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Cover picture: Logo der Sechsten Deutschen Mundgesundheitsstudie (DMS 6) mit dem Schwerpunkt Kieferorthopädie (© Institut der Deutschen Zahnärzte, IDZ)

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ORIGINAL ARTICLE

Prevalence of malocclusions in 8- and 9-year-old children in Germany—Results of the Sixth German Oral Health Study (DMS 6)

Andreas Rainer Jordan[1] · Kathrin Kuhr[1] · Nicolas Frenzel Baudisch[1] · Christian Kirschneck[2]

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Abstract

Purpose Current population-wide data on the prevalence of malocclusions in 8- and 9-year-old children in Germany are not available. Therefore, the primary objective of this study was to collect data on the prevalence of malocclusions in 8- and 9-year-old children in Germany. The secondary objective of this study was to use this information to derive the need for orthodontic care provision.

Methods This is an oral–epidemiological investigation and social science survey at the national level with a focus on tooth and jaw misalignment. The investigation took place between January and March 2021 at 16 study centers across Germany. All relevant data were available for the 705 study participants and were included in the statistical analysis.

Results Overbite was the most common finding with 88.9%. Also widespread were crowding, with at least 60.9%, and lack of space, with a share of 30.9%. All other indication groups had a share below 10%. Rare (<1%) were buccal and lingual occlusions and craniofacial abnormalities. The most severe forms of disease (Orthodontic Indication Group [Kieferorthopädische Indikationsgruppen, KIG] grade 5) were overbite (3.2%), open bite malocclusion (1.0%), undershot (0.6%), and craniofacial abnormalities (0.4%). The proportion of study participants who required orthodontic treatment, in accordance with statutory health insurance provider guidelines, was 40.4%. The proportion of study participants in principle requiring orthodontic treatment for medical reasons was 97.5%. Systemic differences in the need for orthodontic care provision relating to gender, region, or social status were not identified.

Conclusion In general, the need for care provision identified in the orthodontic indication groups corresponds to that shown in previous studies. This suggests that the need for orthodontic treatment in Germany has remained stable over the years.

Keywords Index of Complexity, Outcome and Need · Epidemiology · Orthodontics · KIG classification · Health care research

Prävalenz von Zahn- und Kieferfehlstellungen 8- und 9-jähriger Kinder in Deutschland – Ergebnisse der Sechsten Deutschen Mundgesundheitsstudie (DMS 6)

Zusammenfassung

Ziel Aktuelle, bevölkerungsweite Daten zur Verbreitung von Zahn- und Kieferfehlstellungen in Deutschland liegen nicht vor. Es war daher das primäre Ziel dieser Studie, die Verbreitung von Zahn- und Kieferfehlstellungen bei 8- und 9-jährigen Kindern in Deutschland zu erfassen. Es war das sekundäre Ziel dieser Studie, daraus den kieferorthopädischen Versorgungsbedarf abzuleiten.

Study Registration Before beginning, the study was registered with the German Clinical Trials Register (DRKS www.drks.de): DRKS00022472.

✉ Prof. Dr. Andreas Rainer Jordan
r.jordan@idz.institute

[1] Institute of German Dentists, Universitätsstr. 73, 50931 Cologne, Germany

[2] Department for Orthodontics, University Hospital Regensburg, Franz-Josef-Strauß-Allee 11, 93053 Regensburg, Germany

Methode Es handelt sich um einen oralepidemiologischen Untersuchungs- und sozialwissenschaftlichen Befragungssurvey auf national repräsentativer Ebene mit Scherpunkt auf Zahn- und Kieferfehlstellungen. Die Untersuchungen fanden von Januar bis März 2021 in 16 Studienzentren in Deutschland statt. Für 705 Studienteilnehmende lagen alle relevanten Daten vor, sie wurden in die statistische Auswertung einbezogen.

Ergebnisse Am häufigsten kamen mit 88,9 % Überbisse vor. Ebenfalls weit verbreitet waren Engstand mit mindestens 60,9 % sowie Platzmangel mit einem Anteil von 30,3 %. Alle anderen Indikationsgruppen wiesen jeweils einen Anteil von unter 10 % auf. Selten (< 1 %) wurden Bukkal-/Lingualokklusionen sowie kraniofaziale Anomalien vorgefunden. Die schwerwiegendsten Erkrankungsformen (KIG [Kieferorthopädische Indikationsgruppen] Grad 5) stellten mit 3,2 % der Überbiss, mit 1,0 % der offene Biss, mit 0,6 % der Vorbiss und die kraniofazialen Anomalien (0,4 %) dar. Der Anteil der Studienteilnehmenden, bei denen nach den Richtlinien der gesetzlichen Krankenversicherung eine kieferorthopädische Behandlung angezeigt ist, lag bei 40,4 %. Der Anteil der Studienteilnehmenden, bei denen aus medizinischen Gründen eine kieferorthopädische Behandlung grundsätzlich angezeigt war, lag bei insgesamt 97,5 %. Systematische Unterschiede im Hinblick auf das Geschlecht, die Region oder den Sozialstatus wurden beim Versorgungsbedarf nicht festgestellt.

Schlussfolgerungen Der im Rahmen dieser Studie nach KIG ermittelte Versorgungsbedarf deckt sich weitgehend mit dem in früheren Untersuchungen dargestellten. Damit liegt nahe, dass der kieferorthopädische Behandlungsbedarf in Deutschland über die Jahre weitgehend konstant geblieben ist.

Schlüsselwörter Index of Complexity, Outcome and Need · Epidemiologie · Kieferorthopädie · KIG-Klassifikation · Versorgungsforschung

Introduction

Alongside caries and periodontal diseases, tooth and jaw misalignment are among the most common health problems affecting the oral cavity [1]. Diseases of the masticatory system, i.e., teeth, jaw, temporomandibular joint, and masticatory muscles, can seriously affect well-being and quality of life, causing pain and suffering, affecting food intake or food choice, and making speech difficult [2]. In this sense, orthodontics is heavily orientated towards prevention when orthodontic treatment can prevent the onset of sequelae. It is known that orthodontic abnormalities are associated with impairment of masticatory function [3], breathing [3, 4], phonetics, and swallowing [5, 6], and an enlarged overjet significantly increases the risk of trauma to the front teeth [7] and orthodontic overjet correction can effectively reduce this risk [8].

The causes of orthodontic diseases are multifactorial and range from genetic, epigenetic, and functional factors to environmental factors. The severity of each individual disease is highly variable. Correspondingly, the range of therapeutic options is extensive. The influence of orthodontic treatment on genetic and epigenetic factors is limited; treatment tends to primarily focus on the consequences of these factors. However, in principle, there are preventive options for functional and environmental factors, and often also causal therapeutic options.

Traditionally, tooth and jaw misalignment were classified based on the malocclusion status of the 6-year molars, known as Angle's classification, and the results were used to determine the position of the jaws in relation to one another. The distribution of Angle's classification varies greatly from region to region, although globally all Angle's classifications are represented [1].

In permanent dentition, the prevalence of Angle class I globally is approximately 75%, followed by Angle class II at approximately 20%. Angle class III has a proportion of approximately 6%. An orthodontic–epidemiological study of 494 9-year-olds in southwest Germany also found that Angle class I was the most prevalent in children, followed by Angle classes II and III [9]. In the same study, Angle class II dentitions were observed in approximately 20%; this value is within the variance range of the prevalences reported in 2018 by Alhammadi et al. [1]. Angle class II was observed in 3% of those examined. An epidemiological–orthodontic study conducted as part of school dental examinations in Frankfurt am Main on 1251 school pupils aged between 9 and 11 years analyzed the results in accordance with the diagnostic chart of the statutory health insurance providers in Germany; the Orthodontic Indication Groups (Kieferorthopädische Indikationsgruppen, KIG) [10].

This study found that treatment was indicated, in accordance with the statutory health insurance provider guidelines (KIG ≥ 3), in 41.4% of all examined cases. Stahl et al. discovered that habits, dysfunction, and dyskinesia affecting deciduous to mixed dentition increased significantly [11]. Oral habits were observed more frequently in girls than in boys, whereas articulation disorders were more prevalent in boys.

Overall, it was determined that myofunctional disorders are more prevalent in children with greater sagittal overjet, open bite malocclusions, lateral crossbite, and progenia (Angle class III). A further report from the same team

of authors observed physiological occlusal relationships in one-quarter of children. The number dropped significantly to 7% when children with mixed dentition were examined [12].

The First German Oral Health Study (Erste Deutsche Mundgesundheitsstudie, DMS 1) conducted by the Institute of German Dentists (Institut der Deutschen Zahnärzte, IDZ) in 1989 laid the foundation for population-representative social–epidemiological monitoring of oral health and oral health care provision in Germany [13]. Previously, tooth and jaw misalignment had only been investigated in the former West German states during the First German Oral Health Study in 1989. Current population-wide data on the prevalence of tooth and jaw misalignment in Germany are not available. Against this backdrop, the Sixth German Oral Health Study (DMS 6) included an orthodontic module. The following study objectives were pursued:

The primary objective of this study was to collect data on the prevalence of tooth and jaw misalignment in 8- and 9-year-old children in Germany (primary endpoint).

The secondary objective of this study was to use this information to derive the need for orthodontic care provision (secondary endpoint).

Short methodology overview

A detailed description of the scientific methodology of the Orthodontic Module of the Sixth German Oral Health Study can be found as an independent article in this special issue (Jordan et al. in this issue).

This short overview aims to provide only basic information relating to the applied methodology.

Study design and setting

This is an oral–epidemiological investigation and social scientific survey at the national level with a focus on tooth and jaw misalignment. The investigation took place between January and March 2021 at 16 study centers across Germany (Fig. 1).

Study participants

After obtaining addresses from the municipal administrations responsible for study centers, 1892 people in the birth cohorts 2011 and 2012 were invited to participate in the study. A total of 714 underwent dental examination and socioscientific surveying. All relevant data were available for 705 of the study participants and these were included in the statistical analysis. The response rate was 40.6%. Subsequently, in order to gain insights into possible systemic differences between study participants and nonparticipants,

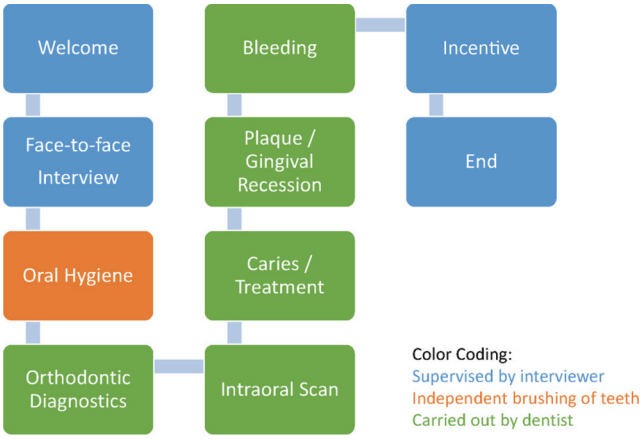

Fig. 1 Process organization at the study center from the perspective of the study participants
Abb. 1 Organisation der Abläufe im Untersuchungszentrum aus Sicht der Studienteilnehmenden

a survey of nonrespondents was conducted. As the analysis did not show any differences between the study participants and the surveyed nonparticipants, it can be assumed that there is no distortion of the study results caused by the proportion of nonrespondents and the study results can be viewed as representative.

Endpoints

The primary endpoint "Prevalence of Tooth and Jaw Misalignment" was operationalized as follows: Orthodontic Indication Group: KIG 1 vs. KIG 2 vs. KIG 3 vs. KIG 4 vs. KIG 5.

The secondary endpoint "Need for Orthodontic Treatment Provision" was based on statutory health care provider criteria and operationalized as follows: KIG 1–2 vs. KIG 3–5.

Furthermore, epidemiological–orthodontic indices were calculated for an international comparison, which will be published elsewhere in this special issue (Kirschneck et al. in this issue).

Results

Sample characterization

In total, 705 study participants were included in the data analysis. 51.4% of the study participants were male and 48.6% were female. The ratio of 8-year-old children (49.4%) to 9-year-old children (50.6%) was balanced. The result data were weighted to correspond to the population distribution in the principal regions in Germany: 22.2% of study participants came from rural areas, 32.9% from major urban centers, and 38.6% from metropolitan

Table 1 Distribution of habits, dyskinesias, and dysfunctions
Tab. 1 Verteilung von Habits, Dyskinesien und Dysfunktionen

		%	(95% CI)	n
Breathing pattern	Nasal breathing	98.7	(97.5–99.3)	683
	Mouth breathing	1.3	(0.7–2.5)	9
If mouth breathing: type	Habitual	80.5	(48.1–94.9)	7
	Anatomical	19.5	(5.1–51.9)	2
Swallowing pattern	Somatic	98.2	(97.0–99.0)	671
	Visceral	1.8	(1.0–3.0)	12
Lip seal	Competent	92.2	(89.9–93.9)	636
	Incompetent	3.1	(2.0–4.7)	21
	Potentially competent	4.7	(3.4–6.6)	33
Mentalis habit		18.0	(15.4–21.1)	125
Tongue dyskinesia: biting		0.4	(0.1–1.2)	3
Tongue dyskinesia: pressing		0.3	(0.1–1.1)	2
Lip dyskinesia: sucking		2.1	(1.2–3.4)	14
Lip dyskinesia: biting		2.4	(1.5–3.8)	16
Lip dyskinesia: pressing		0.2	(0.1–0.9)	2
Inner cheek dyskinesia: sucking		0.3	(0.1–1.1)	2
Inner cheek dyskinesia: biting		13.7	(11.3–16.5)	95
Forced bite		24.8	(21.6–28.2)	162
Sigmatism or speech disorder		21.9	(19.0–25.1)	154
Chewing problems		6.5	(4.9–8.6)	46
Biting fingernails		26.9	(23.8–30.3)	190
Sleep disorders/snoring		18.1	(15.4–21.1)	128
Sucking dyskinesia		6.1	(4.6–8.1)	43

Results of the weighted analysis, therefore rounding differences may occur
CI Confidence Interval

regions. In all, 90.8% of study participants reported good or very good health. In contrast, only 66.9% reported having good or very good oral health. 81.4% of study participants reported that they regularly attend dental check-ups. 9.2% reported only occasionally visiting the dentist. 7.4% reported only visiting a dentist if they have problems with their teeth. 2.0% have never visited a dentist. 8.4% of study participants were in early stage orthodontic treatment. On average, the study participants had 23.4 natural teeth, of which 10.4 were first dentition and 13.0 were permanent dentition teeth. 0.6 teeth were missing. On average, 0.9 teeth were erupting. 61.9% of study participants were caries-free, and 92.4% of permanent dentition was caries-free. An overview of the prevalence of habits, dyskinesia, and dysfunctions is depicted in Table 1.

Primary endpoint

For sociomedical reasons, for the German health care system, the results are primarily presented on the basis of orthodontic indication groups (Tables 2 and 3). When interpreting the results, it should be noted that study participants may have several tooth and jaw misalignments. If these multiple misalignments belong to different induction groups (e.g., one study participant had an edge-to-edge bite and crowding at the same time), both findings are counted and listed in the table. This means that the individual table rows always add up to 100% (subject to rounding differences), because only the most serious finding was counted for one and the same misalignment. However, this does not apply to the column or total summation due to possible double counting of study participants.

The most frequent finding was distal bite (overbite; 88.9%). In contrast to the other indication groups, in this case, severity grade 1 (sagittal overjet of up to 3 mm) is still deemed a physiological dentition status, with pathological overbite enlargement being upwards of KIG grade 2. Also frequent were the indication groups crowding (at least 60.9%) and lack of space (30.3%). All other indication groups were each below 10%. Rare (<1%) were buccal and lingual occlusions and craniofacial abnormalities. The prevalence of the indication groups hypodontia and eruption disorder could not be determined in this study due to the lack of radiological diagnostics. The most severe disease forms (KIG grade 5) were represented by distal bite (3.2%), open vertical overlap (open bite; 1.0%), mesial bite (0.6%), and craniofacial abnormalities (0.4%). With the exception of craniofacial abnormalities, which by def-

Table 2 Orthodontic indication group overview—frequency distribution
Tab. 2 Übersicht Kieferorthopädische Indikationsgruppen – Häufigkeitsverteilung

Indication groups	No findings	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total
	n						*n*
A—Cranial abnormalities	689 (99.6%)	–	–	–	–	3 (0.4%)	692
D—Distal bite malocclusion	–	72 (10.3%)	484 (69.2%)	–	115 (16.5%)	22 (3.2%)	698
M—Mesial bite malocclusion	671 (96.0%)	–	–	–	24 (3.4%)	4 (0.6%)	698
O—Vertical open bite malocclusion	653 (92.9%)[a]		32 (4.6%)	11 (1.6%)	0 (0.0%)	7 (1.0%)	703
T—Vertical deep bite malocclusion	39 (5.7%)	230 (33.4%)	353 (51.2%)	67 (9.8%)	–	–	689
B—Buccal/Lingual occlusion	701 (99.7%)	–	–	–	2 (0.3%)	–	704
K—End-to-end/Crossbite	644 (91.6%)	–	19 (2.7%)	3 (0.4%)	37 (5.3%)	–	704
E—Crowding	275 (39.1%)[a]		364 (51.7%)	59 (8.4%)	5 (0.7%)	–	704
P—Lack of space	474 (69.7%)	–	160 (23.5%)	21 (3.1%)	25 (3.6%)	–	679

Results of the weighted analysis, therefore, rounding differences are possible
[a]Differentiation of "no findings" and "grade 1" is not possible with the collected data; therefore, these categories are listed together. The indication groups U (hypodontia) and S (eruption disorders) were not assessed during this study as no X-ray diagnostic were used

Table 3 Orthodontic Indication Group (Kieferorthopädische Indikationsgruppen, KIG) severity classification according to gender, region, and socioeconomic status
Tab. 3 KIG(Kieferorthopädische Indikationsgruppen)-Schweregradeinteilung nach Geschlecht, Region und sozioökonomischem Status

KIG		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Total
		% (95% CI)					n
Total		2.5 (1.6–4.0)	57.0 (53.3–60.6)	10.0 (8.0–12.4)	25.5 (22.4–28.9)	5.0 (3.6–6.9)	705
Gender	Male	2.5 (1.3–4.6)	57.4 (52.3–62.4)	8.7 (6.2–12.0)	26.4 (22.1–31.2)	5.0 (3.2–7.8)	362
	Female	2.6 (1.4–4.9)	56.5 (51.2–61.7)	11.3 (8.4–15.1)	24.6 (20.3–29.4)	4.9 (3.1–7.8)	343
Region	Northern Germany	4.4 (2.0–9.5)	58.6 (49.9–66.8)	11.7 (7.2–18.4)	22.6 (16.2–30.6)	2.7 (1.0–7.2)	127
	Southern Germany	1.5 (0.5–4.2)	57.2 (50.4–63.8)	14.3 (10.2–19.7)	20.6 (15.6–26.6)	6.4 (3.8–10.7)	205
	Western Germany	1.9 (0.8–4.5)	56.9 (50.6–62.8)	6.0 (3.7–9.7)	29.9 (24.6–35.9)	5.3 (3.1–8.8)	249
	Eastern Germany	3.7 (1.5–8.7)	55.3 (46.5–63.7)	9.0 (5.1–15.3)	27.8 (20.6–36.2)	4.3 (1.9–9.4)	124
SES	Low	1.5 (0.4–5.6)	55.4 (46.6–63.9)	10.1 (5.9–16.6)	27.20 (20.2–35.7)	5.7 (2.8–11.3)	124
	Moderate	3.2 (1.9–5.6)	58.6 (53.6–63.6)	11.4 (8.5–15.0)	22.3 (18.3–26.8)	4.5 (2.8–7.1)	370
	High	2.6 (0.9–7.2)	55.1 (46.2–63.6)	5.8 (2.8–11.4)	36.6 (28.6–45.4)	0.0 (0.0–3.0)	122

Results of the weighted analysis, therefore, rounding differences may occur
KIG Kieferorthopädische Indikationsgruppen (Orthodontic Indication Groups), *SES* Socioeconomic status, *CI* confidence interval

inition can only occur as the most severe form of disease, the other most severe forms of disease were also observed in milder manifestations.

Secondary endpoint

The need for orthodontic care provisions can be derived from the orthodontic indication group severity classifications. The following definitions were applied [14], resulting in the following percentages:

KIG grade 1: 2.5% of study participants were classified as KIG grade 1.

This also included the 0.7% of study participants who has no tooth misalignment and no orthodontic findings (eugnathic dentition). In these cases, there is absolutely no orthodontic treatment indicated. Classification as grade 1 can be justified solely by the fact that the physiological

step in indication group D (sagittal overjet up to 3 mm) is defined as KIG grade 1.

A total of 1.8% of study participants displayed slight tooth misalignment and treatment may be desirable from an esthetic perspective, but not in the sense of a medical indication.

KIG grade 2: 57.0% of study participants had mild tooth misalignment that requires correction for medical reasons, but the cost of which will not be covered by the health insurance provider.

KIG grade 3: 10.0% of study participants had pronounced tooth misalignment that requires correction for medical reasons.

KIG grade 4: 25.5% of study participants had very pronounced tooth misalignment that requires treatment for medical reasons as soon as possible.

KIG grade 5: 5.0 of study participants had extremely pronounced tooth misalignment; it is imperative that they receive treatment for medical reasons.

The percentage of study participants requiring orthodontic treatment in accordance with the guidelines from the statutory health insurance providers is 40.4%. The percentage of study participants for whom, in principle, orthodontic treatment is indicated for medical reasons is 97.5%. Systemic differences in the need for care provision relating to gender, region, or social status were not observed. However, associations with the self-assessment of their own health status, habits, dyskinesias, and dysfunction arose. It was discovered that subjects requiring orthodontic treatment systematically rated their overall health and oral health status worse. Subjects requiring orthodontic treatment were more likely to systematically display mouth breathing (instead of nasal breathing), twice as likely to display incompetent lip sealing, and more likely to display other habits (mentalis habit, biting on their tongue, lip sucking, and fingernail biting), as well as sleep disorders and snoring.

Craniofacial abnormalities were rare. In this study, only 0.4% of study participants were diagnosed with this type of disease. All diagnosed cases were male.

Hypodontia, as described in the system to classify the need for orthodontic treatment, can only be definitively identified with the aid of X-ray diagnostics. Therefore, orthodontic indication group U cannot be evaluated as part of DMS 6 because no X-ray images are available. However, space maintainers (fixed) or replacement teeth (removable, e.g., child dentures) were clinically recorded. 0.4% of study participants had been fitted with a space maintainer following the loss of a tooth, and a further 0.2% had replacement teeth in the form of child dentures. For the reasons mentioned above, it is not possible to draw conclusions about the prevalence of indication group U based on this information.

Tooth retention and tooth displacement, as described in the KIG system to classify the need for orthodontic treatment, can only be definitively identified with the aid of X-ray diagnostics. Therefore, orthodontic indication group S cannot be evaluated as part of DMS 6 because no X-ray images are available. For this reason, a survey of these findings did not take place. An exception is ankylosis/partial retention of the 6-year molars in the surveyed age group, which can be assessed without the aid of a radiological diagnostic scan. Despite the limitations, this parameter was recorded. None of the subjects displayed partial retention of the 6-year molars, and 0.5% of study participants displayed partial retention affecting other permanent teeth (lateral incisors and second premolars). For the reasons mentioned above, it is not possible to draw conclusions about the prevalence of indication group S based on this information.

A *distal bite position malocclusion of the incisors* was frequent and affected 88.9% of study participants. Only 0.8% of study participants displayed no related findings. No tooth misalignment (sagittal overjet up to 3 mm, grade 1) was observed in 11.1% of subjects, and low-grade tooth misalignment (grade 2) was seen in the vast majority of study participants (69.2%). Systematic gender-related or regional differences were not observed. It is noticeable that distal bite cases requiring treatment were found more frequently in those with a higher social status.

In comparison with the distal findings, a *mesial bite position malocclusion of the incisors* was rather rare and affected only 4.0% of study participants; 96.0% of study participants displayed no related findings. All registered cases displayed pronounced (grade 4) or extremely pronounced (grade 5) tooth misalignment. Overbite was more prevalent among boys than girls. There were also differences in regional distribution. Overbite was more frequent in participants with a lower social status.

Discernible *vertical open* bite malocclusions were observed in 7.1% of study participants, while 92.9% of study participants displayed no related findings or low-grade findings. Less pronounced tooth misalignment (grade 2) was observed in 4.6% of participants, pronounced tooth misalignment (grade 3) in 1.6%, and extremely pronounced tooth misalignment (grade 5) in 1.0% of study participants. No systematic differences relating to gender, region, or social status were observed.

Vertical deep bite malocclusions were observed in 94.3% of the study participants. Only 5.7% of study participants displayed no related findings. Slight tooth misalignment (grade 1) was observed in one-third of participants and somewhat pronounced tooth misalignment (grade 2) in 51.2%. 9.8% of study participants displayed pronounced tooth misalignment with traumatic gingival

contact (grade 3). No systematic differences relating to gender, region, or social status were observed.

Transversal malocclusions in the form of buccal or lingual occlusions were rare; they were observed in only 0.3% of study participants. All those affected displayed very pronounced tooth misalignment (grade 4). 99.7% of study participants displayed no related findings. No systematic differences relating to gender, region, or social status were observed.

Transversal malocclusions in the form of unilateral or bilateral crossbite were observed in 8.4% of study participants; 91.6% of study participants displayed no related findings. Somewhat pronounced tooth misalignment (grade 2) was observed in 2.7% of study participants in the form of end-to-end bite. Pronounced crossbite (grade 3) was observed in 0.4% of study participants and very pronounced crossbite (grade 4) in 5.3%. End-to-end bite and crossbite were more prevalent in girls. There were also differences in regional distribution. End-to-end bite and crossbite were more common in those of lower social status.

Discernible *vertical open bite malocclusions* were observed in 60.9% of study participants; 39.1% of study participants displayed no related findings or very low-grade findings. Somewhat pronounced tooth misalignment (grade 2) was displayed in 51.7% of study participants, pronounced tooth misalignment (grade 3) in 8.4%, and extremely pronounced tooth misalignment (grade 4) in 0.7%. No systematic differences relating to gender, region, or social status were observed.

Lack of space was observed in 30.3% of study participants; 69.7% of study participants displayed no related findings. Somewhat pronounced tooth misalignment (grade 2) was observed in 23.5% of study participants, 3.1% of study participants displayed pronounced (grade 3) findings, and 3.6% of study participants displayed extremely pronounced (grade 4) tooth misalignment. Lack of space was observed more frequently in boys than girls. There were also differences in regional distribution. No other differences related to social status were observed.

Discussion

The need for care identified in this study in accordance with orthodontic indication groups (40.4%) generally corresponds to the figure of 41.1% from Glasl et al. in 2006 [10]. It can therefore be assumed that the need for orthodontic care in Germany has remained constant over the years. The percentage of study participants for whom, in principle, orthodontic treatment is indicated for medical reasons was 97.5%. This generally corresponds to earlier investigations, such as DMS 1, which reported the prevalence of absolute eugnathic dentition with no orthodontic abnormalities as 1%. In this study, the percentage of healthy natural orthodontic dentition was 0.7%.

Strengths and limitations

A strength of DMS 6 is its representativeness regarding the population of 8- and 9-year-old children in Germany, which was guaranteed via the geographical selection of one site in each federal state and the random sample collected from the municipal registration authorities. A limitation of this study is the fact that not all orthodontic abnormalities could be recorded: The KIG categories U (hypodontia) and S (eruption disorders, retention, and displacement) could not be assessed because, for ethical reasons, no radiological images of the study participants' jaws could be taken. Due to the fact that, for the aforementioned reasons, the prevalence of KIG grades 3–5, which imply the need for orthodontic provision in KIG categories U and S, could not be surveyed, it can be assumed that the actual need for orthodontic care provision in the study population of 8- to 9-year-old children is higher than the 40.4% identified during this study. Studies have shown that a prevalence of hypodontia in category U of approximately 5% and prevalence of retained/displaced tooth of approximately 6% must be assumed. A further limitation of the methodological aspect of this study is the application of orthodontic indication groups (KIG) as an epidemiological index for a population of 8- and 9-year-old children, as this was developed to determine the extent of reimbursable orthodontic services in the context of statutory health insurance coverage for a population of over 10-year-olds. Therefore, there is a risk that the actual prevalence and the need for orthodontic care provision are underestimated, which will then manifest 1–2 years later in the studied population group as it is known that the majority of orthodontic abnormalities display an increase in prevalence during growth [11]. However, the selection of a collective of 8- and 9-year-old children for DMS 6 was a conscious decision to avoid the possible disruptive influences of early orthodontic treatment which is often administered before 10 years of age.

Interpretation

Regarding the geographical distribution of the individual prevalences and KIG severity grading, it is noticeable that there are no significant differences between the subpopulations of northern, southern, eastern, or western Germany. The higher grades of the KIG categories M (sagittal discrepancy negative overjet) and K (transversal abnormalities) are an exception as they tend to be more frequent in southern and eastern Germany but underrepresented in northern Germany. In contrast, KIG category D (sagittal discrepancy increased overjet) appears to be more frequent in north-

ern Germany than in southern and eastern Germany. There were also no significant differences observed in the individual prevalences and KIG severity classification relating to socioeconomic status (SES). Existing differences can almost certainly be attributed to the sample effects relating to the limited number of cases included in the study.

Future research impulses

During DMS 7, the study participants of the orthodontic module in DMS 6 should be examined again with the aim of obtaining, for the first time, longitudinal data related to the development of orthodontic abnormalities with and without orthodontic treatment having been carried out in the meantime. In some cases, the efficacy of orthodontic therapeutic procedures can also be evaluated. In future epidemiological studies, more attention should be placed on the reliable surveying of myofunctional habits and dyskinesias, as these represented a significant exogenous etiological factor for the onset of orthodontic abnormalities [15].

Conclusion

To determine tooth and jaw misalignment, this study applies the German orthodontic indication groups along with internationally established orthodontic–epidemiological indices to the sample group of 8- and 9-year-old children (early mixed dentition). The primary aim was to determine the need for orthodontic treatment provision in a group with a large proportion of untreated patients. A need for orthodontic treatment provision was identified in 40.4% of subjects. However, it must be taken into account that in later stage mixed dentition (main treatment period in accordance with statutory health care provider guidelines), an increase can be expected due to the progression of tooth and jaw misalignment, and therefore the Orthodontic Indication Group [Kieferorthopädische Indikationsgruppen, KIG] categories U (hypodontia) and S (eruption disorders, retention, and displacement) could not be taken into account. When applying the corresponding guidelines, in international comparison, neither an underprovision nor an overprovision of treatment in Germany is observed. A comparison with the invoicing data of the National Association of Health Insurance Dentists (Kassenzahnärztliche Bundesvereinigung, KZBV) also shows that the need for orthodontic treatment provision generally corresponds to the actual provision of treatment.

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Declarations

Conflict of interest C. Kirschneck declares payment as scientific advisor of the Sixth German Oral Health Study. A.R. Jordan, K. Kuhr and N. Frenzel Baudisch declare that they have no financial or nonfinancial interests that are directly or indirectly related to the work submitted for publication.

Ethical standards The Ethics Committee at Witten/Herdecke University assessed the study in advance from an ethical perspective and approved it (No. 113/2020). The study was begun only after a favorable assessment had been received from the competent ethics committee. Consent to participate: Written informed consent was obtained from the patients or their parents/legally authorized representatives (LAR) in the case of children under 18.

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ORIGINAL ARTICLE

Methodology of the Sixth German Oral Health Study (DMS 6) to survey tooth and jaw misalignment

Andreas Rainer Jordan[1] · Kathrin Kuhr[1] · Cristiana Ohm[1] · Nicolas Frenzel Baudisch[1]

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Abstract

Purpose The aim of this study was (1) to complete and update the oral-epidemiological data situation in Germany (descriptive epidemiology) and (2) to determine the need for orthodontic treatment provision based on the epidemiological data situation (health care epidemiology in the form of demand research).

Methods For this purpose, a longitudinal oral-epidemiological study and social science survey with a primary focus on tooth and jaw misalignment was conducted at a nationally representative level on 705 8- and 9-year-old children across Germany.

Results The methodological principles of the oral-epidemiological study are described, with a focus on the calibration and reliability assessment results from the study dentists, sample weighting, a survey of nonrespondents to estimate the extent of the external validity of the study results, a description of the study participants, and realized cases, as well as information pertaining to the response rate and utilization.

Conclusion Based on the conducted analyses, it can be assumed that the examined 8- and 9-year-old study participants are representative of the statistical population in Germany.

Keywords Index of Complexity Outcome and Need · Epidemiology · Orthodontics · KIG classification · Health services research

Methodik der Sechsten Deutschen Mundgesundheitsstudie (DMS 6) zur Erhebung von Zahn- und Kieferfehlstellungen

Zusammenfassung

Zielsetzung Ziele dieser Studie waren (1) die Vervollständigung und Aktualisierung der oral-epidemiologischen Datenlage in Deutschland (deskriptive Epidemiologie) und (2) die Ermittlung des kieferorthopädischen Versorgungsbedarfs auf Basis der epidemiologischen Datenlage (Versorgungsepidemiologie in Form von Bedarfsforschung).

Methoden Zu dieser Fragestellung wurden eine oral-epidemiologische Längsschnittstudie samt einer sozialwissenschaftlichen Befragung mit dem Schwerpunkt Zahn- und Kieferfehlstellungen auf bundesweit repräsentativer Ebene bei 705 8- und 9-jährigen Kindern durchgeführt.

Study Registration Before beginning, the study was registered with the German Clinical Trials Register (DRKS www.drks.de): DRKS00022472.

✉ Prof. Dr. Andreas Rainer Jordan
r.jordan@idz.institute

[1] Institute of German Dentists,
Universitätsstr. 73, 50931 Cologne, Germany

Ergebnisse Beschrieben werden die methodischen Grundlagen der oral-epidemiologischen Studie hinsichtlich der Ergebnisse der Kalibrierung und der Reliabilitätsanalyse der Studienzahnärzte, bezüglich der Stichprobengewichtung, der Nonrespondenten-Befragung zur Abschätzung des Ausmaßes der externen Validität der Studienergebnisse, hinsichtlich der Beschreibung der Studienteilnehmer und realisierten Fälle sowie der Angaben zur Rücklaufquote und zur Inanspruchnahme.
Fazit Aufgrund der durchgeführten Analysen kann davon ausgegangen werden, dass die untersuchten 8- und 9-jährigen Studienteilnehmer repräsentativ für die statistische Grundgesamtheit in Deutschland sind.

Schlüsselwörter Index of Complexity Outcome and Need · Epidemiologie · Kieferorthopädie · KIG-Klassifikation · Versorgungsforschung

Introduction

Until now, tooth and jaw misalignment have only been investigated as part of the First German Oral Health Study in the states of the former Federal Republic of West Germany in 1989. There are no current population-wide data available on the prevalence of tooth and jaw misalignment in Germany. In particular, there are no systematic epidemiological data on tooth and jaw misalignment from the new federal states. Therefore, the overall orthodontic–epidemiological picture in Germany is incomplete—resulting in uncertainties in the planning of dental care provision. Furthermore, the composition of the general population following the reunification of Germany, due to the various waves of migration, is now subject to different dynamics. This further justifies the collection of new data, thus, providing us with the primary rationale for this study: to complete and update the oral-epidemiological data situation in Germany (descriptive epidemiology).

Alongside the scientific–epidemiological interest, various reports have raised the question of evidence-based practice in the field of orthodontics in recent years. In 2008, the Health Technology Assessment (HTA) of fixed orthodontic appliances by the German Institute for Medical Documentation and Information (DIMDI) concluded that "this reinforces the impression that there is a significant gap between the practical application of orthodontic measures and scientific research into their efficacy" [1]. Following an audit of the provision of orthodontic services, in its final report to the Federal Ministry of Health and the National Association of Statutory Health Insurance Funds, the Federal Audit Office warned of the lack of transparency in orthodontic care provision data [2].

A further report compiled for the Federal Ministry of Health (Bundesministerium für Gesundheit, BMG) by the Institute for Health and Social Research (IGES) on the benefits of orthodontic treatment measures proposed an array of measures to encourage the generation of more evidence and the inclusion of orthodontic topics in national epidemiological investigations [3]. This report raises the question of the actual need for care provision in Germany, from which we derive the second rationale for this study: Determining the need for orthodontic provision based on the oral–epidemiological data (health care epidemiology in the form of demand research).

Methodology

Study planning was based on the methodology recommendation from the Epidemiology and Public Health Working Group at the German Society of Dentistry and Oral Medicine (Deutsche Gesellschaft für Zahn-, Mund- und Kieferheilkunde, DGZMK) [4] and the Guidelines and Recommendations for ensuring Good Epidemiological Practice issued by the German Society for Epidemiology (Deutsche Gesellschaft für Epidemiologie, DGEpi) in 2018 [5]. The reporting follows the Statement Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [6].

Study design

A longitudinal oral–epidemiological study and social science survey with a primary focus on tooth and jaw misalignment conducted at a nationally representative level.

Setting

The objective of the sampling model was to reflect the selected population group in Germany with as little distortion as possible. To implement the target objective, a two-stage sampling process via disproportionate stratified sampling was selected. In the first stage, a sample point was selected in each federal state and used to create area sampling (Table 1). Subsequently, in the second stage, a sample of persons was taken from the identified sample municipality. This was based on the register of persons from municipal registration authorities. This study aimed to encompass a net total of 670 study participants comprised of equal shares from the following age groups:

- Birth cohort 2012 (8 years old at the start of the field study in 2021)

Table 1 Primary sampling units (municipalities) in the sample of the orthodontic module of the Sixth German Oral Health Study (DMS 6) with their respective federal state and simplified classification according to their population size (BIK categories)
Tab. 1 Studienzentren (Kommunen) in der Stichprobe für das kieferorthopädische Modul der Sechsten Deutschen Mundgesundheitsstudie (DMS 6) mit dem jeweiligen Bundesland und vereinfachter Klassifikation nach Bevölkerungsgröße (BIK-Kategorien)

Point	Municipality	Federal state	Simplified BIK categories
1	Reutlingen	Baden–Württemberg	Urban region
2	Nürnberg	Bavaria	Metropolitan region
3	Berlin	Berlin	Metropolitan region
4	Lübbenau/Spreewald	Brandenburg	Rural region
5	Bremen	Bremen	Metropolitan region
6	Hamburg	Hamburg	Metropolitan region
7	Ober-Ramstadt	Hesse	Urban region
8	Region Lubmin	Mecklenburg–Vorpommern	Rural region
9	Braunschweig	Lower Saxony	Urban region
10	Düsseldorf	North Rhine–Westphalia	Metropolitan region
11	Plaidt	Rhineland-Palatinate	Rural region
12	Saarbrücken	Saarland	Urban region
13	Hoyerswerda	Saxony	Rural region
14	Halle/Saale	Saxony–Anhalt	Urban region
15	Großhansdorf	Schleswig–Holstein	Metropolitan region
16	Altenburg	Thuringia	Rural region

- Birth cohort 2011 (9 years old at the start of the field study in 2021)

To survey the 16 sample municipalities, two teams worked parallel to one another in the field, each consisting of a dentist, a person responsible for contacting participants, and an interviewer. Each team (i.e., dentist and interviewer) focused on one sample municipality per week across 6 working days. Following written and personal interviews, the study participants were asked to clean their teeth as thoroughly as possible to allow the dentist to assess their oral hygiene. The study participants were asked in advance to bring and use their own dental hygiene implements.

The subsequent dental medical examination was carried out in the following order:

- Orthodontic–clinical diagnosis,
- Orthodontic intraoral scan (for subsequent orthodontic model measurement),
- Caries and treatment,
- Plaque and gingival recession, and
- Bleeding of the gums.

The duration at the examination center, including registration, social science interview, and oral hygiene totaled about 45 min.

Study participants

The age of the study participants was selected to exclude, as far as possible, those already undergoing orthodontic treatment. This was done to ensure that treatment-naive tooth and jaw misalignment was recorded before any type of treatment had been administered; otherwise, this would result in systematic underestimation of severe disorders. For this reason, the age group of 8- to 9-year-old children in Germany was selected as the statistical population for this study.

Inclusion and exclusion criteria

A target person must fulfill all the inclusion criteria listed below to be included in the study module:

- The target person is registered in one of the randomly selected sample municipalities.
- The target person was born in 2011 or 2012.
- The written consent form, signed by the target person's parent or guardian, has been provided.

A target person was excluded from study participation if they fulfilled at least one of the following exclusion criteria:

- The target person, or their parent/guardian, have insufficient knowledge of the German language to participate in the study.
- Legal provisions.

Variables

The primary objective of this study was to collect data on the prevalence of tooth and jaw misalignment in 8- and 9-year-old children in Germany (primary endpoint). For this purpose, the following indices were applied:

- KIG (Orthodontic Indication Groups) [7], and
- ICON (Index of Complexity Outcome and Need) [8].

The orthodontic indication groups were designated as the primary index for indicating prevalence within the context of the epidemiological question. The ICON index was used as a supporting index and primarily applied during international comparisons.

The secondary endpoint was to derive the need for orthodontic care provision from the prevalence of tooth and jaw misalignment data. The KIG and ICON indices were also used to answer this question.

Primary endpoint

The primary endpoint "Prevalence of Tooth and Jaw Misalignment" was operationalized as follows:

- KIG: KIG 1 vs. KIG 2 vs. KIG 3–5 (primary index).

In addition, the following was operationalized using scientifically broader criteria:

- ICON: Treatment complexity score easy, mild, moderate, difficult, very difficult (secondary index).

Secondary endpoint

The secondary endpoint "Need for Orthodontic Treatment Provision" was based on statutory health care provider criteria and operationalized as follows:

- KIG 1–2 vs. KIG 3–5.

Bias

Parents who could not or chose not to participate in the study with their child were asked about the reasons for their nonparticipation and asked to answer a short questionnaire. The short questionnaire contained questions pertaining to their living situation, the parental assessment of the child's dental condition, orthodontic treatment, frequency of dental visits, and their educational and professional background. This information made a comparison of nonrespondents and study participants possible using key indicators to provide insights into any systematic differences between the two groups.

Study size

The primary focus was the estimation of the prevalence of tooth and jaw misalignment using orthodontic indication group classification. In a clinical–epidemiological survey of 226 school children in classes 4 and 5 (9–13 years old) in 1993, 13.8% of the cases were classified as KIG 1, 34.6% as KIG 2, and 51.6% as KIG 3–5 (unpublished data from the National Association of Statutory Health Insurance Dentists). Further epidemiological surveys of primary school children identified percentages of KIG 1–2 classifications between 54% and 59%, and 41% to 46% for KIG 3–5 [9, 10]. To guarantee a reliable estimate, the standard error of prevalence should be no more than 10% of the prevalence. The standard error of prevalence to prevalence ratio is referred to as precision. To estimate the expected prevalence of 13% (KIG 1) with a confidence level of 95% and a standard error value of 1.3% (precision 10%), $n = 670$ study participants were necessary.

Quantitative variables

Orthodontic characteristics were surveyed in three different ways. The KIG and ICON endpoints were determined using the digital analytical model evaluation of the dental arches and occlusal interlocking in cases of habitual occlusion (Trios 3, 3Shape GmbH, Düsseldorf, Germany). Information on habits, dyskinesias, and dysfunctions was collected in interviews with study participants and dental medical diagnosis. During the dental medical diagnosis, cranial abnormalities, such as cleft lip and cleft palate, were also recorded. For ethical research reasons, comprehensive X-ray examination was not possible within the scope of DMS 6. Generally, tooth retention, tooth displacement, hyperdontia and hypodontia, as listed in the system to classify the need for orthodontic treatment, recorded using the KIG classification system, can only be identified using radiological procedures. In cases where only a clinical examination is conducted, the prevalence is likely underestimated. For this reason, surveying of the mentioned findings did not take place. An exception that could be detected in the target age group without radiological diagnostics was ankylosis and partial retention of the six-year molars. The cephalometric analysis was conducted using calibrated and reliability-tested orthodontic specialists aided by OrthoAnalyzer analysis software (3Shape GmbH, Düsseldorf, Germany).

Statistical methods

To determine the need for orthodontic care provision as per KIG and ICON, and treatment complexity as per ICON, prevalences with the corresponding 95% confidence interval (CI) were reported. The results for the complete analysis set were stratified according to gender, region, and socioeconomic status. For the ICON total score, mean value with the corresponding confidence intervals, median and quartile, and minimum and maximum were given. In addition, the severity grade distribution for each individual KIG or ICON causal group was reported. To calculate the confidence interval for the prevalences, the one-sample case method from Newcombe and Altman was applied [11]. All reported p-values are two-sided. The analyses have an ex-

plorative character, and the *p*-values are only stated for descriptive purposes. The analyses were conducted using IBM SPSS Statistics for Windows, Version 26 (released 2019, IBM Corporation, Armonk, NY, USA), and R Version 3.5.3 (released 2019, R Core Team, R Foundation for Statistical Computing, Vienna, Austria).

Results

Calibration results

Reliability testing was carried out on 5 probands. All characteristics of interests were categorial; therefore, Cohen's kappa (κ) was used for the analysis. Both the intrarater agreement and the interrater agreement of study dentists compared to the gold standard were of interest. The conventional Altman classification system was used for kappa value categorization [12, 13]:

- Kappa to 0.20: Poor agreement (*poor*)
- Kappa 0.21–0.40: Fair agreement (*fair*)
- Kappa 0.41–0.60: Moderate agreement (*moderate*)
- Kappa 0.61–0.80: Good agreement (*good*)
- Kappa >0.80: Very good agreement (*very good*)

The intrarater and interrater agreement in the sections tooth status and tooth-related findings were very good (tooth status: $\kappa \geq 0.92$ and $\kappa \geq 0.93$; tooth-related findings: $\kappa \geq 0.91$ and $\kappa \geq 0.89$). All study dentists were successfully assessed against the gold standard. In addition to the teams that carried out the field work, external orthodontic specialists were trained and calibrated to evaluate the intraoral scans. The analysis was carried out by the orthodontic specialists using OrthoAnalyzer analysis software (3Shape GmbH, Düsseldorf, Germany). Both intrarater and interrater comparisons of the evaluators against the gold standard were of interest. Intraclass correlation coefficients (ICC) were calculated as a statistical measure for the continuous characteristics (ICC type (3,1): two-way mixed, single measure). The Altman classification system, introduced in the previous segment, was used for ICC categorization [12, 13]. The calculated statistical measures for the assessment section in Table 2 are listed for all evaluators. To enable concomitant quality assessment of the surveyed data and to allow intervention for correction in the event of systematic deviation, 10% of all jaw models were subject to double measurement conducted by two different evaluators and no relevant deviations were detected.

Sample weighting

A weighting factor was used for all calculations to correct deviation between the analysis set and the population structure to provide representative statements for the group of 8- to 9-year-old children in Germany. The calculation of the weighting factor was conducted in 3 stages. In the first stage, the sample design was taken into consideration. The sample design for DMS 6 was disproportionately applied to the federal states so that design weighting was calculated for four regions (northern Germany: Bremen, Hamburg, Mecklenburg–Vorpommern, Lower Saxony, Schleswig–Holstein; eastern Germany: Berlin, Brandenburg, Saxony, Saxony–Anhalt, Thuringia; southern Germany: Baden–Württemberg, Bavaria; western Germany: Hesse, North Rhine–Westphalia, Rhineland–Palatinate, Saarland).

Design weighting was inversely proportional to study participant selection probability. In the second stage, nonresponse weighting was applied. The aim was to align the net sample (study participants) with the (originally collected) gross sample. For this purpose, gross sample information and responses from the interviews with nonrespondents were used. To calculate the weighting, a multivariable logical regression model was adjusted to estimate the probability of study participation taking into account the explanatory variables of federal state, age, gender, and nationality. In the third stage, adjustment weighting was carried out. As orientation, information relating to the population data was drawn from official statistics. The characteristics of age, gender, region, nationality, education level of the

Table 2 Orthodontic model analysis: results of the reliability analysis for the intra-individual perspective (within model analysts) and the inter-individual perspective (between model analysts)
Tab. 2 Kieferorthopädische Modellanalyse: Ergebnisse der Reliabilitätsanalyse für die intraindividuelle Perspektive (bei Modellauswertenden) und für die interindividuelle Perspektive (zwischen Modellauswertenden)

Section	Intra-Rater agreement	Inter-Rater agreement
Tooth width	Very good (ICC >0.99)	Very good (ICC >0.99)
Overjet	Very good (ICC >0.94)	Very good (ICC >0.84)
Overbite	Very good (ICC >0.96)	Very good (ICC >0.91)
High dental crowns	Very good (ICC >0.97)	Very good (ICC >0.94)
Front tooth segment	Very good (ICC >0.99)	Very good (ICC >0.99)
Support zone	Very good (ICC >0.97)	Very good (ICC >0.97)
Arch length 6-year molars	Good to very good (ICC: 0.77–0.97)	Moderate to very good (ICC: 0.42–0.91)

ICC intraclass correlation coefficient

father, and household size were taken into account. Final weighting was determined by multiplying the three weighting values and final standardization so that the weighting total corresponds to the extent of the analysis set ($n = 705$).

Survey of nonrespondents

A survey was carried out to gain insights into the systematic differences between study participants and nonrespondents. The questionnaire focused on sociodemographic and oral health-related parameters. A total of 800 households were written to, and 165 parents/guardians returned the completed questionnaire. This corresponds to a nonrespondents' survey response rate of 20.6%. As seen in Table 3, living situation distribution is similar in both groups. Only the percentage of children who live with their natural parents is 6 percentage points lower for study participants than children of parents/guardians who participated in the nonrespondents' survey. Table 4 shows parental estimation of their child's oral health. Table 5 shows the frequency of dental visits. This relates to complaint and control-orientated use of dental services. In this context, only minimal differences were observed between the two groups.

Study participants and realized cases

As can be seen in Fig. 1, a total of 1892 people were written to and invited to participate in the study. This case number corresponds to the unadjusted gross sample. In all, 133 study subjects were excluded from the unadjusted sample and classified as quality-neutral dropouts (QND). Fulfillment of the following criteria resulted in exclusion:

- Letter undeliverable,
- Deceased,
- Moved, no longer lives in the household,
- Poor command of the German language,
- In quarantine at the relevant time,
- Unable due to acute illness,
- Unable due to being in hospital,
- Unable due to undergoing a course of restorative treatment, or
- Unable due to chronic illness.

Alongside 133 quality-neutral dropouts, there were 1045 further exclusions–systematic dropouts. These included study subjects who could be classified using the following criteria:

- Address in original conditions,
- On vacation/travelling,
- Unable for other reasons,
- Not willing due to lack of time,
- Not willing due to being unconvinced of intent and purpose,
- Not willing for other reasons,

Table 3 Living situation of the study participants compared to that of nonrespondents
Tab. 3 Wohnsituation der Studienteilnehmer im Vergleich zu der der Nonrespondenten

With whom does your child primarily live?	Nonrespondent	Study participant
Natural parents	136 (82.4%)	548 (76.8%)
Mother and partner	7 (4.2%)	48 (6.7%)
Father and partner	–	1 (0.1%)
Mother	18 (10.9%)	90 (12.6%)
Father	–	5 (0.7%)
Grandparents/Other relatives	1 (0.6%)	–
Foster parents/Adoptive parents	–	3 (0.4%)
In a children's home	1 (0.6%)	–
Information missing	2 (1.2%)	19 (2.7%)
Total	165 (100%)	714 (100%)

Stated as *n* (%)

Table 4 Estimation of the oral health status of the study participants by the parents/guardians compared to the nonrespondents
Tab. 4 Einschätzung des Mundgesundheitsstatus der Studienteilnehmenden durch die Eltern/Sorgeberechtigten im Vergleich zu den Nonrespondenten

How would you describe the conditions of your child's teeth and gums?	Nonrespondent	Study participant
Very bad	–	3 (0.4%)
Bad	2 (1.2%)	13 (1.8%)
Moderate	17 (10.3%)	115 (16.1%)
Good	72 (43.6%)	405 (56.7%)
Very good	74 (44.8%)	174 (24.4%)
Information missing	–	4 (0.6%)
Total	165 (100%)	714 (100%)

Table 5 Frequency of dental visits by study participants compared to nonrespondents
Tab. 5 Häufigkeit der zahnärztlichen Untersuchungen von Studienteilnehmenden im Vergleich zu Nonrespondenten

Speaking in general: How would you complete the following sentence? I take my child to the dentist ...	Nonrespondent	Study participant
I have never taken my child to the dentist	–	15 (2.1%)
... only when my child has problems with their teeth	5 (3.0%)	44 (6.2%)
... for occasional check-ups	17 (10.3%)	69 (9.7%)
... for regular check-ups	141 (85.5%)	586 (82.1%)
Information missing	2 (1.2%)	–
Total	165 (100%)	714 (100%)

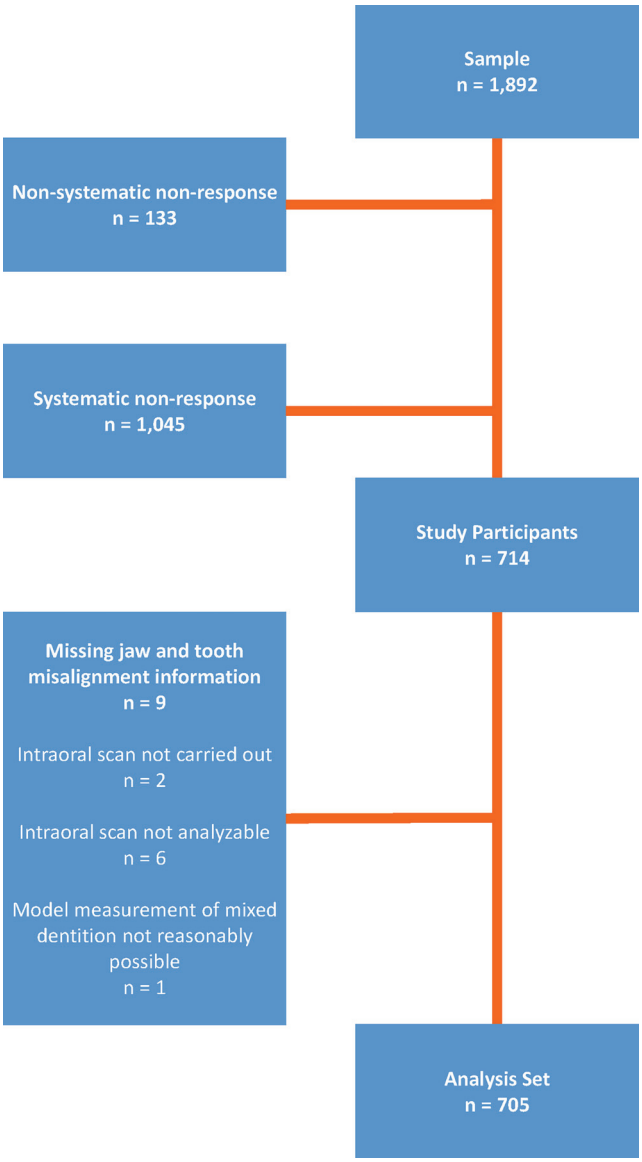

Fig. 1 Flow chart. From the gross sample to analysis set of the German Oral Health Study (DMS) 6 orthodontic module
Abb. 1 Ablaufdiagramm. Von der Rohstichprobe zum Analyseset des kieferorthopädischen Moduls der Deutschen Mundgesundheitsstudie (DMS) 6

- No information on the target person, could not be contacted,
- Strictly rejected participation for data protection reasons,
- Strictly rejected participation for other reasons, complete objector,
- Did not appear at scheduled appointment, no information on the reasons why,
- Examination terminated, and
- Rejected participation because of doubts relating to the coronavirus disease 2019 (COVID-19) pandemic.

Table 6 Response rate calculation in accordance with the American Association for Public Opinion Research (AAPOR)
Tab. 6 Berechnung der Rücklaufquote in Anlehnung an die American Association for Public Opinion Research (AAPOR)

	Sample
Unadjusted gross sample	1892
Quality-neutral drop-outs	133
Adjusted gross sample	1759
Study participants	714
Nonparticipants	1045
Response rate	40.6%

After QND and systematic dropout exclusion, 714 study participants remained.

For case definition, however, further differentiation was made between study participation and valid cases. Only study participant cases with the available jaw scan images were included in the statistical analysis. Using this definition, 714 study participants were registered and 705 cases were included in the data analysis.

Response rate and utilization

The sample response rate reached 40.6% (Table 6). The response rate calculation was based both on response rate 2, in accordance with the American Association for Public Opinion Research [14] and the calculations stated in the cross-sectional survey in the study "Health of children and young people in Germany, 2nd wave" [15].

Discussion

In the first German Oral Health Study in 1989—as in this study—8- to 9-year-old children underwent orthodontic examination. The most common finding was deep bite (34%), followed by enlarged overbite (17%), lateral crossbite (15%), and open bite (11%). According to Angle's classification, 59% of children showed no neutral bite. Boys were significantly more likely to be diagnosed with a deep bite than girls. Habits, dyskinesias, and dysfunctions representing risk factors for tooth and jaw misalignment were very widespread: 53% of the children displayed dyskinesias such as lip and inner cheek biting; 44% of children exhibited fingernail biting; 19% of the 8- and 9-year-old children reported occasionally sucking their thumb. Children who were identified with dysfunctions (orofacial dyskinesias) or, in particular, those who sucked their thumb, displayed significantly more tooth and jaw misalignments. At only 8 and 9 years old, 29% of those surveyed reported being unhappy with their tooth positioning. Dentition corresponding to the anatomical norm (eugnathic) was rare and fully observed in only 1% of children.

Reliability testing

Except for 6-year molar arch length, all examined characteristics displayed very good intrarater and interrater agreement. For the types of sagittal occlusive deviations (neutral/distal/mesial), the agreement was almost 100% with only one deviation observed across all evaluators and runs. Regarding the extent of sagittal occlusive deviations (neutral/less than cusp-on-cusp relation/cusp-on-cusp relation/more than cusp-on-cusp relation), in three of the 10 evaluated jaw halves, we observed interindividual and intraindividual deviations (cusp-on-cusp relation vs more than cusp-on-cusp relation). This is due to the fact that the digital models are difficult to judge objectively. When assessing whether contact point deviations of >1 mm were evident, no intraindividual deviations were observed and interindividual deviations were observed in 3 of the 10 evaluated jaws.

Survey of nonrespondents

While 90% of nonrespondents reported that their child's tooth and gum status was very good, only 80% of study participants reported the same. A possible reason for this may be that the parents/guardians made more realistic oral hygiene statements due to the upcoming dental examination. Within the scope of the nonrespondents' survey, distortion caused by a tendency to give socially desirable responses could also be a reason for the difference in estimation. However, overall, the analysis of the nonrespondents' survey did not show systematic differences between study participants and the surveyed nonrespondents. Therefore, it can be assumed that there is no distortion of the study results stemming for the percentage of nonrespondents.

Conclusions

Based on the conducted analysis, it can be assumed that the examined 8- and 9-year-old children participating in the study are representative of the statistical population in Germany.

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Declarations

Conflict of interest A.R. Jordan, K. Kuhr, C. Ohm and N. Frenzel Baudisch declare that they have no financial or nonfinancial interests that are directly or indirectly related to the work submitted for publication.

Ethical standards The Ethics Committee at Witten/Herdecke University assessed the study in advance from an ethical perspective and approved it (No. 113/2020). The study was begun only after a favorable assessment had been received from the competent ethics committee. Written informed consent was obtained from the patients or their parents/legally authorized representatives (LAR) in the case of children under 18.

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ORIGINAL ARTICLE

Does orthodontic treatment need have an impact on oral health-related quality of life?

Katrin Bekes[1] · Kathrin Kuhr[2] · Cristiana Ohm[2] · Nicolas Frenzel Baudisch[2] · Andreas Rainer Jordan[2]

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Abstract

Objectives The aims of this study were to determine the frequency of oral health-related quality of life (OHRQoL) impairment in a national representative sample of 8 to 9 year olds in Germany and to evaluate the impact of orthodontic treatment need.

Methods Data were collected in the Sixth German Oral Health Study (Sechste Deutsche Mundgesundheitsstudie, DMS 6) and subjects were sampled using a multistage sampling technique. OHRQoL was measured with a modified version of the 5-item Oral Health Impact Profile (OHIP-5) which was administered in a computer-assisted personal interview. Children were also examined for malocclusion and orthodontic treatment need.

Results In all, 1892 children aged 8–9 years were invited to take part. Finally, data of 705 children (48.6% female) could be included in the analysis. The OHIP-5 mean was 1.3 (±2.0). There was no relevant influence from age and gender on the OHIP-5 summary scores ($r < 0.10$), but the summary scores differed when analyzed separately regarding orthodontic treatment need or no orthodontic treatment need (1.5 ± 2.0 vs. 1.2 ± 1.9, $p = 0.020$). Nevertheless, the level appears to be low.

Conclusions Malocclusions with orthodontic treatment need have an influence on OHRQoL.

Keywords Survey · Oral Health Impact Profile (OHIP) · Malocclusion · Index of Orthodontic Treatment Need (IOTN) · Sixth German Oral Health Study (DMS 6)

Hat ein kieferorthopädischer Behandlungsbedarf Auswirkungen auf die mundgesundheitsbezogene Lebensqualität?

Zusammenfassung

Zielsetzung Ziele dieser Studie waren die Ermittlung der Häufigkeit von Beeinträchtigungen der mundgesundheitsbezogenen Lebensqualität (OHRQoL) in einer national repräsentativen Stichprobe von 8- bis 9-Jährigen in Deutschland und die Bewertung des Einflusses des kieferorthopädischen Behandlungsbedarfs.

Methoden Im Rahmen der Sechsten Deutschen Mundgesundheitsstudie (DMS 6) wurden die Daten erhoben, die Probanden wurden anhand einer mehrstufigen Stichprobenmethode ausgewählt. Die OHRQoL wurde mit einer modifizierten Version des 5-Item Oral Health Impact Profile (OHIP-5) erhoben, dafür wurden computergestützte persönliche Interviews durchgeführt. Die Kinder wurden auch auf Zahnfehlstellungen und kieferorthopädischen Behandlungsbedarf untersucht.

Study Registration Before beginning, the study was registered in the German Clinical Trials Register (DRKS, www.drks.de): DRKS00022472.

✉ Katrin Bekes
katrin.bekes@meduniwien.ac.at

[1] Department of Pediatric Dentistry, Medical University Vienna, University Clinic of Dentistry, Sensengasse 2a, 1090 Vienna, Austria

[2] Institute of German Dentists, Universitätsstr. 73, 50931 Cologne, Germany

Ergebnisse Insgesamt wurden 1892 Kinder im Alter von 8–9 Jahren zur Teilnahme eingeladen. Letztendlich konnten die Daten von 705 Kindern (48,6 % weiblich) in die Analyse einbezogen werden. Der OHIP-5-Mittelwert lag bei 1,3 (±2,0). Es gab keinen relevanten Einfluss von Alter und Geschlecht auf die OHIP-5-Summenscores ($r < 0{,}10$), aber die Summenscores unterschieden sich, wenn sie getrennt nach kieferorthopädischem Behandlungsbedarf bzw. keinem kieferorthopädischen Behandlungsbedarf analysiert wurden ($1{,}5 \pm 2{,}0$ vs. $1{,}2 \pm 1{,}9$, $p = 0{,}020$). Dennoch scheint das Niveau niedrig zu sein.
Schlussfolgerungen Zahnfehlstellungen mit kieferorthopädischem Behandlungsbedarf haben Einfluss auf die OHRQoL.

Schlüsselwörter Erhebung · Oral Health Impact Profile (OHIP) · Malokklusion · Index der kieferorthopädischen Behandlungsnotwendigkeit (IOTN) · Sechste Deutsche Mundgesundheitsstudie (DMS 6)

Introduction

Malocclusion is one of the most important and prevalent oral health problems worldwide [1]. It is defined as a developmental condition with a deflection from the normal relation or alignment of the teeth to other teeth in the same arch and/or to the teeth in the opposing arch [2]. It can vary from minor esthetic to severe. According to a recent review [3], the global distributions of Angle class I, class II, and class III malocclusions in permanent teeth are estimated to be 75, 20, and 6%, respectively. Vertical malocclusions, such as deep overbite and open bite affect can be found in around 22% and 5% of the cases, and posterior crossbite can be observed in 9%. Malformation of the dentition can be accompanied with physical (e.g., chewing, swallowing, and speaking skills) and psychological challenges (e.g., esthetics) and can therefore have an impact on a person's daily life [4].

An objective understanding of the patient's opinion regarding his/her health can be derived by patient-reported outcomes which have also received increasing attention in recent years in pediatric dentistry as they support patient-centered care and clinical indicators alone do not reveal the full impact of oral conditions on the psychosocial well-being of a patient [5]. The most important dPRO is oral health-related quality of life (OHRQoL), which "reflects people's perspective on their oral health status including eating, sleeping and engaging in social interaction; their self-esteem; and their satisfaction with respect to their oral health" [6]. OHRQoL can be assessed using questionnaires (dental patient reported measures [dPROMS]). However, some issues arise when measuring OHRQoL in younger patients due to their different phases of physical cognitive, emotional, social and language development, as oral health and health cognition are considered age-dependent [7, 8]. Therefore, several dPROMs exist for children as well as for adults [5, 9], taking into account different age groups. In adults, the Oral Health Impact Profile (OHIP) is the most widely used and accepted instrument internationally [10, 11]. Currently, the short version of the OHIP, the 5-item OHIP (OHIP-5) is recommended for oral health impact measurement [12]. Originally, this instrument was not designed for children or adolescents. However, it has already been applied in some studies to evaluate OHRQoL in younger age groups [13, 14]. Moreover, its validity and reliability were found satisfactory [15]. Therefore, it can be assumed that the OHIP is also applicable for schoolchildren and adolescents.

Until now, there are no national representative data available for OHRQoL in German 8–9 year olds in general as well as regarding to orthodontic treatment need.

Therefore, the aims of this study were to determine the frequency of oral health-related quality of life (OHRQoL) impairment in a national representative sample of 8–9 year olds in Germany and to evaluate the impact of orthodontic treatment need using the 5-item version of the OHIP. The study is part of the Sixth Oral Health Study (Sechste Deutsche Mundgesundheitsstudie, DMS 6), in particular the orthodontic module (module kfo("Kieferorthopädie")-6.1).

Materials and methods

Subjects

The study population represents a nationwide population-representative collective of children aged 8–9 years in Germany. The sampling was stratified according to the characteristics of the federal states and bik region size classes[1]. For this study, a random sample of 16 municipalities was selected from the 90 municipalities of the Fifth Oral Health Study (DMS V), stratified according to federal states. In addition to the federal state as a stratification characteristic, the selection also took into account a simplified variant of the bik region size classes. If the population in the selected sample municipalities was not sufficiently large, so-called synthetic points were formed from several surrounding municipalities. In a second stage, the target persons were cho-

[1] The BIK regions and interdependency areas are a nationwide spatial classification system in Germany that defines the urban-rural relationships at the municipal level for metropolitan areas, urban regions, middle and sub centers.

sen at random. This was based on the personal registers of the residents' registration offices.

Sample size was calculated regarding the primary aim of the study project, which was to assess the prevalence of malocclusions in 8- and 9-year-old children in Germany. Thereby, the number of cases should be sufficient to estimate the current prevalence of malocclusions in Germany (module kfo-6.1) as well as to have sufficient study participants for the planned resurvey in 2030 (module kfo-6.2). The basis for the calculations on the expected number of cases in module kfo-6.2 was the available data set of the comparable cohort of 12 year olds from the DMS V. It was assumed that 95% of the study participants from module kfo-6.1 met the inclusion criteria for inclusion in the panel. With an annual lost-to-follow-up rate of 3% and a response rate of 70%, a sample size of 670 study participants in 2021 resulted in an estimated gross case number of 483 available persons in 2030. In view of the uncertainties with regard to (a) possible impairments of the field work by political measures in connection with the coronavirus disease 2019 (COVID 19) pandemic and (b) the lack of empirical values on the willingness of study participants to participate in a pandemic situation, a comparatively high gross number of addresses was chosen for safety with a so-called triple translation.

The children were invited to the study center with their parents. There, a personal interview was conducted first, followed by tooth brushing and a dental examination. Beside other questions focusing on group prophylaxis and oral hygiene behavior, the computer-assisted personal interview (CAPI) included the assessment of OHRQoL using the OHIP-5. The children were clinically examined by one dentist who was trained and calibrated. Dental examination included orthodontic clinical findings, orthodontic intraoral scan, presence of caries and restorations, plaque and gingival recession, and gingival bleeding.

Approval for this study was obtained from the ethics committee of the local University Review Board (University of Witten Herdecke; No. 113/2020).

Modified OHIP-5 for children

The 5-item OHIP questionnaire (OHIP-5) is an ultrashort version of the original 49-item OHIP which was introduced in Germany and developed using best subset regression [12]. The instrument contains only 10% of the items but captures about 90% of the score information compared with its original version [16]. The 5 items of the OHIP-5 focus on functional limitation, pain, psychological discomfort, physical disability, and handicap. Questions ask about the frequency of events during the last week. Responses are made on an ordinal scale from 0 to 4 (0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, and 4 = very often). Higher scores refer to a worse OHRQoL status. Summing the response codes for the questionnaire items generates an overall OHIP score. The instrument's summary score ranges from 0–20. A summary score of zero indicates the absence of any problems, and a higher OHIP score represents more impaired OHRQoL.

In the present study, a slightly modified German version of the OHIP-5 was used. First, the formal form of "you/Sie" in German was substituted with an informal form "you/Du". Second, the term "teeth, mouth or dentures" in each question was replaced by "teeth, mouth, dentures or braces". Third, the question "Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?" was supplemented with explanations: "Have you had difficulty doing your usual jobs *(e.g., with your family, at school, with your friends)* because of problems with your teeth, mouth, dentures or braces?"

In addition to the 5 items, the children were also asked for a global rating of the oral health and the overall well-being. These global ratings had a 5-point response format (excellent, very good, good, moderate, poor).

When starting the interview about OHRQoL with the child, the interviewer gave a short introduction. "Now I have a few questions for you about problems with your teeth. Here are the questions (questionnaire was shown and handed out). I will read them and you can read along. At the bottom of the page you will see a grey beam that is getting lighter and lighter. In it are the words 'very often', 'often', 'occasionally', 'hardly ever' and 'never'. I'm going to ask you how often you had certain problems with your teeth. Please answer with the words from the grey beam, either 'very often', 'often', 'occasionally', 'hardly ever' or 'never'."

Results

Study population

A total of 1892 children were initially contacted and invited to take part in the study. After the exclusion of quality neutral defaults and systematic failures, 705 study participants (48.6% female) could be included (response rate 40.6%) for data analysis: 49.4% ($N = 348$) of the children were 8 years old, 50.4% ($N = 357$) were 9 years of age.

Modified version of the OHIP-5

All 5 items of the OHIP were considered comprehensible. The children were able to answer all questions. When approached as to whether they had questions or needed assistance, the children indicated that they understood all questions.

Table 1 OHIP-5 mean scores for the whole national sample ($N = 705$)
Tab. 1 Mittlere OHIP-5-Scores für die gesamte nationale Stichprobe ($n = 705$)

OHIP	Mean (±SD)	95% CI	Median	Min–Max
Total	*1.3 (±2.0)*	*1.3 (1.2–1.5)*	*0 [0–2]*	*0–14*
OHIP 1	0.3 (±0.8)	0.3 (0.3–0.4)	0 [0–0]	0–4
OHIP 2	0.4 (±0.8)	0.4 (0.3–0.4)	0 [0–0]	0–4
OHIP 3	0.4 (±0.8)	0.4 (0.4–0.5)	0 [0–1]	0–4
OHIP 4	0.1 (±0.4)	0.1 (0.1–0.1)	0 [0–0]	0–3
OHIP 5	0.1 (±0.4)	0.1 (0.1–0.1)	0 [0–0]	0–3

OHIP-5 5-item Oral Health Impact Profile, *CI* confidence interval, *SD* standard deviation

Oral health-related quality of life

Half of the study participants (50.6%) did not show any impairment of OHRQoL. The mean OHIP-5 score was 1.3 (±2.0; range 0–14; Table 1). Detailed answers of the five questions can be found in Table 2. There was no relevant influence from age and gender on the OHIP-5 summary scores ($r < 0.10$). The most important problem reported by the children (OHIP answer categories 'often' and 'very often') was 'painful aching' (3.2%; Table 2).

Regarding orthodontic treatment need, it could be observed that children in need for treatment showed a significant higher OHIP score (1.5 ± 2.0) than children having no need for treatment (1.2 ± 1.9; $p = 0.020$). However, the level appears to be low. The OHIP item focusing on "difficulty chewing food" also showed a significant difference in mean scores (0.4 ± 0.8 vs. 0.3 ± 0.8; $p = 0.011$; Table 3).

Of the study participants, 90.8% stated that they had a good or very good general health, but only 66.9% rated their oral health being good or very good. Regarding general health, this observation was largely shared when the parents answered the question regarding general health (98.6%). However, the parents rated the oral health status better (81.4%) than the children themselves.

Table 2 Detailed answers of each OHIP item in the whole national sample ($N = 705$)
Tab. 2 Detaillierte Antworten zu jedem Item des OHIP in der gesamten nationalen Stichprobe ($n = 705$)

OHIP	Answer category	% (95% CI)	*N*
OHIP 1 Difficulty chewing any foods	Never	80.4 (77.3–83.2)	566
	Hardly ever	10.3 (8.2–12.7)	72
	Sometimes	7.0 (5.3–9.1)	49
	Often	1.4 (0.7–2.5)	10
	Very often	1.0 (0.5–2.0)	7
OHIP 2 Painful aching	Never	78.7 (75.5–81.6)	555
	Hardly ever	10.5 (8.4–12.9)	74
	Sometimes	7.7 (5.9–9.9)	54
	Often	1.5 (0.8–2.7)	10
	Very often	1.7 (1.0–2.9)	12
OHIP 3 Felt uncomfortable about the appearance	Never	74.1 (70.7–77.2)	521
	Hardly ever	11.9 (9.7–14.5)	84
	Sometimes	11.5 (9.3–14.0)	81
	Often	1.5 (0.8–2.7)	11
	Very often	1.1 (0.5–2.1)	8
OHIP 4 Less flavor in food	Never	92.0 (89.8–93.8)	645
	Hardly ever	5.9 (4.4–7.9)	41
	Sometimes	1.5 (0.8–2.7)	10
	Often	0.6 (0.2–1.5)	4
	Very often	0.0 (0.0–0.5)	0
OHIP 5 Difficulty doing usual jobs	Never	92.1 (89.8–93.9)	648
	Hardly ever	5.3 (3.9–7.2)	37
	Sometimes	2.2 (1.3–3.5)	15
	Often	0.4 (0.2–1.3)	3
	Very often	0.0 (0.0–0.5)	0

OHIP Oral Health Impact Profile, *CI* confidence interval

Table 3 OHIP mean scores in the national sample regarding orthodontic treatment need
Tab. 3 Mittlere OHIP-Scores in der nationalen Stichprobe hinsichtlich kieferorthopädischer Behandlungen

	Orthodontic treatment need ($N=285$)		No orthodontic treatment need ($N=420$)		
OHIP	Mean (±SD)	Median	Mean (±SD)	Median	*P*–value
OHIP 1	0.4 ± 0.8	0 [0–0]	0.3 ± 0.7	0 [0–0]	0.011
OHIP 2	0.4 ± 0.9	0 [0–0]	0.3 ± 0.8	0 [0–0]	0.084
OHIP 3	0.4 ± 0.8	0 [0–1]	0.4 ± 0.8	0 [0–1]	0.852
OHIP 4	0.1 ± 0.4	0 [0–0]	0.1 ± 0.4	0 [0–0]	0.485
OHIP 5	0.1 ± 0.4	0 [0–0]	0.1 ± 0.4	0 [0–0]	0.930
OHIP Total Score	1.5 ± 2.0	1 [0–2]	1.2 ± 1.9	0 [0–2]	0.020

OHIP Oral Health Impact Profile, *SD* standard deviation

Discussion

Compared to adults, the assessment of health-related quality of life in children and adolescents represents a long-neglected topic, which has, however, increasingly moved into the focus of health research in recent times and is also gaining importance at the municipal and national level with regard to urgent questions of disease prevention and health promotion [17]. There is also a growing interest in the relationship between malocclusion or orthodontic treatment need and OHRQoL. Since malocclusion can be observed differently by different patients, it is essential to understand its impact from the patients' perspective [2].

Current literature suggests that children and young people perceive an impact of malocclusions on OHRQoL [18, 19]: malocclusion is linked to decreased OHRQoL. Thereby, the most frequently applied instrument that is used to measure the impact of malocclusions on OHRQoL in children and adolescents is the Child Perception Questionnaire (CPQ). The CPQ was specifically developed for younger age groups (6–14 years) [20, 21]. The present study took another approach for assessing OHRQoL by using the OHIP. The reason for this is that the study is designed in such a way that the study participants will be re-examined in 2030 when they are 17 and 18 years old (module kfo-6.2). Therefore, an instrument was chosen that can be used in adults as well as in children to be able to assess the disease impact over a longer time. In contrast to the CPQ, the OHIP—which was originally developed for adults—has already been applied in adolescent populations to measure OHRQoL regarding tooth avulsion and caries [13, 14]. Further studies conducted in Nigeria, Brazil, and India also used a short form of the OHIP in children to evaluate malocclusion and its impact on quality of life [22–24]. In the present study, the 5-item version of the OHIP was used to measure OHRQoL. In general, the OHIP is a well-validated and internationally widely used questionnaire which has been adapted to many cultural settings [25]. The OHIP-5 is the shortest version of the original questionnaire that started with 49 questions. Other short forms also exist (20-, 19-, 14-item versions). The 5-item version reduces the number of items to 10% of those of the original instrument, it was designed to capture 90% of the information contained in the OHIP-49 summary score with a minimum number of items [26], making it an attractive tool for efficient OHRQoL measurement. Shorter instruments reduce the burden of patients and especially for children, which allows better focusing of their attention.

Recent reviews have shown that malocclusion affects OHRQoL [18, 19, 27], although levels appear to be low [18, 27]. Nevertheless, Alrashed et al. [19] found that the more severe the malocclusion is, the more it is associated with worse quality of life in terms of the psychosocial aspects and some physical aspects of OHRQoL [27]. It can impair quality of life by affecting function, appearance, interpersonal relationships, socializing, self-esteem, and psychological well-being. Current data also suggest that the effect of malocclusions on OHRQoL is modified by the age of the children and their cultural environment [18]. For Germany, data on the impact of malocclusion on OHRQoL are available for 11- to 14-year-old children. Bekes et al. [17] recruited children in a regional sample (Wernigerode, Saxony–Anhalt, Germany) during the annual dental public health examination. OHRQoL was measured using the German version of the CPQ. It was found that summary score differences in children with and without malocclusion were present and statistically significant ($p=0.0001$).

Our study supports these findings. It could be shown that children aged 8 and 9 years with orthodontic treatment need had a significant higher OHIP score (1.5 ± 2.0) than children with no need for treatment (1.2 ± 1.9). The OHIP item representing the functional dimension ("difficulty chewing food") also showed a significant difference in the mean score (0.4 ± 0.8 vs. 0.3 ± 0.8; $p=0.011$). Moreover, children with pain aching tended to have a higher need for care. However, it should be mentioned that the observed level of impairment was low. In a recent review, Alrashed et al. [19] found that the impact of OHRQoL was 0.77 times lower for children with malocclusion than for those without malocclusion (SOR (standardized odds ratio) = 0.77, 95% confidence interval [CI] 0.46–1.30). We were not able to confirm these findings.

The present study has several strengths. One major strength is the representativeness with regard to the population of 8 and 9 year olds in Germany. The relatively high response rate of 40.6% and the number of 705 cases allow valid conclusions to be drawn about oral health in relation to orthodontic anomalies and its impact on OHRQoL. So far, the association of malocclusion and OHRQOL has mainly been evaluated in cross-sectional studies [18]. This study provides national representative data for Germany. No regional sample was used. Another strength of the study is the objectifiability of the orthodontic diagnosis and the classification of the need for treatment or no need for treatment. It was possible to measure the digital models of the jaws captured by intraoral scanner several times if needed. A further strength can be seen in the use of an OHRQoL instrument (OHIP) that has proven over years to have sound psychometric properties and is internationally accepted. On the other hand, one limitation might be that the OHIP has not been applied on a regular basis in studies in younger children up to date.

With the availability of national norm data for German children aged 8 and 9 years, broader application possibilities of the OHIP-5 open up. The data presented can now be used for other studies in Germany that deal with OHRQoL in children in this age group and use the OHIP-5 as OHRQoL instrument. In this way, children with different oral problems as well as different therapy variants can be evaluated with reference to our data from the population-representative sample.

Conclusion

This study suggests that there is an association between orthodontic treatment need and poor oral health-related quality of life (OHRQoL).

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Declarations

Conflict of interest K. Bekes declares payment as scientific advisor of the Sixth German Oral Health Study. K. Kuhr, C. Ohm, N. Frenzel Baudisch and A.R. Jordan declare that they have no financial or nonfinancial interests that are directly or indirectly related to the work submitted for publication.

Ethical standards The Ethics Committee at Witten/Herdecke University assessed the study in advance from an ethical perspective and approved it (No. 113/2020). The study was begun only after a favorable assessment had been received from the competent ethics committee. Written informed consent was obtained from the patients or their parents/legally authorized representatives (LAR) in the case of children under 18.

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ORIGINAL ARTICLE

Comparison of orthodontic treatment need and malocclusion prevalence according to KIG, ICON, and mIOTN in German 8- to 9-year-old children of the Sixth German Oral Health Study (DMS 6)

Christian Kirschneck[1] · Kathrin Kuhr[2] · Cristiana Ohm[2] · Nicolas Frenzel Baudisch[2] · Andreas Rainer Jordan[2]

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Abstract

Purpose The aim of the present study was to compare the malocclusion indices KIG (Kieferorthopädische Indikationsgruppen, Orthodontic Indication Groups), ICON (Index of Complexity, Outcome and Need), and mIOTN (modified Index of Orthodontic Treatment Need) regarding differences in malocclusion prevalence and their assessment of orthodontic treatment need in German 8- to 9-year-old children of the Sixth German Oral Health Study (Deutsche Mundgesundheitsstudie, DMS 6).

Methods The necessary data for the calculation of the KIG, mIOTN, and ICON were collected by a dentist as part of a clinical orthodontic examination during the field phase of the DMS 6 and by a subsequent digital orthodontic model–analytical evaluation of intraoral scans of the dental arches and the occlusal situation in habitual occlusion.

Results Prevalence, severity, and treatment need of tooth and jaw misalignments differed in part considerably depending on the index used for assessment. On the other hand, there were several outcomes which yielded quite similar results for the different indices used, such as orthodontic treatment need, which ranged from 40.4% (KIG) over 41.6% (ICON) to 44.2% (mIOTN). Interestingly, orthodontic treatment need for the individual subject could differ considerably, when assessed using different indices.

Conclusions In general, the results show that the mIOTN is much more conservative in assessing malocclusion prevalences often being smaller than those derived by KIG or ICON. In contrast, KIG and ICON often yield similar prevalences with certain distinct differences due to discrepancies in the respective definitions and also clearly differentiate between treatment possibility and arbitrarily determined treatment need.

Keywords Orthodontic treatment need · Malocclusion prevalence · Orthodontic Indication Groups · Index of Complexity, Outcome and Need · Modified Index of Orthodontic Treatment Need

Availability of data and material All pertinent data are available from the corresponding author upon reasonable request.

Study Registration Before beginning, the study was registered with the German Clinical Trials Register (DRKS www.drks.de): DRKS00022472

✉ PD Dr. Dr. Christian Kirschneck
christian.kirschneck@ukr.de

[1] Department of Orthodontics, University Hospital Regensburg, Franz-Josef-Strauß-Allee 11, 93053 Regensburg, Germany

[2] Institute of German Dentists, Universitätsstr. 73, 50931 Cologne, Germany

Vergleich des kieferorthopädischen Behandlungsbedarfs und der Prävalenz von Malokklusionen nach KIG, ICON und mIOTN bei deutschen 8- bis 9-jährigen Kindern der Sechsten Deutschen Mundgesundheitsstudie (DMS 6)

Zusammenfassung

Ziel Das Ziel der vorliegenden Studie war es, die Indizes KIG (Kieferorthopädische Indikationsgruppen), ICON (Index of Complexity, Outcome and Need) und mIOTN (modifizierter Index of Orthodontic Treatment Need) hinsichtlich Unterschieden in der Malokklusionsprävalenz und deren Einschätzung des kieferorthopädischen Behandlungsbedarfs bei deutschen 8- bis 9-jährigen Kindern der Sechsten Deutschen Mundgesundheitsstudie (DMS 6) zu vergleichen.

Methode Die notwendigen Daten zur Berechnung von KIG, mIOTN und ICON wurden von einem Zahnarzt im Rahmen einer klinisch-kieferorthopädischen Untersuchung während der Feldphase der DMS 6 und durch eine anschließende digitale kieferorthopädische modellanalytische Auswertung von Intraoralscans der Zahnbögen und der okklusalen Situation in habitueller Okklusion erhoben.

Ergebnisse Prävalenz, Schweregrad und Behandlungsbedarf von Zahn- und Kieferfehlstellungen unterschieden sich je nach dem zur Bewertung herangezogenen Index zum Teil erheblich. Andererseits gab es mehrere Endpunkte, die für die verschiedenen verwendeten Indizes recht ähnliche Ergebnisse lieferten, wie etwa der kieferorthopädische Behandlungsbedarf, der von 40,4 % (KIG) über 41,6 % (ICON) bis 44,2 % (mIOTN) reichte. Interessanterweise konnte der kieferorthopädische Behandlungsbedarf des einzelnen Probanden erheblich variieren, wenn er anhand verschiedener Indizes bewertet wurde.

Schlussfolgerungen Im Allgemeinen zeigen die Ergebnisse, dass der mIOTN beim Assessment der Malokklusionsprävalenzen deutlich konservativer ist, sie waren oft geringer als beim Assessment mit KIG bzw. ICON. Dagegen ergeben sich nach KIG und ICON oft ähnliche Prävalenzen mit gewissen deutlichen Unterschieden aufgrund von Diskrepanzen in den jeweiligen Definitionen. KIG und ICON differenzieren auch klar zwischen Behandlungsmöglichkeit und willkürlich festgestelltem Behandlungsbedarf.

Schlüsselwörter Kieferorthopädischer Behandlungsbedarf · Prävalenz von Malokklusion · Kieferorthopädische Indikationsgruppen · Index of Complexity, Outcome and Need · Modifizierter Index of Orthodontic Treatment Need

Introduction

Misaligned teeth and jaws are among the most common health problems affecting the oral cavity, along with caries and periodontal diseases [2]. The primary task of orthodontics is the preventive and corrective treatment and elimination of malfunctions as well as tooth and jaw misalignments with pathological value [15]. This includes the detection, prevention, diagnostics and therapy of malformations of the masticatory system, as well as tooth position and bite anomalies, jaw malformations and deformations of the jaw and the facial skull [12]. Orthodontic abnormalities are also associated with limitations in chewing, breathing, phonetics, and swallowing [12]. In this sense, orthodontics is a preventive discipline if treatment can prevent secondary diseases [15]. The causes of orthodontic anomalies are multifactorial and range from genetic, epigenetic, and functional to environmental factors. The degree of severity of the individual diseases is also extremely variable. The treatment options are correspondingly extensive. Genetic and epigenetic factors are difficult to influence through orthodontic therapy; treatment is primarily directed against the consequences or the phenotypic manifestation. In the case of functional and environmental factors, on the other hand, there are fundamentally preventive options and often a causal therapy option [12].

Current, population-wide data on the prevalence of tooth and jaw misalignments and corresponding orthodontic treatment need in Germany are not available. The last nationwide recording dates from 1989 being the First German Oral Health Study (DMS1) [13]. In particular, there are no systematic epidemiological data on tooth and jaw misalignments from the new federal states. This means that the overall orthodontic and epidemiological picture in Germany is not complete—with corresponding uncertainties for the planning of dental health care, a gap that has now been closed with the current Sixth German Oral Health Study (Deutsche Mundgesundheitsstudie, DMS 6), which for the first time in over 30 years aimed to quantify prevalence, severity and treatment need of tooth and jaw misalignments in the general German population of 8- to 9-year-old children.

Prevalence, severity, and treatment need of tooth and jaw misalignments can be quantified by means of various epidemiological indices, which have been specifically developed for this purpose over the years. Since the Orthodontic Indication Groups (Kieferorthopädische Indikationsgruppen, KIG) represent and reflect the orthodontic care provided by dentists in Germany in statutory health

insurance, they were included in the DMS 6 as a leading index for sociopolitical reasons. In Germany, the Orthodontic Indication Groups are a diagnosis-related classification scheme for assessing reimbursement of orthodontic treatment services within the framework of contractual dental care provided by statutory health insurance [1, 17]. On January 1, 2002, KIG replaced the therapy-oriented indication system that had been in use until then. Malocclusions of the patient are categorized into eleven etiological groups and assigned to one of five degrees of severity. Statutory health insurance in Germany covers payment for orthodontic treatment, if the degree of severity reaches grade 3 in at least one etiological group [1, 17].

The Orthodontic Indication Groups are based on the Index of Orthodontic Treatment Need (IOTN) index, which is used in an analogous manner to assess orthodontic treatment need in Great Britain by the National Health Service (NHS) [2]. IOTN is an internationally well-established index and has been used as epidemiological tool in various studies before [3, 5]. To allow international comparability of results, we also aimed to assess the IOTN as part of the DMS 6—as concerns regarding its complexity, the need for a longer training period, and its reliability in epidemiological studies have been raised; however, we decided to calculate the modified version of the IOTN (mIOTN), which was specifically developed for oral health surveys [6].

ICON (Index of Complexity, Outcome and Need) is probably the most suitable index for epidemiological investigations [11] and was therefore also assessed as part of the DMS 6. The ICON index was developed by Daniels and Richmond (the developers of the Peer Assessment Rating Index, PAR) in 2000 [7] and is based on a consensus process of 97 orthodontists from eight European countries and the USA, which represents a significant advantage over other indices, as ICON is validated across Europe and the USA. The validity of the index has been shown in several studies [8, 16]. It represents an improvement of the PAR index, as it reassesses the individual occlusal parameters in terms of their importance, takes aesthetic aspects into account and, in addition to assessing the treatment result, also enables an assessment of the need for treatment, similar to the Index of Orthodontic Treatment Need (IOTN) [4]. Studies have shown that the ICON can replace the PAR, the Dental Aesthetic Index (DAI) and the IOTN [9], as it takes into account not only the treatment outcome, but also the severity of the anomaly initially present. It can also be used efficiently clinically, since it can be derived in a short time per case using both jaw models and clinical assessments [11].

As prevalence, severity, and treatment need of tooth and jaw misalignments were assessed by three different epidemiological indices in the context of the DMS 6 (KIG, mIOTN, and ICON), it is reasonable to surmise that outcomes will differ, as different criteria for classifying malocclusion prevalence, severity, and treatment need exist for KIG, mIOTN, and ICON. The aim of the present study in the framework of the Sixth German Oral Health Study (DMS 6) was therefore to compare the malocclusion indices Orthodontic Indication Groups (Kieferorthopädische Indikationsgruppen, KIG), ICON, and mIOTN regarding differences in malocclusion prevalence and their assessment of orthodontic treatment need in German 8- to 9-year-old children of the Sixth German Oral Health Study (DMS 6).

Materials and methods

The DMS 6 is an oral epidemiological examination and social science survey on a nationally representative level with a focus on tooth and jaw misalignments. The investigations took place from January–March 2021 in 16 study centers in Germany. After an address drawing in the municipal administrations of the study centers, 1892 people from the birth cohorts of 2011 and 2012 were invited to take part in the study. A total of 714 study participants were dentally examined and socially questioned. All relevant data were available for 705 study participants and included in the statistical analysis. The response rate was 40.6%, and 51.4% of the study participants were male (female: 48.6%), the proportion of 8-year-old children was 49.4% (9-year-olds: 50.6%). A survey of nonrespondents was then conducted to gain insight into any systematic differences between study participants and nonstudy participants. Since the analysis did not show any systematic differences between the study participants and the nonstudy participants surveyed, no distortion of the study results can be assumed due to the proportion of nonrespondents and the study results can be regarded as representative.

The necessary data for the calculation of the KIG, mIOTN, and ICON were collected, on the one hand, by a dentist as part of a clinical orthodontic examination during the field phase of the DMS 6 and, on the other hand, by the subsequent digital orthodontic model–analytical evaluation of intraoral scans of the dental arches and the occlusal situation in habitual occlusion. Habits, dyskinesias, and dysfunctions were recorded, on the one hand, by questioning the study participants and, on the other hand, by a dental diagnosis. Craniofacial anomalies, such as cleft lip and palate, were also recorded as part of the dental diagnosis.

For reasons of research ethics, a comprehensive X-ray examination as part of the DMS 6 was not possible. Tooth retention, tooth displacement, hyper- and hypodontia, as they are recorded according to KIG, can only be reliably detected with the help of radiation-invasive methods. In a purely clinical study, the prevalences would probably be

underestimated. For this reason, the above findings were not collected. For further details regarding the methodology of the DMS 6, please refer to the methods paper of the DMS 6 [10].

KIG

The assessment of the Orthodontic Indication Groups (Kieferorthopädische Indikationsgruppen, KIG) was carried out as described in the guidelines of the Federal Committee of Dentists and Health Insurance Companies for orthodontic treatment in the version dated June 4, 2003 and published on September 24, 2003 in the Federal Gazette No. 226 (p. 24966) dated December 3, 2003 [1], supplemented by the content presented in the monograph "Orthodontic Accounting" [17]. In contrast to clinical practice, not only the highest degree of severity was recorded, i.e., not only the category with the highest score was documented, but the degree of severity was determined and recorded separately for each of the etiological groups, since a study participant could also have several different types of malocclusions of different degrees of severity. Orthodontic treatment need is present in cases of severity degrees 3, 4, and 5 according to the regulations of the statutory health insurance in Germany [1].

mIOTN

The modified Index of Treatment Need (mIOTN) was calculated as described in the literature [6, 14]. The mIOTN consists of two components. The aesthetic component IOTN-AC was determined as part of the clinical orthodontic examination using a standardized series of images; it is identical to the aesthetic component in the Index of Complexity, Outcome and Need (ICON). The dental component includes 5 malocclusions: missing teeth, overjet, crossbites, displacement of contact points (crowding), and overbite. The aim of mIOTN is to determine a definite need for orthodontic treatment. There are no further classifications according to severity/complexity. In a first step, it is determined for each component or each malocclusion whether there is a definite need for treatment. Only if no need is determined for any of the components, a subject is assigned the category "No need for treatment".

ICON

The Index of Complexity, Outcome and Need (ICON) was evaluated as described in the literature [7, 9]. As with the orthodontic indication groups (KIG), not only the highest degree of severity was recorded, i.e., not only the category with the highest score value, but the degree of severity was determined and recorded separately for each of the 7 groups, since a study participant could also have several different types of malocclusions and degrees of severity. The aesthetic component ICON-AC, which is identical to the assessment of the aesthetic component of the IOTN-AC, was determined using a standardized questionnaire. In order to determine the total score, the severity of the 7 malocclusion groups is multiplied by a respective weighting factor and the values obtained are added up to the actual ICON index value (weighted total score, range 1–122). If the total score is greater than 43, treatment according to ICON is mandatory. In addition, the ICON index was used to assess the complexity of the treatment.

Results

Orthodontic treatment need

According to KIG, orthodontic treatment need corresponding to KIG degrees 3, 4, and 5, was found in 40.4% ($N = 285$) of surveyed German children 8–9 years old. According to ICON, treatment need in the same population corresponding to a total ICON score greater than 43 was determined to be 41.6% ($N = 278$) and according to mIOTN 43.3% ($N = 305$) only considering the dental component and 44.2% ($N = 312$) also considering the aesthetic component of mIOTN. The mean value of the aesthetic component was 3.2 points. Since treatment according to ICON is indicated from a total score of 44 points, it is possible due to the weighting factor that an indication for treatment is triggered solely by the aesthetic assessment of the teeth, without further clinical findings having to be available. This is the case from an aesthetic rating of "7" (out of 10). This affected 2.5% of the study participants. For KIG aesthetic evaluations are irrelevant and not considered.

A scatter plot shows that subjects, who have been identified to be in need of orthodontic treatment by one index, are not necessarily assessed the same way by another index, as seen in a comparison of KIG and ICON (Fig. 1). Ideally, one would expect a linear dependency in which, for example, all ICON scores in the grade 1 KIG group are also in the lower range, at least not exceeding the limit score of 43/44 points. However, this is not the case. The same applies to KIG grade 5: If the indices would yield congruent results, it would be expected in this case that the ICON scores would all be beyond the absolute treatment indication of 44 points. This is not the case either. The evaluation shows that the intersection, in which both indices indicate a treatment indication (upper right quadrant) is only 46.6%.

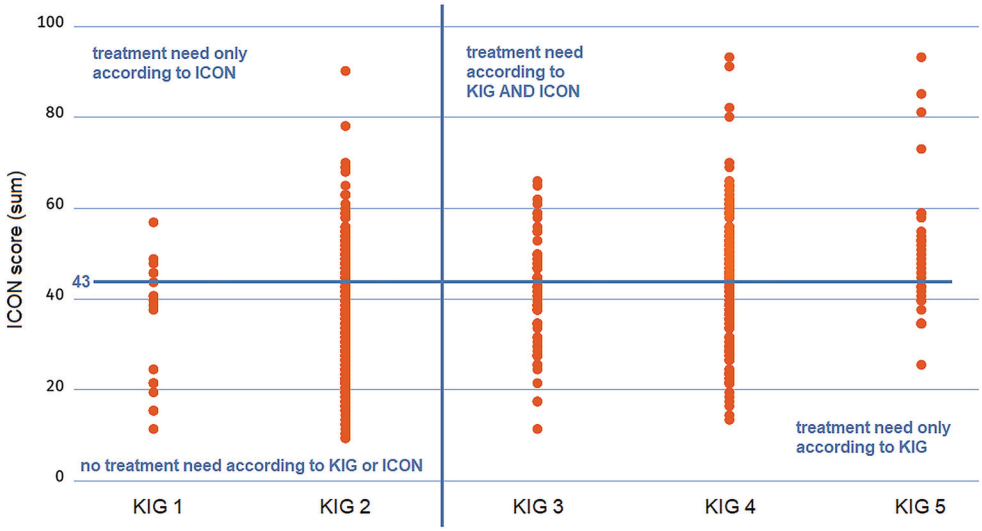

Fig. 1 Scatterplot depicting subjects categorized into different KIG grades and corresponding ICON scores. Orthodontic treatment need (and severity of malocclusion) is assessed differently by both epidemiological indices for the individual subject, although the orthodontic treatment need determined for the total population is quite similar (KIG 40.4%, ICON 41.6%). *KIG* orthodontic treatment need (Kieferorthopädische Indikationsgruppen), *ICON* Index of Complexity, Outcome and Need

Abb. 1 Scatterplot zur Einteilung der Probanden in verschiedene KIG-Grade und entsprechende ICON-Scores. Der kieferorthopädische Behandlungsbedarf (und Schweregrad der Malokklusion) wird von den beiden epidemiologischen Indizes für den einzelnen Probanden unterschiedlich bewertet, obwohl der für die Gesamtpopulation ermittelte kieferorthopädische Behandlungsbedarf relativ ähnlich ist (KIG 40,4%, ICON 41,6%). *KIG* Kieferorthopädische Indikationsgruppen, *ICON* Index of Complexity, Outcome and Need

Severity/complexity of malocclusion

Severity of malocclusion is expressed in KIG by different KIG degrees from 1–5. This is somewhat mirrored in ICON by the complexity of malocclusion treatment, which is also expressed in five degrees from "easy", "mild", "moderate" over "difficult" to "very difficult". Severity or complexity of malocclusion is not considered in mIOTN. KIG degrees 1, 2, 3, 4, and 5 were found in 2.5% ($N=18$), 57.0% ($N=402$), 10.0% ($N=70$), 25.5% ($N=180$), and 5.0% ($N=35$) of the study population, respectively, and ICON complexities "easy", "mild", "moderate", "difficult" and "very difficult" in 22.1% ($N=148$), 57.8% ($N=386$), 16.6% ($N=111$), 1.8% ($N=12$), and 1.7% ($N=11$).

Craniofacial anomalies

Craniofacial anomalies, which is predominantly the presence of oral clefting, were found in 0.4% ($N=3$) of the study population according to KIG, whereas ICON and mIOTN do not include this assessment.

Buccal and lingual nonocclusion

Buccal and lingual nonocclusion was found in 0.3% ($N=2$) of the study population according to KIG, whereas ICON and mIOTN do not include this assessment.

Distal and mesial malocclusion

Distal malocclusion is assessed in KIG according to the degree of sagittal dental overjet of incisors and categorized in three degrees of severity with degrees 2, 4 and 5 corresponding to an increased overjet of 3–6 mm, 6–9 mm and greater than 9 mm, respectively. Mesial malocclusion is determined by the degree of reverse overjet with degree 4 corresponding to a reverse overjet up to 3 mm and degree 5 over 3 mm. mIOTN on the other hand considers only an overjet of greater than 6 mm as distal malocclusion and a reverse overjet of greater than 3.5 mm as mesial malocclusion (if masticatory or speech anomalies are present, mesial malocclusion is already considered from a reverse overjet of 1 mm onwards). By contrast, ICON does not rely on sagittal dental overjet in this assessment, but rather considers occlusion in the buccal segment with any cusp relation deviating from cusp to embrasure as malocclusion not differentiating between mesial and distal malocclusion. Distal malocclusion according to KIG (degrees 2, 4, and 5) was found in 88.9% ($N=621$) of surveyed German children 8–9 years old and mesial malocclusion (degrees 4 and 5) in 4.0% ($N=28$). According to mIOTN, prevalence of distal malocclusion was 19.7% ($N=137$), which corresponds to KIG degrees 4 and 5 combined, and of mesial malocclusion 0.6%. According to ICON mesial and distal malocclusion combined amounted to 76.5% ($N=512$) at the left and 77.7% ($N=519$) at the right jaw side.

Dental crowding

Dental crowding according to KIG is assessed separately for the anterior (category E) and posterior (category P) segments of the dental arch with three degrees of severity 2, 3, and 4, respectively (degree 2 corresponding to mild crowding of > 1 mm [anterior segment] up to 3 mm, degree 3 moderate crowding up to 4 mm in the posterior segments and 5 mm in the anterior segment and degree 4 corresponding to severe crowding exceeding 4 mm or 5 mm in the posterior or anterior segments). mIOTN does not differentiate between anterior and posterior segments and considers any proximal contact point deviation of 4 mm or above between neighboring teeth as dental crowding. ICON also does not differentiate between anterior and posterior segments defining 5 degrees of crowding with degrees 1, 2, 3, 4, and 5 corresponding to 2.1–5 mm, 5.1–9 mm, 9.1–13 mm, 13.1–17 mm, and > 17 mm (or impacted teeth, which could not be assessed in this study) of crowding, respectively, but only considering crowding in the upper dental arch. Crowding according to ICON and in the posterior segments according to KIG is determined by comparing the sum of the mesiodistal crown diameters to the respectively available arch length, whereas crowding according to mIOTN and in the anterior segment according to KIG is defined via proximal contact point deviations. Anterior dental crowding according to KIG was found in 60.8% ($N = 428$) of German children 8–9 years old (mild/moderate/severe in 51.6%, 8.4%, and 0.7%, respectively) and posterior dental crowding in 29.2% ($N = 206$) of children (mild/moderate/severe in 23.5%, 3.1%, and 3.6%, respectively). According to mIOTN prevalence of dental crowding was 4.0% ($N = 28$). According to ICON dental crowding was present in 6.9% ($N = 46$) of the study population with degrees 1, 2, and 3 found in 5.7%, 1.0%, and 0.2%, respectively, and degrees 4 and 5 not found at all.

Dental spacing

Dental spacing is not assessed by KIG and mIOTN indices, but only by ICON and only in the upper dental arch differentiating three degrees of spacing with degrees 1, 2, and 3 corresponding to 2–5 mm, 5–9 mm, and > 9 mm of spacing. Prevalence in the study population according to ICON was 68.7% ($N = 459$) with degrees 1, 2, and 3 contributing 32.2%, 29.1%, and 7.4%, respectively.

Crossbite

KIG differentiates three types of posterior crossbite, namely cusp-to-cusp bite (degree 2), bilateral (degree 3), and unilateral crossbite (degree 4) with prevalences in the study population being 2.7% ($N = 19$), 0.4% ($N = 3$), and 5.3% ($N = 37$), respectively, amounting to a total prevalence of transversal malocclusions of 8.4% ($N = 59$). mIOTN on the other hand defines crossbite as a forced bite, i.e., a discrepancy between retruded contact position and intercuspal position of more than 2 mm, which was found in 23.0% of children ($N = 162$), also considering anterior crossbites, which indicate a mesial occlusion rather than a transversal problem. ICON follows the same principle as KIG defining any transverse relationship of cusp to cusp or worse as crossbite with the prevalence determined as 11.6% ($N = 78$), but also considers anterior crossbites. The definition of the crossbite according to mIOTN and ICON, which pool transversal and sagittal traits, does thus not correspond to the crossbite definition of KIG, which only considers the posterior crossbite.

Open bite

Open bite according to KIG is defined as a vertical gap between incisal edges or cusps of upper and lower anterior or posterior teeth of up to 1 mm (degree 1), more than 1 mm (degree 2), 2 mm (degree 3), or 4 mm (habitual aetiology: degree 4, skeletal aetiology: degree 5). mIOTN only considers open bite from a vertical gap of 4 mm onward (corresponding to KIG degrees 4 and 5) as open bite, whereas ICON severity grading corresponds to the KIG system, except that no differentiation is made between habitual and skeletal aetiology (both classified as degree 4) and that only anterior open bite is considered by ICON. Open bite according to KIG was found in 7.1% ($N = 50$) of surveyed German children 8–9 years old (degrees 2, 3, and 4 in 4.6%, 1.6%, and 1.0%, respectively—degree 1 could not be assessed). According to mIOTN, prevalence of open bite was 1.0% ($N = 7$) and according to ICON open bite was present in 12.4% ($N = 83$) of the study population with degrees 1, 2, 3, and 4 found in 5.4%, 4.5%, 1.5%, and 1.0% of subjects, respectively.

Deep bite

Deep bite according to KIG is defined as an increased vertical overlap between incisal edges of upper and lower anterior teeth of more than 3 mm (degree 2) or more than 3 mm with traumatic contact of incisal edges to the gingiva of the antagonist jaw (degree 3). mIOTN only considers KIG degree 3 as deep bite, whereas ICON defines deep bite as lower incisor coverage greater than one third (degree 1), two thirds (degree 2), or full coverage and beyond (degree 3). Deep bite according to KIG was found in 61.0% ($N = 420$) of German children 8–9 years old (degrees 2 and 3 in 51.2% and 9.8%, respectively). According to mIOTN prevalence deep bite was 9.8% ($N = 67$) and according to ICON 76.8% ($N = 513$) with degrees 1, 2, and 3 contributing 57.3%, 18.7%, and 0.8%.

Discussion

We could confirm our hypothesis that prevalence, severity, and treatment need of tooth and jaw misalignments as assessed by the three epidemiological indices differed in part considerably depending on the index used for assessment. On the other hand, there were several outcomes which yielded quite similar results for the different indices used, such as orthodontic treatment need, which ranged from 40.4% (KIG) to 44.2% (mIOTN). This shows that despite the different composition of the international ICON and mIOTN indices with regard to malocclusions and components, but also weighting factors considered, an almost identical orthodontic treatment need was determined compared to the Orthodontic Indication Groups (KIG). In an international comparison, this finding confirms that the German KIG system can be regarded as a valid and interchangeably useable instrument for determining the need for orthodontic treatment. Furthermore, the KIG system and the orthodontic treatment need derived is in concordance with orthodontic treatment need as determined by other international indices, suggesting that the KIG system does not cause an over- or undersupply regarding orthodontic treatment delivered in the German population. This is supported by various previous studies on children from different European countries—a European international comparison with the available data shows that the orthodontic treatment need of 40.4% (KIG) to 44.2% (mIOTN), which was determined in the present study for the German population of 8–9 year olds, is European average. In an Estonian study [18], a significantly increased treatment need of 64.3% was indicated. On the other hand, a Croatian study reported a need for orthodontic treatment for 34% in children in the mixed dentition phase [20]. For the examined age group of 8- to 9-year-old children, there are only a few studies available for a comparison, so that the study results can only be classified in the international context to a limited extent.

Interestingly, although orthodontic treatment need for the study collective in general was determined to be quite similar across the various indices, for the individual subject it was not. As Fig. 1 clearly shows, some subjects rated with no treatment need by one index had a treatment need when assessed by another index and vice versa. This is certainly due to the fact that different definitions, weightings, and demarcation points for the minimal severity of the respective type of malocclusion requiring treatment were rather arbitrarily determined for the individual indices and are not based on actual epidemiological data regarding the effects or functional–medical benefits of orthodontic treatment, when administered for different initial severities and types of malocclusion, which should be a focus of future research, although some findings in this regard are already available in the literature [12].

Although severity of malocclusion as determined by KIG and complexity of treatment as determined by ICON are not directly comparable, as they assess different entities, a certain comparison is possible, as a higher severity of malocclusion in consequence leads to a higher complexity of treatment, as suggested by direct comparison of mild malocclusion severity (KIG) and mild treatment complexity (ICON), which showed similar prevalences of about 57%. Interestingly, prevalence of treatment complexity assessed as "difficult" and "very difficult" by ICON was considerably less than prevalence of severe and very severe malocclusion according to KIG (degrees 4 and 5), indicating that also severe malocclusions can be effectively treated orthodontically without extreme difficulty.

Prevalence of craniofacial anomalies such as oral clefting and buccal and lingual nonocclusions was only assessed by KIG and can therefore not be compared between indices. Furthermore, due to the low prevalence found in the study population (0.3–0.4%), no valid epidemiological generalizations can be made.

Distal malocclusion, i.e., Angle class II, was found in 88.9% of subjects according to KIG and only 19.7% according to mIOTN, whereas ICON pools this assessment with mesial occlusion (with prevalence rates of about 4.0% according to KIG) [7], thus, yielding slightly biased prevalences of 76.5% and 77.7% for the left and right jaw sides. These distinctly differing results can be easily explained by the different demarcation point used for the extent of sagittal overjet supposed to require orthodontic treatment, which is set at >3 mm by mIOTN [6] and >6 mm by KIG [1], thus, yielding a lower prevalence for distal malocclusion for mIOTN. As ICON uses a completely different assessment of not optimal intercuspidation of antagonist teeth in the posterior dental arch, which includes any deviation from the ideal neutral occlusion [7], prevalence rates are quite high and similar to those derived by KIG, as the KIG system also defines distal occlusion starting from any deviation from normal overjet of 3 mm as degree 2 [17]. A quite similar situation is evident for mesial occlusion with prevalences determined as 4.0% by KIG and 0.6% by mIOTN with ICON not enabling this assessment. As in the KIG system any reverse overjet present is already classified as mesial occlusion [1], this is only the case for reverse overjets of >3.5 mm (with exceptions if functional problems are present), thus, explaining the considerably lower prevalence of mesial occlusion according to mIOTN [6].

A similar situation is present for dental crowding with prevalence according to mIOTN (4.0%) and ICON (6.9%) being much smaller than according to KIG (60.8% anterior, 29.2% posterior crowding). As mIOTN only considers contact point deviations larger than 4 mm as crowding [6], which is quite extensive, prevalence is correspondingly low, whereas KIG considers all proximal contact point de-

viations larger than 1 mm in the anterior segment as dental crowding, thus, yielding the significantly higher prevalence rate [1]. As ICON assesses dental crowding via a comparison of mesiodistal crown widths and available arch length across the entire dental arch [9], differently than mIOTN or KIG, this might explain the significantly lower prevalence compared to the anterior segment according to KIG, but also the posterior segment, as KIG only considers mesiodistal crown widths and available arch length of the orthodontic support zone (canine and premolars) separately for each quadrant. Furthermore, dental crowding is mostly more pronounced in the lower dental arch due to tertiary crowding occurring at the lower incisors, which could also contribute to the lower prevalence found by ICON, which only assessed the upper dental arch [7]. As dental spacing is only assessed by ICON, a comparison to KIG and mIOTN cannot be made. Interestingly, prevalences of the different degrees of dental spacing were quite high reaching 68.7% in total—a fact that indicates that this malocclusion despite its high prevalence is not adequately reflected and considered by the KIG and ICON indices.

Prevalence of crossbite was found to be quite different for KIG (8.4%), mIOTN (23.0%), and ICON (11.6%). This is mainly due to completely different definitions of crossbite according to the different indices. Whereas KIG and ICON consider cusp-to-cusp bite, unilateral and bilateral crossbite morphologically, mIOTN follows a functional definition with crossbite defined as forced bite, i.e., a discrepancy between retruded contact position and intercuspal position of more than 2 mm [6], which does not necessarily correspond to the static bite situation in habitual occlusion. Furthermore, mIOTN and ICON both also consider a reverse overjet, which is a sagittal trait, whereas KIG defines crossbite as a transversal problem. Prevalence of crossbite according to ICON is thus approximately 4% (prevalence of reverse overjet according to KIG) higher than crossbite prevalence according to KIG. Furthermore, the definition of crossbite according to ICON also encompasses buccal and lingual nonocclusion, which are categorized separately in KIG.

Open bite prevalence according to KIG (7.1%) differed considerably from that assessed by mIOTN (1.0%) and ICON (12.4%). As discussed before, mIOTN is much stricter in the definition of open bite only considering vertical gaps of 4 mm and beyond as open bite [6], whereas KIG and ICON already consider open bites as any vertical gap present [1, 7], explaining the higher prevalence rates found. Prevalence according to ICON was still higher than that according to KIG most likely due to the fact that slight open bites of up to 1 mm (degree 1) could not be separately assessed by KIG and are thus missing in the KIG prevalence, which is thus slightly underestimated compared to ICON.

When considering deep bite prevalences, KIG (61.0%) and ICON (76.8%) yielded distinctly higher prevalences than mIOTN (9.8%). Again, mIOTN only designates quite extensive deep bites > 3 mm as such with contact of incisal edges to the gingiva of the antagonist jaw [6], whereas KIG considers any deep bite > 3 mm regardless of traumatic gingival contact present or not, thus, explaining the higher prevalence found according to KIG [1]. The highest deep bite prevalence was found for ICON, which is most likely due to the different definition of deep bite, as not an absolute value (such as 3 mm) for overbite is used in the assessment according to ICON, but rather the coverage of lower incisors by upper incisors being greater than one third of the labial surface [7], which may be less than the demarcation of 3 mm used by KIG and mIOTN depending on the relative height of the lower incisors.

A methodological limitation of the ICON and mIOTN indices is the fact that neither was developed for early mixed dentition, but they were rather developed for permanent (adult) dentition. In particular, when assessing the aesthetic component of the indices (AC) using a chart of ten orthodontic anomalies of increasing severity, there are problems in the transferability of the results, since the chart only shows the permanent dentition, which is not completely reliably transferrable to the 8- and 9-year-old children. Since the aesthetic component is weighted by a factor of 7 in the ICON index, there is a certain potential for bias here. Another shortcoming is the fact that tooth retention, tooth displacement, hyper- and hypodontia could not be assessed within the scope of the DMS 6, because no X-ray images were available for ethical reasons. However, it was clinically recorded whether a space maintainer or a replaced tooth (removable, e.g., children's prosthesis) was present and whether a tooth was in semi-retention. Another limitation on the methodological side is the use of the Orthodontic Indication Groups (KIG) as an epidemiological index in a population of 8- to 9-year-old children, while these are used to determine the reimbursement of orthodontic services within the framework of statutory health insurance for a population of > 10-year-olds. There is also a risk of underestimating the actual prevalence and orthodontic treatment need that arise 1–2 years later in the studied population aged > 10 years, since it is known that most orthodontic anomalies have a tendency to be aggravated during growth [19].

Conclusions

In general, the results show that the mIOTN (modified Index of Orthodontic Treatment Need) is much more conservative in assessing malocclusions with prevalences often being smaller than those derived by KIG (Kieferorthopädische In-

dikationsgruppen, Orthodontic Indication Groups) or ICON (Index of Complexity, Outcome and Need). The reason for this is the fact that the mIOTN is a very simplified index that does not consider various severities of malocclusions, but was rather developed to only differentiate dichotomously between treatment need or no treatment need. In contrast, KIG and ICON often yield similar prevalences with certain distinct differences (e.g., for dental crowding) due to discrepancies in the respective definitions, how a certain type and severity of malocclusion is assessed and graded. Both KIG and ICON also clearly differentiate between treatment possibility and arbitrarily determined treatment need, as both indices define most malocclusions as any deviation from the norm (degree 2 or more in KIG, degree 1 or more in ICON, possibility for treatment) and only later apply demarcation points and recommendations, which severity actually requires treatment (treatment need), although these demarcation points were not derived based on epidemiological data, but rather clinical expertise and consensus. All patients not meeting requirements for treatment need, but having a malocclusion according to KIG/ICON degrees 2 and 1, thus, also presumably have the chance to profit from orthodontic treatment by correcting the malocclusion present, which is considered by KIG and ICON, but not by mIOTN.

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Declarations

Conflict of interest C. Kirschnek declares payment as scientific advisor of the Sixth German Oral Health Study. K. Kuhr, C. Ohm, N. Frenzel Baudisch and A.R. Jordan declare that they have no financial or nonfinancial interests that are directly or indirectly related to the work submitted for publication.

Ethical standards The Ethics Committee at Witten/Herdecke University assessed the study in advance from an ethical perspective and approved it (No. 113/2020). The study was begun only after a favorable assessment had been received from the competent ethics committee. *Consent to participate:* Written informed consent was obtained from the patients or their parents/legally authorized representatives (LAR) in the case of children under 18.

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E-mail: svenja.grossmann@ukb.uni-bonn.de

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The *Journal of Orofacial Orthopedics* provides orthodontists and dentists who are also actively interested in orthodontics, whether in university clinics or private practice, with highly authoritative and up-to-date information based on experimental and clinical research. The journal is one of the leading publications for the promulgation of the results of original work both in the areas of scientific and clinical orthodontics and related areas. All articles undergo peer review before publication. The German Society of Orthodontics (DGKFO) also publishes in the journal important communications, statements and announcements.

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Publishing Director: Marion Bornemann (V.i.S.d.P.)

Publishers Editor: Susanne Redeker

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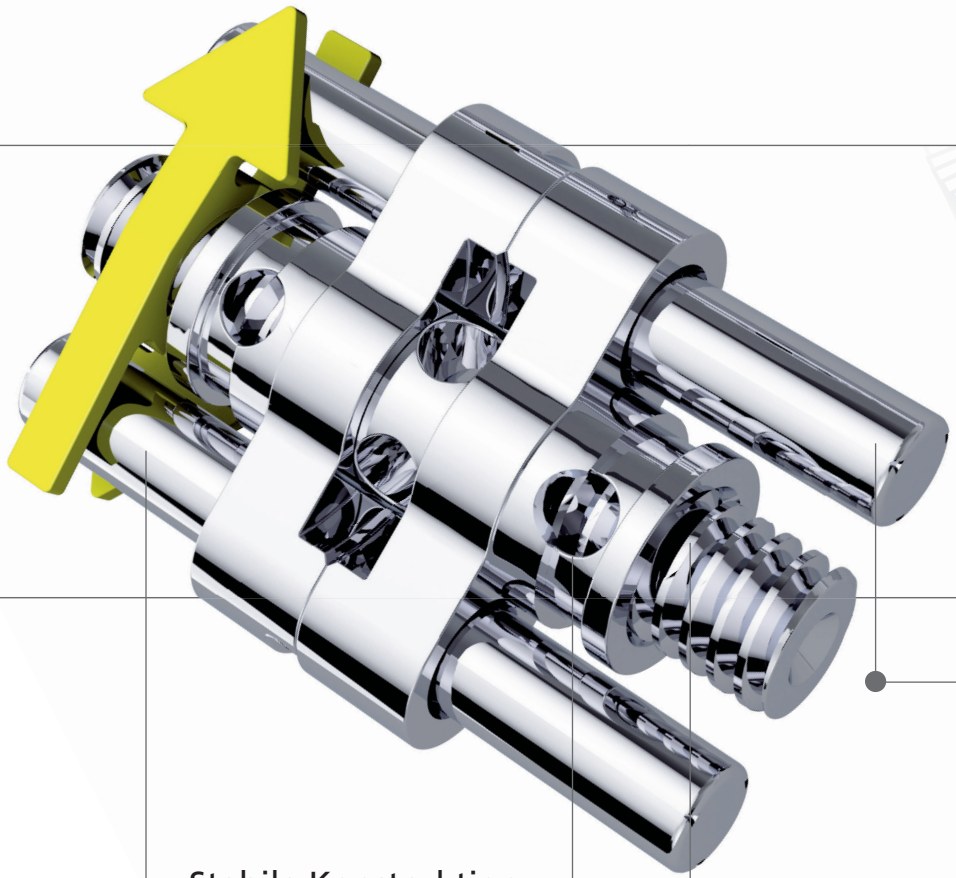

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