of Würzburg over a time interval of about 14 months. In order to acquire a sufficiently large patient cohort, a multicentre study design was chosen that included three university departments of orthodontics (University Hospital of Würzburg, University Hospital of Regensburg and University Hospital of Erlangen, altogether 104 patients) and one orthodontic dental practice (146 patients). This cohort was the same sample as in our earlier investigation [14].

All the patients of the cooperating partners who fulfilled the following inclusion criteria were asked to participate in the study: (1) age between 7 and 17 years, (2) satisfactory knowledge of the German language with (3) adequate reading skills and (4) an indication for complete orthodontic diagnostics. Patients with congenital craniofacial anomalies and those with already initiated or completed orthodontic treatment in the past were excluded. There was no other preselection of the participants.

Methods

The ethics committee of the University Hospital of Würzburg approved the research (# 305/17), which was carried out in accordance with the Declaration of Helsinki. All the participants and parents gave their oral and written informed consent.

Psychological questionnaires

The selection of the psychological questionnaires was conducted in cooperation with the Institute of Clinical Psychology of the University of Würzburg. For international comparability purposes, we only used acknowledged English language questionnaires with a validated German version. The specific characteristics of the questionnaires are illustrated in Fig. 1.

The German version of the Child Oral Health Impact Profile (COHIP-G19; 19 items) was used to assess OHRQoL as the target parameter of the investigation [22]. This questionnaire is validated for children and adolescents aged between 7 and 17 years and uses a 5-point Likert-type scale. The higher the total value of the COHIP-G19, the better the perceived OHRQoL.

The KIDSCREEN-10 index (10 items) was used to assess HRQoL. This questionnaire is a very economic and reliable tool for measuring HRQoL and is available in many languages. It also uses a 5-point Likert-type scale. The higher the total value of the KIDSCREEN-10 index, the better the perceived HRQoL [20].

In order to identify behavioural problems as possible influencing factors on OHRQoL, all the patients completed the Strengths and Difficulties Questionnaire (SDQ; 25 items). This is a validated screening tool for detecting emotional problems, hyperactivity, problems with regard to social interaction with peers and prosocial behaviour in children and adolescents. The 3-point Likert-type scale

ranges from "not true" to "certainly true". Higher total values indicate a higher probability of behavioural problems [16].

We used the Rosenberg Self-Esteem Scale (RSES) to examine our patients' self-esteem. This is a 10-item questionnaire assessing self-esteem according to a 4-point Likert scale. High values indicate high self-esteem [25].

Course of the study

As the patients were recruited from three university departments of orthodontics and one orthodontic dental practice, all the cooperating partners were informed about the study design and were trained in how to assess all the required parameters. An orthodontist with many years of experience in clinical practice conducted this training.

All the patients of the cooperating partners who fulfilled the inclusion criteria were asked to participate in the study. A trained member of the staff from the cooperating partners informed all the patients and their parents about the concept of the study. If both patients and parents gave their informed consent, the former were included in the research.

On the day of the orthodontic diagnostics at the start of therapy, the patients received the questionnaires (altogether 64 items; duration about 25 min) and completed them independently and without any influence of their parents. The standardised orthodontic diagnostics consisted of detailed anamnesis, functional diagnoses, extraoral photos (norma frontalis, smile image and norma lateralis), an orthopantomogram, lateral cephalometrics and impressions for plaster models. On this basis, we assessed a selection of orthodontic parameters that evaluate specific tooth or jaw anomalies. An overview of these parameters is depicted in Table 1. If average values were available, we defined the variable as the absolute value of the difference from this average value and marked these parameters with "Δ".

All the information and orthodontic findings on the patients were pseudonymised using a 4-digit code. Only one copy of the encryption list was stored physically separate from the questionnaires, and without access for the treating physicians, in order to guarantee data protection.

In order to achieve consistent quality of all parameters, the same experienced scientific member of the University of Würzburg who trained the cooperating partners also conducted the analysis of the questionnaires and the orthodontic measurements. No interrater reliability analysis was therefore necessary. Intrarater reliability was assessed by remeasuring all the orthodontic parameters in 20 randomly selected patients after 2 months by the same examiner.

Statistical analysis

A professional biometrician at the Centre of Clinical Studies at the University Medical Centre Regensburg supported all the statistical analyses using the software programme IBM®, SPSS®, Statistics Version 24.0 for Windows (IBM, Ehningen, Germany). All the continuous variables are presented as the mean (*M*), standard deviation (*SD*), minimum (*min*) and maximum (*max*) value. The normal distribution of the data was verified using graphic control charts. Categorical data are presented as absolute and relative frequencies.

The intrarater reliability of the orthodontic parameters was verified by calculating the intraclass correlation coefficients (*ICC*) for all the variables of the 20 patients that had been analysed twice.

Simple linear regression models were calculated to assess the predictive values of all the specific orthodontic parameters (= predictors) on the COHIP-G19 (= criterion). The degrees of freedom (*F*), the coefficient of determination (R^2), the *p*-value and the regression coefficient (*B*) are presented. The linear relationships between the predictors and criterion were verified graphically using scatter plots.

In a second step, we analysed which of the variables were independent predictors of OHRQoL using a multiple linear regression analysis. We considered all the orthodontic variables that had a significant impact on the COHIP-G19 in the simple linear regressions. We also took into account the age of the patients and the psychological parameters (KIDSCREEN-10, SDQ, RSES), as they also had a significant impact on the COHIP-G19 in our preparatory investigation [14]. In an automated forward-type selection model, predictors were added stepwise to the linear regression model, while the variable with the most statistically significant improvement of fit was added in each step.

The significance level was 5% for all the procedures.

Results

Descriptive results

The intrarater reliability of all the orthodontic parameters examined was very high (ICC ≥0.900). The mean value of the COHIP-G19 as the central variable in the investigation was $M = 63.20$ ($SD = 7.52$; range 19.00 to 75.00). This questionnaire was completed by 248 of the 250 participants. The distribution of the patient cohort was evenly balanced (52.4% male and 47.6% female).

The descriptive statistics of the orthodontic parameters are illustrated in Tables 2 and 3. In some patients, individual orthodontic variables could not be determined because of individual problems such as agenesis of teeth or poor quality of the photos or x-rays. Some of the *N* values there-

Table 1 Definition of the specific orthodontic parameters
Tab. 1 Definition der spezifischen kieferorthopädischen Parameter

	Variable	Unit	Definition	Average value
Photo analysis	Lip closure		Lip closure without contraction of the perioral muscles (0 = incompetent or potentially competent lip closure/1 = competent lip closure)	–
	Type of face		Type of face, according to the evaluation of A.M. Schwarz (0 = straight face/1 = forwards or backwards face)	–
	Position of the chin		Position of the chin, according to the evaluation of A.M. Schwarz (0 = straight chin/1 = forward or backward chin)	–
Model cast analysis	SI-upper	mm	Summa incisiva—upper jaw: sum of the width of the following teeth: 12, 11, 21 and 22	–
	SI-lower	mm	Summa incisiva—lower jaw: sum of the width of the following teeth: 32, 31, 41 and 42	–
	Medial diastema	mm	Width of the gap between 11 and 21	0.0 mm
	Deviation of the midline	mm	Deviation of the upper and the lower dental midline	0.0 mm
	Little-index-upper	mm	Sum of the deviations of the contact points of the upper frontal teeth (13 mesial to 23 mesial) parallel to the occlusal plane	0.0 mm
	Little-index-lower	mm	Sum of the deviations of the contact points of the lower frontal teeth (33 mesial to 43 mesial) parallel to the occlusal plane	0.0 mm
	Δ-Space-upper	mm	Sum of all crowding and of all gaps in the area of the upper frontal teeth (13 mesial to 23 mesial); *absolute value of the difference to the standard value*	0.0 mm
	Δ-Space-lower	mm	Sum of all crowding and of all gaps in the area of the lower frontal teeth (33 mesial to 43 mesial); *absolute value of the difference to the standard value*	0.0 mm
	Δ-Occlusion	mm	Largest deviation from neutral occlusion in the sagittal direction (right or left); *absolute value of the difference to the standard value*	0.0 mm
	Δ-Overjet	mm	Sagittal relation of the frontal teeth; *absolute value of the difference to the standard value*	2.0 mm
	Δ-Overbite	mm	Vertical relation of the frontal teeth; *absolute value of the difference to the standard value*	2.0 mm
Cephalometric analysis	Δ-SNA	°	Angle between the Sella, Nasion and A-Point; *absolute value of the difference to the standard value*	81.0
	Δ-SNB	°	Angle between the Sella, Nasion and B-Point; *absolute value of the difference to the standard value*	79.0
	Δ-ANB	°	Angle between the A-Point, Nasion and B-Point; *absolute value of the difference to the standard value*	2.0
	Δ-SN-SpP	°	Angle between the Sella-Nasion line and the planum of the upper jaw; *absolute value of the difference to the standard value*	7.0
	Δ-SN-MeGo	°	Angle between the Sella-Nasion line and the planum of the lower jaw; *absolute value of the difference to the standard value*	33.0
	Δ-SpP-MeGo	°	Angle between the planum of the upper and lower jaw; *absolute value of the difference to the standard value*	26.5
	Δ-1-SN	°	Angle between the most anteriorly positioned incisor of the upper jaw and the Sella-Nasion line; *absolute value of the difference to the standard value*	103.0
	Δ-1-MeGo	°	Angle between the most anteriorly positioned incisor of the lower jaw and the planum of the lower jaw; *absolute value of the difference to the standard value*	93.0
	Δ-1-upper-NPog	mm	Sagittal distance between the Nasion-Pogonion line and the incisal edge of the most anteriorly positioned incisor of the upper jaw; *absolute value of the difference to the standard value*	6.5 mm

Table 1 (Continued)
Tab. 1 (Fortsetzung)

	Variable	Unit	Definition	Average value
	Δ-1-lower-NPog	mm	Sagittal distance between the Nasion-Pogonion line and the incisal edge of the most anteriorly positioned incisor of the lower jaw; *absolute value of the difference to the standard value*	2.5 mm
	Δ-Labrale sup-EL	mm	Sagittal distance between the esthetic line (EL) and the upper lip; *absolute value of the difference to the standard value*	–2.0 mm
	Δ-Labrale inf-EL	mm	Sagittal distance between the esthetic line (EL) and the lower lip; *absolute value of the difference to the standard value*	–0.5 mm

Table 2 Descriptive statistics of the specific orthodontic parameters (nominal variables)
Tab. 2 Deskriptive Statistik der spezifischen kieferorthopädischen Parameter (nominale Variablen)

	Variable	*N*	Options	Rate	%
Photo analysis	Lip closure	248	Competent	195	78.6
			Incompetent or potentially competent	53	21.4
	Type of face	247	Straight face	80	32.4
			Forwards or backwards face	167	67.6
	Position of the chin	248	Straight chin	38	15.3
			Forwards or backwards chin	210	84.7

N sample size

Table 3 Descriptive statistics of the specific orthodontic parameters (metrical and ordinal variables)
Tab. 3 Deskriptive Statistik der spezifischen kieferorthopädischen Parameter (metrische und ordinale Variablen)

	Variable[a]	Unit	*N*	*M*	*SD*	*Min*	*Max*
Model cast analysis	SI-upper	mm	230	30.97	2.20	26.10	37.21
	SI-lower	mm	242	22.93	1.45	19.15	26.99
	Medial diastema	mm	237	0.35	0.67	0.00	3.70
	Deviation of the midline	mm	243	1.13	0.92	0.00	4.50
	Little-index-upper	mm	238	6.30	4.24	0.00	27.91
	Little-index-lower	mm	240	3.86	2.68	0.49	15.84
	Δ-Space-upper	mm	238	2.28	1.92	0.00	11.00
	Δ-Space-lower	mm	240	2.34	1.85	0.00	10.00
	Δ-Occlusion	mm	242	5.12	2.90	0.00	16.00
	Δ-Overjet	mm	244	3.33	2.24	0.00	11.50
	Δ-Overbite	mm	244	2.08	1.36	0.00	9.31
Cephalometric analysis	Δ-SNA	°	244	3.04	2.18	0.00	10.00
	Δ-SNB	°	244	3.10	2.16	0.00	11.80
	Δ-ANB	°	244	2.43	1.74	0.00	7.40
	Δ-SN-SpP	°	244	2.81	2.15	0.00	9.70
	Δ-SN-MeGo	°	244	4.81	3.48	0.00	17.80
	Δ-SpP-MeGo	°	244	4.99	3.53	0.00	15.80
	Δ-1-SN	°	245	6.32	4.78	0.20	23.50
	Δ-1-MeGo	°	245	6.14	4.38	0.00	22.00
	Δ-1-upper-NPog	mm	245	2.73	2.29	0.00	12.20
	Δ-1-lower-NPog	mm	245	2.19	1.82	0.00	7.70
	Δ-Labrale sup-EL	mm	245	1.99	1.70	0.00	8.00
	Δ-Labrale inf-EL	mm	245	2.21	1.87	0.00	9.50

N sample size, *M* mean value, *SD* standard deviation, *Min* minimum value, *Max* maximum value
[a]See Table 1 for definitions

Table 4 Simple linear regression analyses with COHIP-G19 as the dependent variable and the specific orthodontic parameters as predictors
Tab. 4 Einfache lineare Regressionsanalysen mit dem COHIP-G19 als abhängige Variable und den spezifischen kieferorthopädischen Parametern als Prädiktoren

	Predictor[a]	Unit	*N*	R^2	*B*	*95% CI*		*p*	*S*
						Lower limit	*Upper limit*		
Photo analysis	Lip closure		246	0.019	2.576	0.259	4.894	0.029	*
	Type of face		245	0.000	0.032	–2.003	2.068	0.975	n. s.
	Position of the chin		246	0.018	–2.810	–5.410	–0.210	0.034	*
Model cast analysis	SI-upper	mm	228	0.004	–0.212	–0.668	0.243	0.359	n. s.
	SI-lower	mm	240	0.001	0.186	–0.482	0.855	0.584	n. s.
	Medial diastema	mm	235	0.010	–1.138	–2.601	0.325	0.127	n. s.
	Deviation of the midline	mm	241	0.005	0.569	–0.479	1.617	0.286	n. s.
	Little-index-upper	mm	236	0.061	–0.447	–0.672	–0.221	0.000	**
	Little-index-lower	mm	238	0.001	–0.076	–0.439	0.288	0.682	n. s.
	Δ-Space-upper	mm	236	0.003	–0.223	–0.734	0.228	0.390	n. s.
	Δ-Space-lower	mm	238	0.000	–0.022	–0.548	0.504	0.934	n. s.
	Δ-Occlusion	mm	240	0.000	–0.052	–0.386	0.282	0.760	n. s.
	Δ-Overjet	mm	242	0.065	–0.863	–1.279	–0.448	0.000	**
	Δ-Overbite	mm	242	0.023	–0.848	–1.546	–0.150	0.018	*
Cephalometric analysis	Δ-SNA	°	242	0.011	–0.364	–0.805	0.077	0.105	n. s.
	Δ-SNB	°	242	0.007	–0.301	–0.744	0.142	0.181	n. s.
	Δ-ANB	°	242	0.020	–0.623	–1.172	–0.075	0.026	*
	Δ-SN-SpP	°	242	0.001	0.082	–0.369	0.533	0.719	n. s.
	Δ-SN-MeGo	°	242	0.000	–0.015	–0.293	0.263	0.918	n. s.
	Δ-SpP-MeGo	°	242	0.001	0.051	–0.222	0.323	0.715	n. s.
	Δ-1-SN	°	243	0.001	–0.059	–0.259	0.141	0.563	n. s.
	Δ-1-MeGo	°	243	0.000	–0.004	–0.224	0.216	0.971	n. s.
	Δ-1-upper-NPog	mm	243	0.014	–0.394	–0.810	0.022	0.064	n. s.
	Δ-1-lower-NPog	mm	243	0.008	–0.372	–0.895	0.152	0.164	n. s.
	Δ-Labrale sup-EL	mm	243	0.007	–0.363	–0.926	0.200	0.205	n. s.
	Δ-Labrale inf-EL	mm	243	0.002	–0.177	–0.691	0.336	0.497	n. s.

N sample size, R^2 coefficient of determination, *B* regression coefficient, *p* *p*-value, *S* significance, *COHIP-G19* Child Oral Health Impact Profile, 19 item, German version, *CI* confidence interval, *n. s.* = not significant
*Significance (S) for $p \leq 0.05$
**Significance (S) for $p \leq 0.01$
[a]See Table 1 for definitions

fore deviate from the total number of patients participating in the investigation.

The descriptive analyses of the demographic and psychological factors have already been described in our previous investigation [14].

Simple linear regression analysis

The results of the simple linear regression analysis of all the specific orthodontic parameters examined are depicted in Table 4.

There was a significantly higher total COHIP-G19 score in patients with a competent lip closure than in those with an incompetent or potentially competent lip closure ($R^2 = 0.019$; $F(1, 244) = 4.796$; $p = 0.029$, $B = 2.576$). The position of the chin was also correlated with OHRQoL ($R^2 = 0.018$; $F(1, 244) = 4.531$; $p = 0.034$, $B = –2.810$), with higher overall COHIP-G19 scores in patients with straight chins. Of the parameters of the model cast analysis, the Little-index-upper ($R^2 = 0.061$; $F(1, 234) = 15.232$; $p < 0.001$, $B = –0.447$), the Δ-Overjet ($R^2 = 0.065$; $F(1, 240) = 16.750$; $p < 0.001$, $B = –0.863$) and the Δ-Overbite ($R^2 = 0.023$; $F(1, 240) = 5.724$; $p = 0.018$, $B = –0.848$) were significantly correlated with the COHIP-G19. The greater the difference to the average values, the lower the perceived OHRQoL of the patients. In the cephalometric analysis, Δ-ANB ($R^2 = 0.020$; $F(1, 240) = 5.007$; $p = 0.026$, $B = –0.623$) was the only parameter that correlated with the COHIP-G19, with a higher OHRQoL in patients with an ANB-value matching the average value.

Table 5 Multiple linear regression analysis with COHIP-G19 as the dependent variable. Forward-type selection of all the demographic, psychological and specific orthodontic parameters that had a statistically significant impact on the COHIP-G19 (p-value <0.05) in the simple linear regressions

Tab. 5 Multiple lineare Regression mit dem COHIP-G19 als abhängige Variable. Vorwärtsselektion aller demographischen, psychologischen und spezifischen kieferorthopädischen Parameter, die im Rahmen der einfachen linearen Regressionen einen signifikanten Zusammenhang mit dem COHIP-G19 ($p < 0{,}05$) aufwiesen

	Model	Predictors	R^2	R^2-*Change*	p	S
Forward-type selection of the predictors	1	SDQ	0.197	0.197	0.000	**
	2	SDQ, KIDSCREEN-10	0.244	0.047	0.000	**
	3	SDQ, KIDSCREEN-10, Δ-Overjet	0.289	0.045	0.000	**
	4	SDQ, KIDSCREEN-10, Δ-Overjet, Little-index-upper	0.308	0.019	0.020	*
	5	SDQ, KIDSCREEN-10, Δ-Overjet, Little-index-upper, Δ-Overbite	0.323	0.015	0.036	*

	N	R^2	Predictors	*B*	*95% CI*		*p*	*S*
					Lower limit	*Upper limit*		
Final model of the multiple linear regression analysis	205	0.323	Constant	61.839	55.196	68.482	0.000	**
			SDQ	–0.502	–0.715	–0.290	0.000	**
			KIDSCREEN-10	0.190	0.096	0.284	0.000	**
			Δ-Overjet	–0.467	–0.916	–0.019	0.041	*
			Little-index-upper	–0.291	–0.524	–0.057	0.015	*
			Δ-Overbite	–0.725	–1.401	–0.050	0.036	*

N sample size, R^2 coefficient of determination, *B* regression coefficient, *p* *p*-value, *S* significance, *COHIP-G19* Child Oral Health Impact Profile—19 item, German version, *CI* confidence interval, *SDQ* Strengths and Difficulties Questionnaire
*Significance (S) for $p \leq 0.05$/
**Significance (S) for $p \leq 0.01$

The results of the simple linear regression analysis of the impact of the demographic and psychological parameters on OHRQoL have already been published in our previous investigation [14]. In this, we demonstrated a statistically significant correlation between OHRQoL and age, general HRQoL, self-esteem and behavioural problems. In contrast, no significant correlation was found between OHRQoL and sex, BMI and SES.

Multiple linear regression analysis

The results of the multiple linear regression analysis are shown in Table 5.

All the demographic, psychological and orthodontic parameters that had a statistically significant impact on the COHIP-G19 (p-value <0.05) in the simple linear regression analyses were considered to be potential predictors for the multiple linear regression analysis. These were age, the KIDSCREEN-10, the SDQ, the RSES, lip closure, the position of the chin, the Little-index-upper, the Δ-Overjet, the Δ-Overbite and the Δ-ANB. As in the single linear regression analyses, the COHIP-G19 was the criterion for the multiple linear regression analysis.

We used a forward-type selection of the aforementioned parameters for the final multiple regression analysis. The order of the selection in the model was as follows: (1) SDQ (R^2-change = 0.197; $p < 0.001$); (2) KIDSCREEN-10 (R^2-change = 0.047; $p < 0.001$); (3) Δ-Overjet (R^2-change = 0.045; $p < 0.001$); (4) Little-index-upper (R^2-change = 0.019; $p = 0.020$); and (5) Δ-Overbite (R^2-change = 0.015; $p = 0.036$). Adding further variables (age, RSES, lip closure, position of the chin and Δ-ANB) did not significantly improve the R^2-change. These parameters were therefore not included in the final multiple regression model.

Using the five selected parameters, the final multiple linear regression model ($R^2 = 0.323$; $F(5, 199) = 18.972$; $p < 0.001$) was statistically significant and explained 32.3% of the total variance in OHRQoL.

Discussion

The present investigation is a prospective interdisciplinary, multicentre, cohort study. The advantage of this multicentre design is that we were able to recruit a patient cohort that was large enough for the statistical evaluation. However, the basis for a multicentre study is that all cooperating partners must meet the same standards concerning data assessment. To this end, the principal investigator trained and informed all the cooperating partners with regard to the exact course of the study and gave support whenever needed. In order to avoid any interrater bias, the evaluation of all the parameters was carried out by the same experienced orthodontist

at the University Medical Centre Würzburg. The intrarater reliability was very high, demonstrating an excellent reproducibility of the results.

The selection of the questionnaires for assessing OHRQoL and the other psychological parameters was conducted in cooperation with the Institute of Clinical Psychology at the University of Würzburg. All the questionnaires were age-adapted to children and adolescents [1, 11].

There are only two instruments available in the German language that guarantee German validation and international comparability when it comes to assessing OHRQoL in children and adolescents: the Child Perceptions Questionnaire (CPQ-$G_{11–14}$) and the COHIP-G19. Although the CPQ-$G_{11–14}$ is the more widely used questionnaire, with high reliability and validity [2, 3, 13, 17], we decided to use the COHIP-G19 because the validation of the CPQ-$G_{11–14}$ is restricted to adolescents aged from 11 to 14. In contrast, the COHIP-G19 is validated for the ages 7 to 17. As a result, we were able to recruit a patient cohort with all kinds of orthodontic anomalies, from early mixed dentition to permanent dentition. Another advantage of the broader range of age of the COHIP-G-19 is that it enables longitudinal comparisons for further investigations. Additionally, the COHIP-G19 fulfils the requirement of a short and economic questionnaire for assessing OHRQoL in children and adolescents; it consists of only 19 questions compared to the 37 items of the CPQ-$G_{11–14}$ [5, 24]. As we assessed additional psychological parameters such as HRQoL, behavioural problems and self-esteem, the length of the questionnaires used played an important role. We therefore chose short questionnaires that also guarantee German validation and international comparability. To this end, we decided to use the KIDSCREEN-10 index to assess HRQoL, the RSES to determine self-esteem and the SDQ to assess behavioural problems [16, 20, 25]. Taken together, all the patients had to answer 64 items that took a combined total of about 25 min. Nevertheless, we also met the requirements of the recent meta-analysis by Kragt et al. that investigations on OHRQoL should not forget to consider important psychological cofactors [13].

In our previous investigation, we were able to identify a significant correlation between OHRQoL and the objective orthodontic treatment need [14]. Therefore, teeth and jaw misalignments seem to have a significant impact on OHRQoL. In continuing this investigation, the main aim of this study was to determine which orthodontic anomalies are responsible for this correlation. There are very few studies available with such a purpose. In comparison to a control group, Johal et al. (2007) demonstrated a significantly limited OHRQoL in patients with an increased overjet and medial diastema [10]. However, Ramos-Jorge et al. (2015) were unable to prove the correlation between OHRQoL and overjet. Instead, they found a significant impact of a frontal open bite on OHRQoL [19]. Sierwald et al. (2015) also investigated the impact of overjet and overbite on OHRQoL, but only found a significant correlation for the overjet [23]. This was confirmed by Kallunki et al. in 2018 [12]. In summary, the literature provides us with inconsistent information about the impact of specific orthodontic findings on OHRQoL.

In the present investigation, we analysed the parameters of the photos, model casts and cephalometric analyses for possible correlation with the COHIP-G19. By using simple linear regression analyses, we were able to demonstrate significant correlations between OHRQoL and lip closure (competent lip closure vs. incompetent or potentially competent lip closure), the position of the chin (straight chin vs. forwards or backwards chin), the Little-index-upper, the Δ-Overjet, the Δ-Overbite and the Δ-ANB.

In a further step, we investigated if the correlations between these specific orthodontic findings and OHRQoL are also significant if demographic and psychological parameters are also assessed. We therefore performed a multiple linear regression analysis that took into account the age of the patients, the KIDSCREEN-10 index, the RSES, the SDQ, and all the specific orthodontic parameters that had a significant impact on the COHIP-G19 in the simple linear regression analyses. Using a forward-type selection of the aforementioned parameters, we were able to demonstrate that psychological (KIDSCREEN-10 and SDQ) and some orthodontic parameters (Δ-Overjet, Little-index-upper and Δ-Overbite) together had a significant impact on OHRQoL. It should be noted that all three selected orthodontic parameters are located in the visible part of the jaw and might therefore affect patient perceptions. It is also noteworthy that the overjet and overbite were analysed with respect to their average values. Consequently, it is not possible to specify if an increased or decreased overjet or overbite has a different impact on OHRQoL. Further investigations with larger patient cohorts might clarify this. Thus, our multiple linear regression analysis shows that both psychological and orthodontic parameters have to be considered when analysing OHRQoL. To date, this is the first published multiple linear regression analysis with this purpose. Knowledge of the orthodontic findings affecting OHRQoL might help orthodontists to understand why patients choose to undergo orthodontic therapy.

Conclusion

The aim of this prospective interdisciplinary, multicentre, cohort study was to investigate the impact of specific orthodontic findings on the OHRQoL of children and adolescents. To this end, we considered a huge variety of specific orthodontic parameters, some of them for the first time in

this context. As a consequence, we were able to identify six parameters that significantly influence OHRQoL.

In cooperation with the Institute of Clinical Psychology at the University of Würzburg, we selected validated and internationally acknowledged questionnaires to assess both OHRQoL and psychological cofactors that potentially influence OHRQoL such as self-esteem or behavioural problems. Using a multiple linear regression analysis, we were able to demonstrate that psychological and specific orthodontic parameters have a significant impact on OHRQoL at the same time. It is therefore necessary to consider both psychological and orthodontic parameters when interpreting OHRQoL. Further longitudinal studies are required to investigate if the treatment of these malocclusions also improves the OHRQoL of children and adolescents.

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Compliance with ethical guidelines

Conflict of interest F. Kunz, P. Platte, S. Keß, L. Geim, F. Zeman, P. Proff, U. Hirschfelder and A. Stellzig-Eisenhauer declare that they have no competing interests.

Ethical standards All procedures performed in studies involving human participants or on human tissue were in accordance with the ethical standards of the institutional and/or national research committee and with the 1975 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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