REVIEW ARTICLE

Long-term effects of orthodontic interceptive expansion treatment

A retrospective study

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Abstract
Purpose The aim of this retrospective cohort study was to evaluate the long-term effects of interceptive orthodontic treatment with a removable expansion plate, based on transversal, sagittal, and vertical parameters.
Methods A total of 90 patients needing interceptive treatment due to a crossbite or space deficiency were included. Records consisting of clinical photos, radiographs, and digital dental casts were collected for evaluation at two time points: the start of interceptive treatment (T0) and the start of comprehensive treatment (T1). Molar occlusion, overjet, overbite, presence and type of crossbite, mandibular shift, and transversal measurements were recorded for comparison.
Results After expansion with removable appliances, a significant increase in intermolar width was achieved and could be maintained over the observation period ($p < 0.001$). However, no significant changes regarding overjet, overbite, or molar sagittal occlusion were observed. Crossbite correction was successful in 86.9% of patients with unilateral crossbite and in 75.0% of patients with bilateral crossbite ($p < 0.001$).
Conclusion Early expansion with a removable expansion plate is a successful method to correct crossbites and increase intermolar width in the early mixed dentition phase. Results remain stable until the start of comprehensive treatment in the permanent dentition.

Keywords Orthodontics · Removable orthodontic appliance · Retrospective study · Expansion plate · Long-term stability

Langfristige Auswirkungen einer kieferorthopädischen interzeptiven Expansionsbehandlung
Eine retrospektive Studie

Zusammenfassung
Zielsetzung Ziel dieser retrospektiven Kohortenstudie war es, die Langzeiteffekte einer interzeptiven kieferorthopädischen Behandlung mit einer herausnehmbaren Expansionsplatte anhand von transversalen, sagittalen und vertikalen Parametern zu bewerten.
Methoden Insgesamt 90 Patienten, die aufgrund von Kreuzbiss oder Engstand eine interzeptive Behandlung benötigten, wurden eingeschlossen. Die Dokumentation, bestehend aus klinischen Fotos, Röntgenbildern und digitalen Zahnabdrücken, wurde zu 2 Zeitpunkten ausgewertet: zu Beginn der interzeptiven Behandlung (T0) und zu Beginn der Hauptbehandlung (T1). Zum Vergleich wurden Molarenokklusion, Overjet, Overbite, das Vorhandensein eines und die Art des Kreuzbisses, die Unterkieferverschiebung und die transversalen Maße erfasst.

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Ergebnisse Nach der Erweiterung mit herausnehmbaren Apparaturen wurde eine signifikante Zunahme der Intermolarenbreite erzielt, die während des Beobachtungszeitraums beibehalten werden konnte ($p < 0{,}001$). Es wurden jedoch keine signifikanten Veränderungen in Bezug auf Overjet, Overbite oder molare sagittale Okklusion beobachtet. Die Korrektur des Kreuzbisses war bei 86,9% der Patienten mit einseitigem Kreuzbiss und bei 75,0% der Patienten mit beidseitigem Kreuzbiss erfolgreich ($p < 0{,}001$).

Schlussfolgerung Die frühzeitige Expansion mit einer herausnehmbaren Dehnplatte ist eine erfolgreiche Methode zur Korrektur von Kreuzbissen und zur Vergrößerung der Intermolarenbreite in der frühen Wechselgebissphase. Die Ergebnisse bleiben bis zum Beginn einer umfassenden Behandlung im bleibenden Gebiss stabil.

Schlüsselwörter Kieferorthopädie · Herausnehmbare Apparatur · Retrospektive Studie · Expansionsplatte · Langzeitstabilität

Introduction

When patients are referred in the mixed dentition phase, orthodontists have the opportunity to interact with the dental occlusion. The goal of interceptive orthodontic treatment is to prevent development of malocclusion and to correct occlusal discrepancies. The most common deviations from normal occlusal development that are good indication for interceptive orthodontics are the following: posterior and anterior crossbites, space deficiency, excessive protrusion of the upper incisors, premature loss, and ankylosis of deciduous teeth [1, 2].

Even though interceptive treatment does not always eliminate the need for comprehensive treatment, it attempts to reduce its complexity. This benefits both patients and orthodontists [1, 3–6]. According to Ackerman and Proffit, around 15% of patients in primary or mixed dentition phase could benefit from interceptive interventions that would avoid comprehensive treatment in a later stage, provided that interceptive treatment is successfully followed through [1].

Other advantages of an early intervention might be better compliance at a younger age [11, 12] and the simpler nature of the intervention itself. When treating transversal discrepancies at a younger age, the midpalatal suture is less mature and lower forces can be used to expand it.

On the other hand, the total treatment time is prolonged, which often results in lack of compliance and potential damage to the teeth [6]. Early interceptive treatment may be considered as an extra burden for the patient and it can only be justified if the long-term results are stable. The literature also suggests that the results of interceptive treatment may also be beneficial for patients' self-image and self-esteem during early adolescence [2, 6, 13–15].

One of the most frequent reasons to start treatment in the early mixed dentition phase is crossbite with functional shifts, since posterior crossbites occur in 7.1–22% of patients in the primary or early mixed dentition phase [6–9]. The available literature suggests that there is an association between crossbites and the development of skeletal and dental asymmetries and early correction aims to restore normal growth and function. However, high-quality studies regarding this matter are lacking [10].

The two most frequently used protocols to expand the upper arch include slow maxillary expansion (SME; 0.25–0.5 mm/week) and rapid maxillary expansion (RME; 0.5 mm/day). A wide variety of appliances are available to achieve maxillary expansion, with acrylic plates, quadhelix, and hyrax appliances being among the most well-known expansion appliances. The choice of appliance usually depends on the preference of the practitioner and the age and level of compliance of the patient [16–18].

For both SME and RME, the majority of the generated expansion is due to dentoalveolar changes and to a smaller extent to skeletal changes. There is more literature studying the transversal effects of RME directly after treatment than there is for SME [16–18]. However, the available literature suggests with moderate evidence that transverse dentoalveolar effects of RME and SME are similar immediately after treatment. For the skeletal and the long-term effects of these interventions, scientific evidence is still lacking and more research is needed [16–18].

Thus, the aim of this retrospective cohort study was to evaluate the long-term effects of interceptive treatment with a removable expansion plate in the early mixed dentition phase.

Materials and methods

This retrospective cohort study was performed in patients who underwent interceptive treatment by means of a removable expansion plate at the Department of Orthodontics, University Hospitals Leuven, Belgium. The study was approved (registration number s56398) by the ethics committee of University Hospitals Leuven.

In order to identify potentially relevant patients, a digital search was performed in the hospital's database, which was afterwards complemented with a manual search of the active patient files.

Inclusion criteria were

- Healthy children in the mixed dentition phase who received interceptive treatment with a removable expansion plate and
- Availability of a complete set of records (intra-oral photographs, digital dental casts, panoramic and cephalometric radiographs) at the start of interceptive treatment (T0) and at the start of comprehensive orthodontic treatment (T1).

Exclusion criteria were the following:

- Patients with syndromes or craniofacial disorders.
- Cases of noncompliance where treatment was stopped, loss of the appliance during active treatment or loss during follow-up.
- Patients who had previous orthodontic treatment.

All included patients were in need of interceptive treatment due to frontal or posterior crossbite, lack of space, or canine impaction. Treatment was performed between 2010 and 2015 by postgraduate students in orthodontics with a removable expansion plate. The basic design consisted of an acrylic base with a symmetrical jackscrew, bilateral bite planes, Adams clasps on the first permanent molars, button clasps between the deciduous molars, and a labial bow (Fig. 1a). Appliance design was adapted according to the malocclusion present and sometimes comprised extra mesialization or distalization springs or a tongue fence (Fig. 1b). Patients were instructed to wear the appliance full-time and could only remove it for brushing, which includes keeping the appliance in place during meals. Parents were instructed to activate the appliance once a week to achieve expansion of 0.25 mm/week. Follow-up was every 8 weeks. During the check-ups, the labial bow was manually adapted to remain passive, in order to prevent lingual or labial incisor inclination. Both instructions and reinforcement of motivation were given verbally by the practitioner.

After active treatment, including slight overcorrection of the crossbite or space deficiency, the appliance was worn full-time in a passive state for retention for approximately 3 months. Afterwards patients continued to wear the appliance for another 3 months at night only. These periods depended on the active expansion time: the longer the time needed to resolve the crossbite, the longer the retention period.

In a minority of cases, the malocclusion required also specific extra appliances or additional activation during or as a second phase of interceptive treatment such as the following: extrusion of impacted teeth, crisscross elastics, tongue fence, lingual bar or lip bumper, space maintainers, sectional fixed appliances or a palatal bar.

The following data were extracted from the patient files: gender, date of birth, age at T0 and T1, appliance design, treatment time, retention period and timespan between T0 and T1. The presence of the following findings were scored by one observer for T0 and T1: frontal or posterior crossbite, presence of a functional shift, occlusion of the first permanent molars on the right and left side, overjet, and overbite.

A lateral crossbite was scored when one or more teeth from the deciduous or permanent canine to the first molar had a transverse discrepancy in relation to its antagonist. If one of the four anterior teeth was in crossbite, this was scored as a frontal crossbite. An edge-to-edge relation was also scored as a crossbite.

Linear measurements were performed on digital dental casts using the DigiModel® software (OrthoProof B.V.®, Nieuwegein, The Netherlands). These digital casts were made either by directly scanning alginate impressions or by scanning plaster models. At T0 and T1, one observer
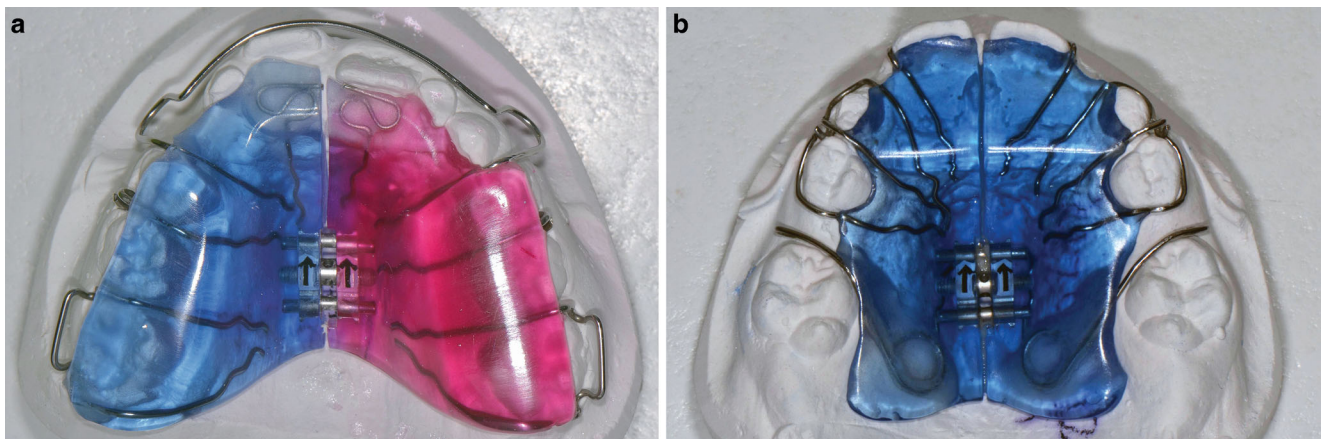

Fig. 1 Appliance designs. **a** Basic design with bilateral bite plane. **b** Specific design without bite plane and springs for individual tooth movement (mesialization and distalization)
Abb. 1 Designs der Apparatur. **a** Basisdesign mit bilateraler Aufbissfläche. **b** Spezifisches Design ohne Aufbissfläche und Federn für individuelle Zahnbewegungen (Mesialisierung und Distalisierung)
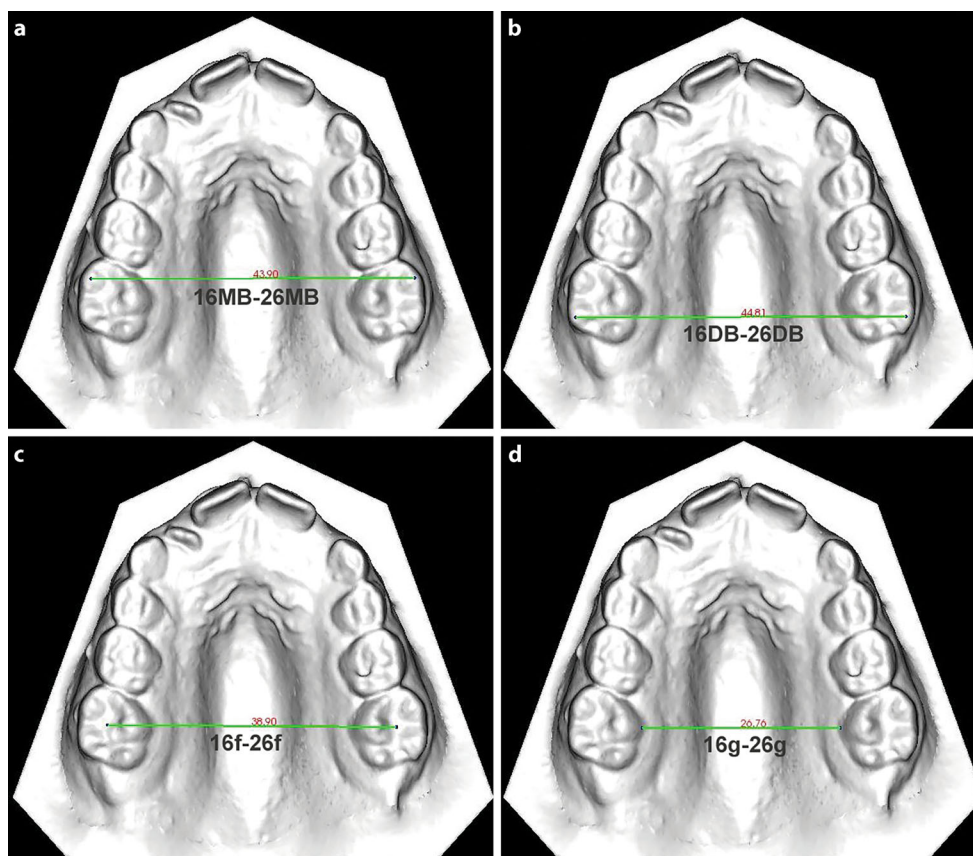
Fig. 2 Digital linear measurements performed on digital dental casts. **a** *16MB–26MB* distance between the mesiobuccal cusps of the first maxillary permanent molars. **b** *16DB–26DB* distance between the distobuccal cusps of the first maxillary permanent molars. **c** *16f–26f* distance between the central fossae connected to the vestibular groove of the first maxillary permanent molars. **d** *16g–26g* distance between the most lingual and cervical point of the first maxillary permanent molars

Abb. 2 Digitale lineare Messungen an digitalen Zahnabdrücken. **a** *16MB–26MB* Abstand zwischen den mesiobukkalen Höckern der ersten permanenten Oberkiefermolaren. **b** *16DB–26DB* Abstand zwischen den distobukkalen Höckern der ersten permanenten Oberkiefermolaren. **c** *16f–26f* Abstand zwischen den zentralen Fossae, die mit der vestibulären Vertiefung der ersten permanenten Oberkiefermolaren verbunden sind. **d** *16g–26g* Abstand zwischen dem am weitesten lingualen und zervikalen Punkt der ersten permanenten Oberkiefermolaren

made the following measurements on the occlusal plane mode (Fig. 2):

- 16g–26g: distance between the most lingual and cervical point of the first maxillary permanent molars,
- 16f–26f: distance between the central fossae connected to the vestibular groove of the first maxillary permanent molars,
- 16MB–26MB: distance between the mesiobuccal cusps of the first maxillary permanent molars, and
- 16DB–26DB: distance between the distobuccal cusps of the first maxillary permanent molars.

These anatomical points were chosen based on previous research evaluating expansion treatment effects [19]. Measurements were omitted if one or both first molars were absent, partially impacted or if the landmarks were unclear due to caries or bad impressions. This was the case in three patients. Other available data from these patients were still used for analysis.

At T0 and T1, cephalometric analysis was performed by one observer. The ANB angle, mandibular plane angle according to Steiner (SN-GoGn), and the Wits appraisal were noted.

Statistical analysis

Models of 20 randomly selected patients were measured twice by the same observer and intraobserver reliability was evaluated using the intraclass correlation coefficient (ICC). This resulted in double measurement of 561 linear distances. Of these distances, 508 were also measured by a second observer for evaluation of the interobserver reliability with the ICC.

Another pool of 20 random patients was used to evaluate intraobserver reliability of the cephalometric measurements. The lateral cephalograms at T0 and T1 were traced twice by the same observer, resulting in 40 pairs of measurements for each variable.

The Wilcoxon signed rank test was used to assess changes between T0 and T1 on continuous variables or ordinal variables with multiple levels. The sign test was used to assess change between T0 and T1 on ordinal variables with few levels. To assess changes between the time points on binary variables, the McNemar test was performed.

Linear models were used to assess the association between patient factors (age, gender, crossbite, type of appliance) and the changes in molar width. When a characteristic was measured by multiple variables such as for intermolar width (four measurements) and occlusion (two measurements, left and right) the raw p-values were calculated as well as the Holm p-values, hence, correcting for multiplicity. Differences with p-values smaller than 0.05 were considered as statistically significant. Statistical analysis was performed using SAS software (version 9.4 of the SAS System for Windows, Cary, NC, USA).

Results

Sample description

The digital search resulted in 199 files. After applying the selection criteria, 90 patients were included: 54 girls and 36 boys. The main reasons for exclusion were the following: 71 patients did not start treatment after the first consultation, while 38 stopped during treatment due to appliance loss or non-compliance or lack of records.

At the start of interceptive treatment (T0) the mean age of the patients was 8.7 years (standard deviation [SD] 1.0).

The majority of patients ($n = 63$) had an expansion plate with acrylic coverage of the lateral teeth (87.5%). Two smaller groups of patients had no acrylic coverage ($n = 5$, 6.9%) or coverage of all the occlusal/incisal surfaces ($n = 4$, 5.6%). The type of removable appliance could not be defined in 18 patients.

A total of 32 patients presented no lateral crossbite (35.6%), 46 had a unilateral crossbite (51.1%), and 12 had a bilateral crossbite (13.3%).

Table 1 Occlusal characteristics at T0 and T1 and evaluation of changes (T0–T1)
Tab. 1 Okklusale Merkmale bei T0 und T1 und Bewertung der Veränderungen (T0-T1)

	Variable	N/Total (%)	Variable	N/Total (%)	Variable	N/Total (%)
T0	*Crossbite*		*Occlusion R*		*Occlusion L*	
	None	19/90 (21.1%)	1/2 MO	2/89 (2.3%)	3/4 MO	1/89 (1.1%)
	Right	27/90 (30.0%)	1/4 MO	1/89 (1.1%)	1/2 MO	1/89 (1.1%)
	Right+frontal	4/90 (4.4%)	NO	17/89 (19.1%)	1/4 MO	1/89 (1.1%)
	Left	11/90 (12.2%)	1/4 DO	13/89 (14.6%)	NO	24/89 (27.0%)
	Left+frontal	4/90 (4.4%)	1/2 DO	28/89 (31.5%)	1/4 DO	19/89 (21.4%)
	Bilateral	8/90 (8.9%)	3/4 DO	14/89 (15.7%)	1/2 DO	21/89 (23.6%)
	Bilateral+frontal	4/90 (4.4%)	1 DO	12/89 (13.5%)	3/4 DO	11/89 (12.4%)
	Frontal	13/90 (14.4%)	>1 DO	2/89 (2.3%)	1 DO	9/89 (10.1%)
					>1 DO	2/89 (2.3%)
T1	*Crossbite*		*Occlusion R*		*Occlusion L*	
	None	72/90 (80.0%)	>1 MO	1/89 (1.1%)	1 MO	2/89 (2.3%)
	Right	4/90 (4.4%)	1/2 MO	1/89 (1.1%)	3/4 MO	1/89 (1.1%)
	Right+frontal	1/90 (1.1%)	1/4 MO	3/89 (3.4%)	1/2 MO	2/89 (2.3%)
	Left	2/90 (2.2%)	NO	27/89 (30.3%)	1/4 MO	1/89 (1.1%)
	Left+frontal	1/90 (0.0%)	1/4 DO	20/89 (22.5%)	NO	25/89 (28.1%)
	Bilateral	2/90 (2.2%)	1/2 DO	16/89 (18.0%)	1/4 DO	18/89 (20.2%)
	Bilateral+frontal	2/90 (2.2%)	3/4 DO	8/89 (9.0%)	1/2 DO	26/89 (29.2%)
	Frontal	7/90 (7.8%)	1 DO	12/89 (13.5%)	3/4 DO	6/89 (6.7%)
					1 DO	8/89 (9.0%)
T0–T1			*Occlusion R*		*Occlusion L*	
	Improvement		33/88 (37.5%)		26/88 (29.5%)	
	Status quo		43/88 (48.9%)		44/88 (50.0%)	
	Deterioration		12/88 (13.6%)		18/88 (20.5%)	
	P-value raw		0.0025		0.2912	
	P-value Holm		0.0049		0.2912	

NO neutro-occlusion, *MO* mesio-occlusion, *DO* disto-occlusion

Table 2 Expansion time, retention period full-time (FT) and half-time (HT) wear
Tab. 2 Expansionszeit, Retentionsphase Voll- (FT) und Teilzeittragedauer (HT)

Variable (days)	N	Mean	SD	Median	IQR	Range
Expansion time	90	209.4	113.5	171.0	(130.0; 276.0)	(40.0; 567.0)
Retention FT	90	75.3	61.2	56.0	(39.0; 96.0)	(0.0; 440.0)
Retention HT	87	111.8	82.6	93.0	(61.0; 154.0)	(0.0; 409.0)
Time until T1	90	947.9	423.0	931.0	(658.0; 1197.0)	(43.0; 2174.0)

SD standard deviation, *IQR* interquartile range

Table 3 Intra- and interobserver reliability
Tab. 3 Intra- und Inter-Observer-Reliabilität

	Variable	ICC (95% CI)	N paired measurements
Intraobserver reliability DigiModel measurements	16G–26G	0.999 (0.998; 0.999)	44
	16F–26F	0.987 (0.977; 0.993)	42
	16MB–26MB	0.995 (0.991; 0.997)	42
	16DB–26DB	0.992 (0.985; 0.996)	42
Interobserver reliability DigiModel measurements	16G–26G	0.998 (0.997; 0.999)	40
	16F–26F	0.996 (0.992; 0.998)	38
	16MB–26MB	0.997 (0.994; 0.998)	38
	16DB–26DB	0.994 (0.988; 0.997)	38
Intraobserver reliability cephalometric measurements	SN-GoGn	0.993 (0.988; 0.996)	40
	ANB angle	0.987 (0.976; 0.993)	40
	Wits	0.993 (0.987; 0.996)	40

ICC intraclass correlation coefficient, *CI* confidence interval

A frontal crossbite was diagnosed in 25 patients (27.8%) and a functional shift was present in 55 patients (61.1%).

The mean overjet and overbite were 3.5 mm (SD 2.5) and 1.8 mm (SD 2.0), respectively. An open bite was present in 8 patients. At T0, the group had mean cephalometric values of 35.4° (SD 5.6), 4.0° (SD 2.5), and –0.6 (SD 2.8) for the SN-GoGn angle, ANB angle, and Wits appraisal, respectively.

At T1, 79 patients (87.8%) had no lateral crossbite, 7 (7.8%) had a unilateral crossbite, and 4 (4.4%) had a bilateral crossbite. A frontal crossbite was diagnosed in 9 patients (10.0%) and 8 (8.9%) were diagnosed with a functional shift.

The mean overjet was 4.1 mm (SD 2.3) and the mean overbite was 3.2 mm (SD 1.7). An open bite was persistent in 2 patients.

The cephalometric values at T1 presented mean values of 35.1° (SD 6.2) for the SN-GoGn angle, 3.5° (SD 2.3) for ANB angle, and –0.6 (SD 2.8) for Wits appraisal. Further descriptive details of the sample can be found in Table 1.

The time of active expansion treatment was very variable (209 days, SD 113), as was the time of retention (full time 75 days with SD 61, half time 111 days with SD 82) and the mean period between the end of the interceptive treatment and the start of comprehensive treatment (T1) was 948 days (SD 423). The mean and median values for these variables can be found in Table 2.

All crossbites were corrected immediately after completion of interceptive treatment. This was confirmed clinically but records were study casts were not taken.

The inter- and intraobserver reliability for the DigiModel® (OrthoProof B.V.®, Nieuwegein, The Netherlands) and cephalometric measurements were excellent. Details for each variable can be found in Table 3.

Detailed comparison T0–T1

The intermolar width at T1 was compared to that at T0 to assess the amount of expansion that was still present after a time interval without any active treatment. A total of 87 sets of models were available for evaluation (missing data were due to poorly defined anatomical landmarks because of caries or nonerupted permanent molars). For all four points (16G–26G, 16F–26F, 16MB–26MB, 16DB–26DB), a statistically significant increase of the transverse distance was observed. Also after Holm correction for multiple testing, the *p*-values remained significant (Table 4).

The success of lateral and frontal crossbite and functional shift correction was also evaluated and all *p*-values were significant (Table 5).

As secondary outcomes, the improvements of molar relationship, overjet, and overbite were also evaluated. The occlusion at the right and left side was analyzed in 88 patients, as in 2 patients the occlusion could not be scored

Table 4 Changes intermolar width, overjet, overbite T0–T1
Tab. 4 Veränderungen von intermolarer Breite, Overjet, Overbite T0-T1

Intermolar distance	N	Mean	SD	Med	Min	Max	Q1	Q3	P(Raw)	P(Holm)
16g–26g	87	2.5	1.8	2.4	–2.7	7.6	1.2	3.6	<0.0001	<0.0001
16f–26f	87	2.9	2.2	2.6	–2.3	12.6	1.4	4.0	<0.0001	<0.0001
16MB–26MB	87	2.9	2.0	2.4	–2.3	9.4	1.6	4.5	<0.0001	<0.0001
16DB–26DB	87	2.8	2.0	2.37	–2.4	9.3	1.4	4.2	<0.0001	<0.0001
Other occlusal traits	N	Mean	SD	Med	Min	Max	Q1	Q3	P	
Overjet	87	0.1	1.6	0.0	–4.0	7.0	–1.0	1.0	0.9396	
Overbite	87	0.1	1.5	0.0	–5.0	4.0	–0.5	1.0	0.3097	

SD standard deviation, *Med* median, *Min* lowest value, *Max* highest value, *Q1* percentile 25, *Q3* percentile 75, *P* P-value from Wilcoxon signed rank test comparing T0 and T1

Table 5 Improvement of crossbite and functional shift between T0 and T1
Tab. 5 Verbesserung von Kreuzbiss und Zwangsführung T0-T1

Variable	T0: No crossbite N/Total (%)	T0: Unilateral crossbite N/Total (%)	T0: Bilateral crossbite N/Total (%)
P-value lateral crossbite ≤ 0.0001 (Sign test)			
T1: No crossbite	30/32 (93.75%)	40/46 (86.96%)	9/12 (75.00%)
T1: Unilateral crossbite	2/32 (6.25%)	4/46 (8.70%)	1/12 (8.33%)
T1: Bilateral crossbite	0/32 (0.00%)	2/46 (4.35%)	2/12 (16.67%)
–	–	*T0: No frontal crossbite*	*T0: Frontal crossbite*
P-value frontal crossbite = 0.0025 (McNemar test)			
T1: No frontal crossbite	–	59/65 (90.77%)	22/25 (88.00%)
T1: Frontal crossbite	–	6/65 (9.23%)	3/25 (12.00%)
–	–	*T0: No functional shift*	*T0: Functional shift*
P-value functional shift ≤ 0.0001 (McNemar test)			
T1: No functional shift	–	32/33 (96.97%)	48/55 (87.27%)
T1: Functional shift	–	1/33 (3.03%)	7/55 (12.73%)

due to unerupted permanent molars. Neutral occlusion with a deviation of one fourth premolar width in the distal or mesial direction was accepted as standard. Every change closer to this occlusion was scored as an improvement and every change further away as a worsening. On the right side, 33 patients (37.5%) showed an improvement, status quo was observed in 43 patients (48.9%), and a worsening of occlusion in 12 patients (13.6%). On the left side, there was an improvement in 26 patients (29.5%), status quo was observed in 44 patients (50.0%), and a worsening in 18 patients (20.5%). The *p*-value was significant for the right side, but nonsignificant for the left side (Table 1).

Concerning the overjet and overbite, values between 1–3 mm were defined as acceptable. No statistically significant differences could be found between T0 and T1 (Table 4). There was an almost even distribution of patients who demonstrated an improvement, a stable, or a deteriorated overjet or overbite.

Influencing factors

No statistically significant relation was found between the amount of treatment-induced increase in width and factors such as age, gender or type of appliance. When evaluat-

Table 6 Correlation crossbite T0 and width increase
Tab. 6 Kreuzbiss T0 und Breitenzunahme, Korrelation

Outcome	Difference (95% CI)	P-values Raw	Holm
16G–26G	1.2 (0.3; 2.1)	0.0082	0.0327
16F–26F	1.3 (0.2; 2.4)	0.0228	0.0683
16MB–26MB	1.1 (0.0; 2.1)	0.0454	0.0863
16DB–26DB	1.1 (0.0; 2.1)	0.0431	0.0863

Crossbite T0: lateral and/or frontal
Difference >(<)0 means higher (lower) value for crossbite
Holm correction for multiple testing (4 measurements of width change)

ing the influence of the presence of a crossbite prior to treatment, the raw *p*-values were all statistically significant for every variable. After correction for multiple testing, only one variable—gingival distance—remained significant (Table 6).

Discussion

Studies quantifying the effects of maxillary expansion with expansion plates or other appliances normally use plaster models and digital sliding calipers [19–21]. However, nowadays plaster models have been replaced by their digital equivalent. Thus, this study was performed on digital casts. This digital method has been proven to be as accurate and reliable as measuring on conventional gypsum casts [22, 23].

Another recent development to evaluate the effects of expansion treatment is digital superimposition and geometric morphometric analysis of 3D models obtained by intraoral scans [24, 25].

Our results show a significant increase in intermolar width at all four defined molar points at an average of 2.6 years after the end of active treatment. Although an increase of 2.5 to 2.9 mm might seem like a discrete amount of expansion, in terms of crossbite correction this translates into a success of 87.0% of the unilateral and 75.0% of the bilateral crossbites.

These percentages of success are lower compared to those reported by Petrén et al. [20], Bjerklin et al. [26], and Hermanson et al. [27], but the amount of expansion is in line with their findings. The lower success rate could be explained by the rather strict definition used in this study to score crossbites: edge-to-edge relation on just one tooth was already regarded as a crossbite. When evaluating the patients with persisting crossbites at T1, we saw that these were mostly due to local crossbites or an edge-to-edge relation of one or two teeth because of replacement of primary teeth. A relapse of lateral or frontal crossbites was found in only 8 patients and was associated with noncompliance and in 2 cases with persistence of an open bite (2 of the 8 cases).

In open bite cases, interdigitation is not present to stabilize the transversal result. Such complications were also reported as common after removable plate therapy in previous studies [21, 28, 29]. In addition, frontal crossbites are more difficult to correct with removable appliances, as bodily movement is difficult to achieve. On the other hand, some research suggests that the success after applying a removable appliance equaled that of a fixed appliance in view of stability [30].

Removable appliances are easy to use and clean as the appliance can be removed for brushing. Earlier studies by Petrén et al. [20, 28] concluded that the quad-helix was more cost effective and could be more efficient. However, this largely depends on the experience of the practitioner. No concerns regarding social appeal during the use of this appliance were registered in the patient files. Although compliance could be a problem, our sample did not have problems in this regard.

Regarding overjet and overbite, no significant difference was found between T0 and T1. This is in agreement with results of other studies evaluating long-term effects of expansion treatment with removable plates [20, 26].

However, the observed effects on the sagittal occlusion were contradictory: on the right side, significant changes became apparent ($p = 0.0025$), while nonsignificant changes appeared on the left side. The results also showed more improvement on the right side compared to the left (Table 1). This could be explained by the higher number of unilateral crossbites on the right side. A unilateral crossbite is typically present in combination with a functional shift and with a midline deviation to the ipsilateral side [20, 28]. When solving the crossbite, the mandible corrects itself from a rotated position, implying an improvement of the occlusion on the crossbite side and sometimes a deterioration or unchanged conditions on the noncrossbite side. Thus, unilateral worsening of the occlusion may be interpreted as an inherent side effect of unilateral crossbite correction.

Another possible explanation could be premature loss of deciduous teeth. With the transition from the mixed to the permanent dentition, individual use of the leeway space may happen.

No specific influence of age could be observed, probably because of the homogeneity of the sample for this parameter.

A limitation of this study was that in 6 cases, additional appliances such as crisscross elastics, a palatal bar or a headgear were used after the removable expansion plate. In 2 of the 90 patients included, a distalization spring was added for the first molars mostly to upright them in case of tipping due to premature loss of a second deciduous molar. Hence, transversal and sagittal effects in these patients cannot only be attributed to the expansion only.

Second, a control group without malocclusion is lacking. This would have helped rule out the influence of growth, but such a group is not easy to recruit. Patients in the mixed dentition phase without malocclusion (in this specific case without crossbite or lack of space) do not attend orthodontic consultations very often. Even when they do, it is typically not justified to take records and follow them up for years solely for research purposes. In addition, the aim of our study was to detect longitudinal differences in the included patients to evaluate the effect of the appliance, rather than to perform a cross sectional comparison with external groups. However, previous studies including

controls showed conflicting results ranging from an average increase of 1.9–2 mm intermolar distance over a 3-year follow-up period in one study [20], versus only 1–1.2 mm increase over a 7-year period in another study [26]. In both studies, the control groups consisted of around 20 patients. It is also important to take into consideration that no power analysis was performed in the present study. All patients complying with the inclusion criteria and treated between the years 2010 and 2015 were included, which avoids selection bias. Due to the retrospective and exploratory nature of this study and the many statistical tests performed, a formal sample size calculation would have been a challenge.

Lastly, it should be taken into account that treatment was performed in the mixed dentition phase, the contribution of the next phase of exfoliation can be regarded as a confounding factor for the evaluation of the treatment effects.

At T1, the majority of crossbites and functional shifts were solved, making the later comprehensive treatment less complex for the patient and the practitioner. However, future research is needed to evaluate whether interceptive treatment does actually decrease comprehensive treatment time or whether it significantly affects the Index of Orthodontic treatment need (IOTN) values at the start of comprehensive treatment. Other interesting parameters to evaluate would be a detailed analysis of the effect on the dental midlines. Since the functional shift is eliminated, one would expect the midlines to correct simultaneously.

Conclusion

If patients are referred to orthodontists in the mixed dentition phase and expansion is indicated, a removable expansion plate is a viable treatment option for successful and stable correction of crossbites and to increase intermolar width. Success of treatment does depend on patient cooperation wearing the removable appliance, but possibly simplifies later comprehensive treatment.

Declarations

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