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SCIENTIFIC SECTION

Space conditions and prevalence of anterior spacing and crowding among nine-year-old schoolchildren

Christopher J. Lux
Department of Orthodontics, University of Jena, Germany

Britta Dücker
Department of Orthodontics, University of Heidelberg, Germany

Maria Pritsch
Institute of Medical Biometry and Informatics, University of Heidelberg, Germany

Uwe Niekusch
Community Dental Service, Rhein-Neckar-Kreis, Gesundheitsamt Heidelberg, Germany

Gerda Komposch
Department of Orthodontics, University of Heidelberg, Germany

Objective: To give detailed insight into the space conditions and prevalence of spacing and crowding in schoolchildren at nine years of age. The reliability and validity of screening methods was also assessed.

Design: Epidemiological survey.

Setting: South-western part of Germany (Rhein-Neckar-Kreis); elementary schools in a region with a low orthodontic care rate.

Sample and methods: 494 nine-year-old German schoolchildren (237 males, 257 females, median age 9 years) were examined orthodontically in cooperation with the local community dentistry service. A special measurement ruler was developed to enhance validity and reliability of space measurements on location in the schools.

Results and conclusions: Concerning space conditions in the incisor segments: in the maxilla the variety encountered comprised both space excess and moderate to severe crowding. This was considerably larger in the maxilla than in the mandible. Severe crowding (>5 mm) was found more often in the maxilla than in the mandible and affected around 2–3% of the maxillary dentitions. Also severe contact point displacements (IOTN Grade 4) were mainly restricted to the maxilla (prevalence approximately 3%).

In the canine–premolar segments, the arch segments in males were in general around 0.5 mm larger than among the females, also within each dental stage. In general, the maxilla was more often affected by posterior crowding than the mandible. Anterior crowding seemed to be more prevalent than posterior crowding. With respect to the screening methods used in the present study, reliable and valid measurements were also found to be possible in schools. This may open up further opportunities for orthodontic screening by community dentistry services or similar organizations.

Key words: Space conditions, prevalence of crowding and spacing, epidemiological registration of space anomalies, validity and reliability of orthodontic measurements

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Introduction

Björk *et al.*[1] have previously pointed out that a thorough investigation on the occurrence of malocclusions among schoolchildren is of major importance in the planning of orthodontic treatment within the public dental health service. The subsequent literature on the prevalence of malocclusions has shown that crowding is a very common and consistent problem in children and adolescents.[2–7] A detailed insight into the distribution of space anomalies depending on the different stages of dental development was given by Helm[2] who conducted

Address for correspondence: Professor Dr Christopher J. Lux, Department of Orthodontics, University of Jena, 07740 Jena, Germany.
Email: christopher.lux@med.uni-jena.de

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a large epidemiological study in 3842 Danish schoolchildren between 7 and 18 years of age. Thilander and Myrberg[6] investigated orthodontic anomalies in 5459 Swedish schoolchildren and found crowding in every fourth schoolchild (26.3%). Spacing was seen to be half as common as crowding. The prevalence of malocclusion in nine-year-old Finnish schoolchildren was investigated by Hannuksela[3] who found crowding to be the most common anomaly followed by postnormal occlusion. Within the NHANES III survey Proffit *et al.*[4] investigated crowding at various ages and found that crowding and irregularity of incisors affects nearly half of children, worsens in adolescence and continues to increase in adults, particularly in the mandible. The high prevalence of crowding was also supported by Ingervall and Ratschiller[8] as well as Bässler-Zeltmann *et al.*[9] who estimated the treatment need in nine-year-old Swiss/German schoolchildren and who found crowding in at least one arch segment in about every second child. Thilander *et al.*[10] revealed in a Bogotanian population that half of the orthodontically relevant anomalies were occlusal deviations, one-third space discrepancies and one-fifth dental anomalies.

So far, a large number of studies on the prevalence of malocclusion in different populations have been published. Helm[2] as well as Thilander *et al.*[10] in general divided these studies into four major classes, namely (i) estimates of the total frequency of malocclusion, (ii) typological classifications of malocclusions (e.g. Angle classification), (iii) studies focusing on single traits of malocclusion, and (iv) the determination of malocclusion indices. An updated overview of these studies has been given by Thilander *et al.*[10] In general, most investigations give a rough insight into treatment need or into orthodontic screening categories on a very general level, e.g. the presence or absence of malocclusion with or without the need for orthodontic treatment.[11] With respect to space anomalies, the focus of most studies was on distinguishing between the presence or absence of diastema or spacing and crowing beyond a certain borderline value.[2,3,11] Hence, the aim of the present investigation was to provide a more detailed insight into space conditions, i.e. the prevalence of spacing and crowding in the incisor segments and the size of the lateral segments among nine-year-old schoolchildren. Moreover, it was investigated whether reliable and valid orthodontic screenings are generally possible in schools. Besides space anomalies, a number of orthodontically relevant occlusal traits (which were characterized by a good reliability, e.g. overjet) were additionally registered, and this will be presented in another publication.

Subjects and method

The present investigation is based on the examination of 494 schoolchildren (237 males, 257 females). The ages of the children ranged between 8 years 6 months and 9 years 6 months and the median age was 9.0 years in both sexes. After the approval of the local ethics committee (University of Heidelberg, ref. 161/2001), orthodontic examinations were carried out along with a dental examination concerning caries in elementary schools comprising children of all socioeconomic groups. In general, the entire school classes were examined and all children of appropriate age were included in the study. Parents were informed of the examination in advance, and in the respective county it was regularized that dental/orthodontic screenings could be carried out within the framework of community dentistry, without the necessity of an informed consent. In cooperation with the local community dentistry service, schoolchildren in the Rhein-Neckar-Area (south-western Germany) were examined. The only selection criterion for appropriate towns and schools was a low supply rate for orthodontic treatment. As a result, examinations were carried out in towns with population figures between around 2000 and 36000 inhabitants, which rather represents the rural population and the population of small and medium-sized towns. In the present investigation, 11.1% of the children underwent some kind of orthodontic treatment at the time of the examination with an average elapsed treatment time of 7.6 months. No child had a multibracket appliance at the time of the examination. With respect to sample size calculation, assuming a prevalence of 10%, $n=500$ children are required for a precision of $\pm 2.6\%$ with a confidence interval of 95%. From the clinical point of view, this was regarded as satisfactory and around $n=500$ was considered to be an adequate sample size. However, due to the extreme range of prevalences (depending on the anomaly), sample size calculations will remain in this study to a certain degree uncertain.

Intraoral measurements

Space conditions were assessed separately for the incisor section and the lateral sections (canines–premolars and deciduous predecessors) in each jaw.[1] Following Björk *et al.*,[1] the reference points for the measurement of the lateral segments were the distal contact point of the lateral incisor to the mesial contact point of the first molar, if the lateral incisor was correctly positioned and fully erupted. If the lateral incisor was missing, not fully erupted or displaced, the mesial contact of the canine (deciduous canine) was used instead.[1] To facilitate

Figure 1 Measurement of the posterior arch segments by means of the modified ruler

measurement on location in the schools, a special ruler was developed based on the 'Münchner Modell' (Dentaurum, Ispringen, Germany). In the present study, a small metal plate was laser welded to one end of the ruler, and during measurement the metal plate was hooked between the first molar and the second deciduous molar. The length of the lateral segment could then be easily read on the anterior demarcation point (Figure 1). Moreover, the space demand for the unerupted permanent canines and premolars was estimated on the basis of the reference values described by Schulze.[12] Based on a literature review, Schulze[12] determined the average space demand for the permanent canines and premolars: 21.9 and 21.1 mm (males and females respectively) in the maxilla and 21.5 and 20.7 mm (males and females respectively) in the mandible.

The space deviations in the frontal arch segment were determined by evaluating each contact point, i.e. the space deficiency (overlap) and the space excess at each contact point between incisors were summed. In case an incisor on one side was missing, the incisor on the opposite side was used to evaluate the space condition. If both the central and the lateral incisors were missing or could not be used for measurement, the following mean values were used to fix the space demand: upper central incisor: 9 mm, upper lateral incisor: 7 mm, lower central incisor: 5.5 mm, lower lateral incisor: 6 mm.[8,9] To facilitate the registration of the anterior space anomalies in the elementary schools, a ruler with a stepped scale with values between 0.5 and 2.0 mm in steps of 0.5 mm was constructed. Al-Nimri and Richardson[13] developed such a stepped scale for the 'interception gauge' in order to measure incisor crowding in the setting of community dentistry. In addition, contact point displacements were registered between permanent teeth.[14] Finally, a maxillary median diastema was recorded if there was spacing of at least 2 mm between the upper central incisors.[1]

Validity and reliability of measurements

Interexaminer reliability

Interexaminer reliability was determined through the measurement of 30 children, on the same day, by two observers (CJL and BD) working independently from each other. The mean of the differences between the two examiners (systematic bias), the 95% confidence interval (CI) of the true bias, and the reproducibility coefficient (which is 1.96 times the standard deviation of the differences between the replicate measurements) were determined. In addition, the intra-class correlation coefficient (ICC) and its corresponding 95% CI were determined. The ICC relates the inter-examiner variance to the total variance, providing a relative measure of the agreement between the two observers.[15] Table 1 shows the results for the space measurements. If the 95% CI for the systematic error is zero, no relevant systematic drift (bias) has occurred at the 5% level of significance.[15] For a detailed description of the statistical methods concerning measurement errors and reproducibility the reader is referred to Bister *et al.*[15] It can be concluded for most parameters that there is no relevant systematic bias on the 95% level of confidence. The strongest systematic deviation was found for the lower anterior space analysis, with a 95% CI for the bias of −0.74 and −0.06. In general, the measurement errors are very small for measuring the lateral segments by means of the ruler and for the contact point displacements. Higher measurement errors (in the upper jaw mainly random errors) were found for anterior space analysis in both jaws. For the assessment of inter-examiner reliability concerning Björk's dental stages[1] (Figure 2) Cohen's weighted kappa was used and a value of 0.858 was found which indicates very high inter-examiner agreement,[16] here: agreement in 27/30 children = 90%.

Validity of the ruler – validity of measurements

To evaluate the validity of the ruler with respect to lateral arch lengths, 30 lateral segments were measured on plaster casts twice, i.e. by means of the constructed ruler and a digital calliper (Mitutoyo Digimatic Caliper,

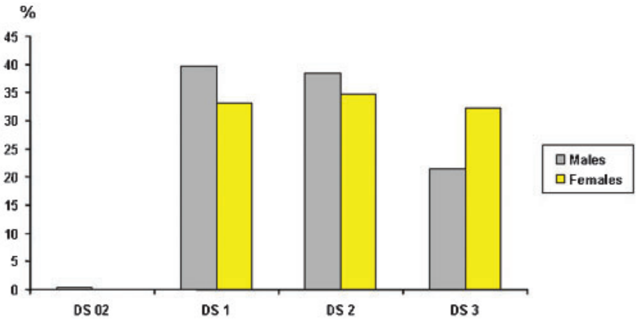

Figure 2 Distribution of dental stages (Björk)[1] according to gender (in %; males and females=100% respectively): DS02=deciduous teeth erupted, DS1=incisors erupting, DS2=incisors fully erupted, DS3=canines and premolars erupting

Mitutoyo Corp., Aurora, IL, USA), providing the gold standard. As a result, the mean of the differences between replicate measurements, representing the systematic error, was 0.024 mm. The 95% CI for the true bias was [−0.05; 0.10], indicating no systematic error, and the reproducibility coefficient for the comparison between the ruler and the digital calliper was 0.42 mm which was considered acceptable.

Statistical testing

The statistical testing was carried out with SAS Version 9.1 (SAS Institute Inc., Cary, NC, USA) and comprised testing of sex differences, testing of differences between groups with various anomalies (independent measurements) and of differences between upper and lower jaw as well as left and right sides (dependent measurements). In the case of independent measurements, a Mann Whitney U-test, and in the case of dependent measurements, a Wilcoxon matched pairs signed rank test was used. Differences in the distribution of categorical data (e.g. dental stages) were evaluated using Fisher's exact test. A Kruskal–Wallis test was used to evaluate differences between the three dental stages (DS1–DS3). A significance level of $\alpha=0.05$ was chosen for all statistical tests. Due to multiple testing and estimation, the *P* values and the confidence levels of intervals cannot be interpreted in a strong confirmatory sense.

Results

Dental stages

Figure 2 shows the distribution of the subjects according to the dental stages (DS), separately for males and females. Sex differences were statistically significant ($P=0.026$), and may in particular be related to a higher prevalence of DS3 among the females, i.e. the females were dentally more mature than the males. Hence, sex differences concerning the space parameters were evaluated separately within each dental stage.

Anterior space conditions

Table 2 shows the descriptive statistics concerning the anterior space availability in both jaws, separately for males and females. Sex differences were statistically significant only for DS2 in the maxilla among the males; furthermore no sex differences were found for anterior space conditions. With respect to maxillo–mandibular differences, in the mandible a slight space deficiency was found which was not present in the maxilla (median −1 mm in the mandible versus 0 mm in the maxilla in both sexes, $P<0.001$). In addition, significant differences between the dental stages were found in both sexes and jaws, i.e. there was a tendency for a spontaneous improvement of the anterior space situation from DS1 to DS3 (Table 2). Figure 3 shows the distribution of anterior spacing and crowding. In general, in the maxilla

Table 1 Measurement error: mean of the differences (systematic error), the 95% CI for the bias, the reproducibility coefficient and the ICC with its 95% CI.

Parameter	Mean of the diff. (bias)	95% CI for the bias	Reproducibility coefficient	ICC	95% CI for ICC
Post. segment (upper right)	−0.13	−0.25/−0.02	0.63	0.98	0.96/0.99
Post. segment (upper left)*	−0.25	−0.58/0.08	1.83	0.72	0.55/0.89
without outlier*	−0.10	−0.28/0.07	0.96	0.92	0.86/0.97
Post. segment (lower left)	−0.18	−0.38/0.01	1.08	0.94	0.90/0.98
Post. segment (lower right)	0	−0.12/0.12	0.68	0.94	0.91/0.98
Upper anterior space	−0.02	−0.45/0.42	2.37	0.84	0.74/0.95
Lower anterior space	−0.4	−0.74/−0.06	1.85	0.78	0.63/0.92
Upper contact point displ.	0.02	−0.15/0.18	0.91	0.89	0.81/0.96
Lower contact point displ.	0.12	−0.04/0.28	0.88	0.88	0.79/0.96

*These values were distorted by an outlier, i.e. false reading on the ruler. The respective values without the outlier are given additionally.

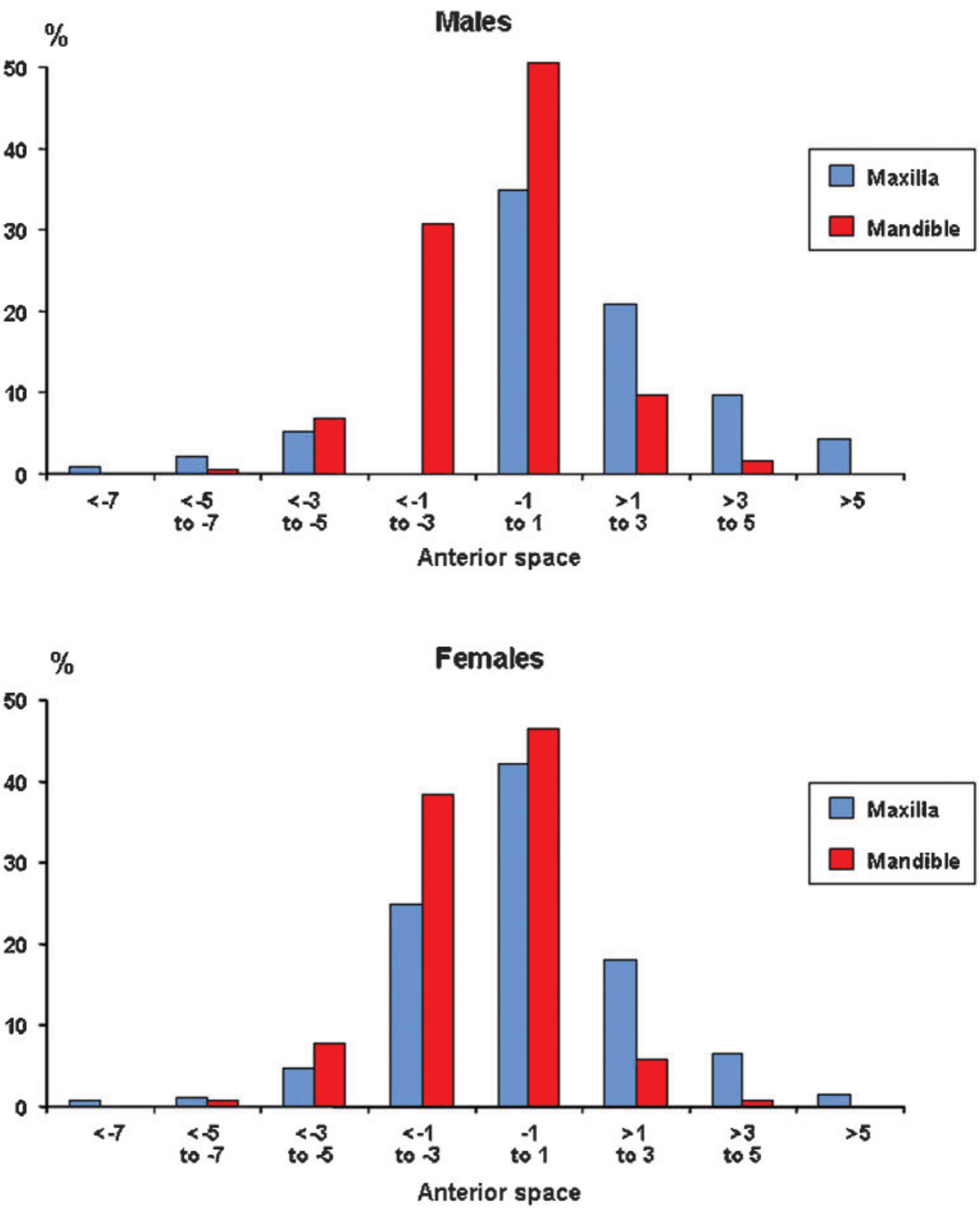

Figure 3 Distribution (relative frequency in %, maxilla and mandible=100% respectively) of the anterior space situation (positive values=space excess (spacing), negative values=space deficiency (crowding), separately for males and females (males: n=235 in maxilla and n=237 in the mandible; females: n=256 in both jaws)

the variance encountered was substantially larger than in the mandible with more children exhibiting both space excess and moderate or severe crowding.

The prevalence of anterior space deficiency and excess is shown in Table 3. Mild crowding (>1–3 mm) was a frequent finding (ranging between 22.1 and 38.3%) in both jaws, with a somewhat higher prevalence in the mandible. The prevalence of moderate crowding (>3–5 mm) ranged between 4.7 and 5.1% in the maxilla and between 6.8 and 7.8% in the mandible. Severe crowding (>5 mm) was found more often in the maxilla than in the mandible, affecting 2–3% of the maxillary dentitions. Spacing (including median diastema) was found quite often in the maxillary anterior arch segment with a higher frequency among the males, whereas it seldom occurred in the mandible (Table 3). A maxillary median diastema (⩾2 mm) was registered in 13.5% among the males and in 8.2% among the females.

Contact point displacements were found more frequently in the maxilla than in the mandible (Table 4). Moderate displacements (>2 and ⩽4 mm corresponding to IOTN Grade 3) were found in about every fourth child in the maxilla and in about every tenth child in the mandible. Severe contact point displacements (>4 mm) corresponding to IOTN Grade 4 were mainly restricted to the maxilla (prevalence around 3%).

Sizes of the lateral arch segments

Significant sex differences were found with respect to the length of the lateral arch segments ($P<0.001$ in all segments). When tested within each dental stage, these differences were statistically significant in the maxilla in DS2 and DS3, and in the mandible in DS3. In both jaws, the arch segments – among the males – were in general 0.5 mm larger than among the females. This difference was also present within each dental stage (Table 5). In addition, significant differences were found between maxilla and mandible (Table 5), i.e. in both sexes the median lengths of the mandibular posterior segments were 0.5 mm larger than the maxillary ones (this also applies for the left side, not depicted). Figure 4 shows

Table 2 Descriptive statistics of the anterior space conditions in the upper and lower jaw, separately for males and females (negative values depict space deficiencies). *P*-values indicate differences between maxilla and mandible. In addition, the medians within each dental stage (DS1, DS2 and DS3) are given and are marked by an asterisk (*) if significant group differences between the three dental stages were found ($P<0.05$, Kruskal–Wallis test).

Males: anterior space	Maxilla ($n=235$)	Mandible ($n=237$)	*P* value
Median	0	−1	<0.001
Medians DS 1/2/3	−1/1/0*	−1.5/−1/−0.5*	
Minimum	−15	−6	
Maximum	8	4	
Mean	0.26	−0.80	
SD	2.97	1.68	

Females: anterior space	Maxilla ($n=256$)	Mandible ($n=256$)	*P* value
Median	0	−1	<0.001
Medians DS 1/2/3	−0.5/0/0.5*	−1.5/−1/−1*	
Minimum	−11.5	−5.5	
Maximum	6	4.5	
Mean	−0.11	−1.10	
SD	2.45	1.62	

Table 3 Prevalence of anterior crowding and spacing in both jaws (in %, maxilla and mandible=100% respectively), separately for males and females.

	Males		Females	
Prevalence of anterior space anomalies (in %)	Maxilla	Mandible	Maxilla	Mandible
Crowding >1–3 mm	22.1	30.8	25.0	38.3
Crowding >3–5 mm	5.1	6.8	4.7	7.8
Crowding >5 mm	3.0	0.4	2.0	0.8
Spacing >3 mm	14.0	1.7	8.2	0.8

Table 4 Prevalence (relative frequency in %, maxilla and mandible=100% respectively) of contact point displacements among males (maxilla: $n=225$, mandible: $n=236$) and females (maxilla: $n=254$, mandible: $n=256$).

Contact point displ. (%)	Gender	Maxilla	Mandible
Moderate (IOTN Grade 3) (>2 and ⩽4 mm)	Males	24.9	8.9
	Females	28.0	10.2
Severe (IOTN Grade 4) (>4 mm)	Males	2.7	0.4
	Females	3.1	0.4

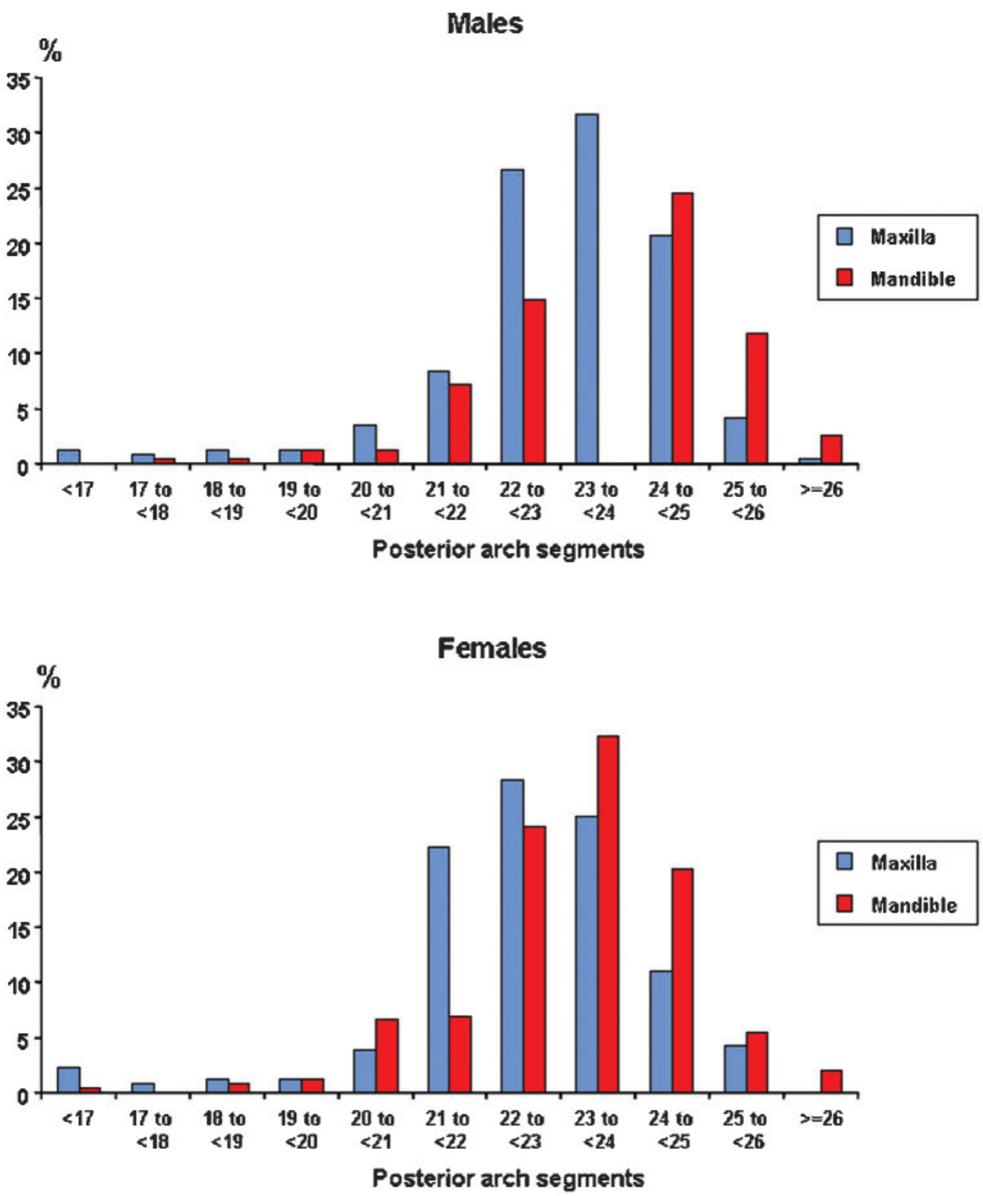

Figure 4 Length of the posterior arch segments: distribution (relative frequency in % of the maxillary (right side) and mandibular (right side) arch segments (=100% respectively), separately for males and females (males: n=237; females: n=257)

the distribution of the posterior arch lengths in the maxilla and mandible, separately for males and females. In general, a shift towards larger arch segments clearly emerges in the mandible.

When the mean values described by Schulze[12] were used to identify patients with mild (>1–3 mm), moderate (>3–5 mm) and severe (>5 mm) posterior crowding, mild crowding on the left and/or right side was found in the maxilla in 6.3% (males) and 5.4% (females), and in the mandible in 3.0% (males) and 3.1% (females). Moderate crowding was also more prevalent in the maxilla than in the mandible. In the maxilla, a prevalence for moderate crowding of 3.8% (males) and 1.9% (females) was found, whereas only 0.4% (males) and 1.6% (females) were affected in the mandible. Severe posterior crowding (>5 mm) on the right and/or left side was only encountered in the maxilla with prevalences between 1.7 and 1.9%. In general, the maxilla was more frequently affected with crowding than the mandible. The conventions for the use of the IOTN index[14] assume an impaction of permanent teeth, if the lateral segments (canines and premolars) are smaller than or equal to 18 mm in the maxilla, and smaller than or equal to 17 mm in the mandible. In the present study, this degree of crowding was found in the maxilla in 4.2% among the males and in 3.9% among the females, in contrast to the mandible where it occurred only in 0.8% among the females (no male patient affected).

Discussion

With respect to the results of the present study, severe anterior crowding (>5 mm) was predominantly found in the maxilla with a prevalence ranging between 2 and 3%, and moderate anterior crowding (>3–5 mm) was equally distributed in both jaws with a prevalence in the maxilla and mandible between 4 and 8%. The prevalence of mild anterior crowding (>1–3 mm) was extremely high, ranging from 22.1% (males, maxilla) to 38.3% (females, mandible). This high prevalence of anterior crowding is also in agreement with Ingervall and Ratschiller[8] who found anterior crowding (⩽2 mm) in the maxilla in 32% and in the mandible in 33%. Also Helm[2] found that in DS2, i.e. after the full eruption of the permanent incisors, maxillary crowding was largely restricted to the four permanent incisors. When the prevalence of mild anterior crowding is evaluated, the results of Moorees and Chadha[17] must be taken into account. They showed that immediately after the emergence of the central and lateral incisors, a slight mandibular crowding is physiological. This crowding is partly relieved when the crowns of the lateral incisors are fully erupted (transitional crowding), in other words mild incisor crowding may resolve spontaneously without treatment. Bässler-Zeltmann *et al.*[9] found crowding (2 mm and over in one of the segments) in 53.4% of the children. In most cases crowding was located in the anterior segments (primary crowding). In the present study, too, mild crowding (>1–3 mm) was more prevalent in the incisor segment than in the lateral segments. The same applies for moderate crowding (>3–5 mm), where anterior crowding was slightly more prevalent in the maxilla, and distinctly more prevalent in the mandible when compared to posterior crowding. In the present study, severe crowding (>5 mm) and severe contact point displacements were primarily a maxillary problem. With respect to spacing, Helm[2] found a systematic tendency towards a more common occurrence among males than among the females. This is in keeping with the present study, in which anterior spacing including median diastema was predominantly found in the maxilla, and more often among the males than the females (nearly twice as often). However, in the appraisal of space excess, the results of Helm[2] should be considered, i.e. he showed that in DS3 and DS4 spacing in the maxillary incisor segment decreased, partly due to the physiological closure of diastemas.

Methods used and limitations of the study

In the present study, nine-year-old schoolchildren were selected because this age group is comparatively well-investigated in orthodontic literature thus facilitating international comparisons, and because orthodontic treatment will soon become relevant.[8,9,11,18] In older

Table 5 Descriptive statistics for the posterior space situation in the upper and lower jaw, separately for males and females. *P* values indicate differences between maxilla and mandible. In addition, the medians within each dental stage (DS1, DS2 and DS3) were given and marked by an asterisk (*) if significant group differences between the three dental stages were found ($P<0.05$, Kruskal–Wallis test).

Males: length of arch segments	Maxilla (right side, $n=237$)	Mandible (right side, $n=237$)	*P* value
Median	23	23.5	<0.001
Medians DS 1/2/3	23/23/23	23.5/23.5/23	
Minimum	14.5	17.5	
Maximum	26.5	27	
Mean	22.75	23.38	
SD	1.63	1.40	

Females: length of arch segments	Maxilla (right side, $n=257$)	Mandible (right side, $n=257$)	*P* value
Median	22.5	23	<0.001
Medians DS 1/2/3	22.5/22.5/22	23.5/23/22.5*	
Minimum	14.5	16.5	
Maximum	25.5	27.5	
Mean	22.28	22.94	
SD	1.70	1.51	

children, the influence of orthodontic treatment increases which biases the results. Selecting younger children would limit the clinical relevance of the study because usually the late mixed-dentition stage is the recommended timing for referring patients to specialists with moderate crowding.[19,20] In the present study, in 11% of the children orthodontic treatment had already been initiated with removable orthodontic appliances (mainly plates, functional appliances). No child had a multibracket appliance at the time of the examination and the treatment time elapsed by the onset of the investigation was rather short. Hence the effect of the orthodontic treatment already in progress on the results of the present study can be regarded as limited. Nevertheless, both the inclusion and exclusion of children with commenced orthodontic treatment will underestimate the prevalence of children with extreme space anomalies. Hence, regions with a low orthodontic supply rate were selected in the present study, and this is bound to lead to a stronger representation of the rural population as well as the population of small and medium-sized towns.

However, in severe cases an early interception can be indicated as preventing impaction of teeth or extreme malalignment of teeth.[20] As a consequence, Kirschen[18] demanded that an orthodontic screening should be carried out at 9 and 12 years of age. In this context, it should be borne in mind that crowding is influenced by the dental developmental stage.[2,10,17] Helm[2] showed that, among girls, the average onset of the respective dental stages occurred six months earlier than among boys. This is also borne out by the distribution according to the dental stages found in this study. Hence, in the present investigation, the influence of the dental stages on malocclusion has been considered as well as by additionally evaluating the respective median values separately for DS1 to DS3. Besides, all tests concerning gender differences were carried out within each dental stage. Concerning posterior crowding, it has to be stressed that it is in general difficult and to a certain degree arbitrary to estimate posterior crowding on the basis of mean values. Due to the fact that in every mixed dentition analysis the estimated degree of crowding depends on the reference values respectively used for the permanent canines and premolars,[9,21] the focus in the present investigation was primarily on the absolute sizes of the canine–premolar segments.

Conclusions

- Concerning space conditions in the incisor segments: in the maxilla, the variance encountered comprised both space excess and moderate to severe crowding which was considerably larger than in the mandible. Moderate crowding (>3–5 mm) was found in about 5% of the maxillary dentitions and slightly more often (6–8%) in the mandible. Severe crowding (>5 mm) occurred more often in the maxilla than in the mandible, affecting around 2–3% of the maxillary dentitions. There is a tendency towards a spontaneous improvement of the anterior space situation from DS1 to DS3 (transitory stage of mandibular incisor crowding).
- Moderate contact point displacements (IOTN Grade 3) were a common finding in the maxilla (prevalence around 20–30%) and more prevalent than in the mandible (prevalence 10%). Severe contact point displacements (IOTN Grade 4) were mainly restricted to the maxilla (prevalence around 3%).
- With respect to the canine–premolar segments, the arch segments, among the males, were in general around 0.5 mm larger than among the females, also within each dental stage. In addition, in both sexes, the median lengths of the mandibular posterior segments were around 0.5 mm larger than the maxillary segments. In general, the maxilla was more frequently affected by posterior crowding than the mandible. In addition, anterior crowding seemed to be more prevalent than posterior crowding.
- With respect to the screening methods used, reliable and valid measurements were also possible in schools. In the present study, the orthodontic measurements with the developed ruler were not time-consuming and were not rejected by any child. This may open up further possibilities for orthodontic screening by community dentistry services or similar organizations.
- The present study highlights the clinical significance of crowding in orthodontics and thus highlights the need for orthodontic screenings/examinations at nine years of age. Already at this age, a considerable proportion of children were affected by moderate and severe crowding which may impair the further dental development.

Contributors

Christopher J. Lux and Gerda Komposch were responsible for study concept/design and obtaining ethical approval, and Christopher J. Lux was responsible for conducting the study, data interpretation and final approval of the article. Britta Dücker conducted the measurements on location in the schools (during the measurement error study along with Christopher J. Lux). Maria Pritsch conducted the statistical evaluation and was responsible for data analysis, and Uwe Niekusch was responsible for logistic and administrative support within the community dental service. Christopher J. Lux is the guarantor.

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