ORIGINAL ARTICLE

Side effects of twistflex retainers—3D evaluation of tooth movement after retainer debonding

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Abstract

Purpose Evaluation of tooth movement after retainer debonding in retainer-associated misalignment cases.

Methods This pilot study is based on a retrospective data analysis. Adult patients (age 25.5 ± 4.9 years) wearing fixed twistflex retainers and having visible retainer-associated misalignment were included and examined for tooth movement after retainer debonding. Orthodontic study models were taken at retainer debonding (t0) and 14 ($\pm$1) weeks later (t1). They were digitally superimposed using 2D/3D dental imaging software and tooth movement was analyzed in all three dimensions.

Results A total of 23 teeth (12 upper teeth: 10 incisors, 2 canines; 11 lower teeth: 7 incisors, 4 canines) were analyzed. Mean overall tipping was $1.11 \pm 0.82°$ in the mesial/distal direction (angulation, x-axis), $2.02 \pm 1.9°$ in the buccal/lingual direction (inclination, y-axis) and $1.28 \pm 0.99°$ around the tooth axis (z-axis). Mean overall bodily movement was 0.30 ± 0.31 mm in the mesial/distal direction (angulation, x-axis), 0.10 ± 0.13 mm in the buccal/lingual direction (inclination, y-axis), and mean in- or extrusion 0.22 ± 0.24 mm (z-axis). Mean tipping and bodily movement were more pronounced in the upper jaw.

Conclusion The present data shows that tooth movement after debonding of twistflex retainers can be expected in misalignment cases.

Keywords Orthodontic appliances, fixed · X-effect · Retention · Bonded retainers · Orthodontic retainers

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Unerwünschte Nebenwirkungen von Twistflex-Retainern – eine 3-D-Evaluation von Zahnbewegungen nach Retainerentfernung

Zusammenfassung

Ziel Evaluation von Zahnbewegungen nach Retainerentfernung in Fällen von retainerassoziierter Zahnfehlstellungen.

Methoden Diese Pilotstudie basiert auf einer retrospektiven Datenanalyse. Erwachsene Patienten (Alter 25,5 ± 4,9 Jahre) mit sichtbarer retainerassoziierter Zahnfehlstellung bei intakten Twistflex-Retainern wurden in die Studie einbezogen und hinsichtlich einer spontanen Zahnstellungskorrektur nach Retainerentfernung untersucht. Dazu wurden Gipsmodelle vom Zeitpunkt der Retainerentfernung (t0) sowie 14 (±1) Wochen danach (t1) in einer 2-/3-D-Bildverarbeitungssoftware digital überlagert und die Zahnstellungsänderungen wurden in allen 3 Dimensionen analysiert.

Ergebnisse Insgesamt 23 Zähne (12 Oberkieferzähne: 10 Inzisiven, 2 Eckzähne; 11 Unterkieferzähne: 7 Inzisiven, 4 Eckzähne) wurden analysiert. Die durchschnittliche Kippbewegung in beiden Kiefern betrug 1,11 ± 0,82° in mesiodistaler Richtung (Angulation, x-Achse), 2,02 ± 1,9° in bukkolingualer Richtung (Inklination, y-Achse) und 1,28 ± 0,99° um die eigene Achse (z-Achse). Die durchschnittliche körperliche Bewegung betrug 0,30 ± 0,31 mm in mesiodistaler (Angulation, x-Achse) und 0,10 ± 0,13 mm in bukkolingualer Richtung (Inklination, y-Achse), die durchschnittliche In- bzw. Extrusion 0,22 ± 0,24 mm (z-Achse). Das durchschnittliche Ausmaß der Zahnbewegung war deutlicher im Oberkiefer.

Schlussfolgerung Die vorgelegten Daten zeigen, dass nach dem Debonding von Twistflex-Retainern bei Zahnfehlstellungen eine Zahnbewegung erwartet werden kann.

Schlüsselwörter Festsitzende kieferorthopädische Apparaturen · X-Effekt · Retention · Geklebte Retainer · Kieferorthopädische Retainer

Introduction

After orthodontic treatment, removable or fixed retention appliances are commonly used to stabilize treatment results [1]. Fixed flexible spiral wire lingual retainers were introduction in the 1970s and are often considered the gold standard in the postorthodontic retention phase [2–4]. Long-term studies suggest that they show stable mechanical properties and an adequate stabilization of teeth [5, 6].

Failure rate of wire lingual retainers is estimated to be at 3.5–53% [7, 8]. Most common causes of failures are debonding and wire fracture [9]. Leaving adequate space between the composite sites that attach the retainer to the teeth seemed to be essential for the success of a retainer system [10]. To reduce failure, authors promote the use of flexible spiral wires with a small diameter because they showed an increased detachment force and performed better in bond strength and deflection as compared to stiff wires [4, 10]. In contrast, Zacchrisson stated that decreasing wire diameters could increase the risk of wire fracture [11]. Rebonding to enamel seemed to result in lower mean bond strength for rectangular and three-stranded steel wires in comparison with the initial bond strength [12].

Taner and Aksu found in a prospective clinical study that most bonding failures of fixed flexible spiral wire lingual retainers happened within the first month [13]. However, other studies describe that failure occurs within the first 3–6 month and decreases after 1 year [9, 14, 15]. Therefore, clinical re-examination of retainers for up to 2 years has been proposed [16].

Irrespective of the anticipated benefits, fixed lingual retainers can cause side effects, such as caries and periodontal damage in cases of poor oral hygiene [5, 17–20]. Undesirable changes in tooth position in the presence of an intact retainer were also observed with increasing frequency [14, 16, 21–24]. Since lingual retainers are able to exert forces and torques on teeth [25–27], they have recently been suspected of causing these undesirable tooth movements. Authors describe common symptoms like torque differences of two adjacent incisors ("X-effect") or opposite inclinations of contralateral canines ("twist effect"), whereas the center of rotation seems to be in the area of the central incisors [23, 28]. Nevertheless, it is unclear whether retainers themselves induce force that results in tooth movement and how those misaligned teeth react after retainer debonding.

Therefore, the aim of this retrospective pilot study was to gain further information on fixed retainer-associated tooth misalignment and the impact of retainer debonding on those teeth.

Methods

Study design

The pilot study is based on a retrospective data analysis of adult patients (age: 25.5 ± 4.9 years) with severe retainer-associated misalignment during orthodontic retention with fixed twistflex retainers.
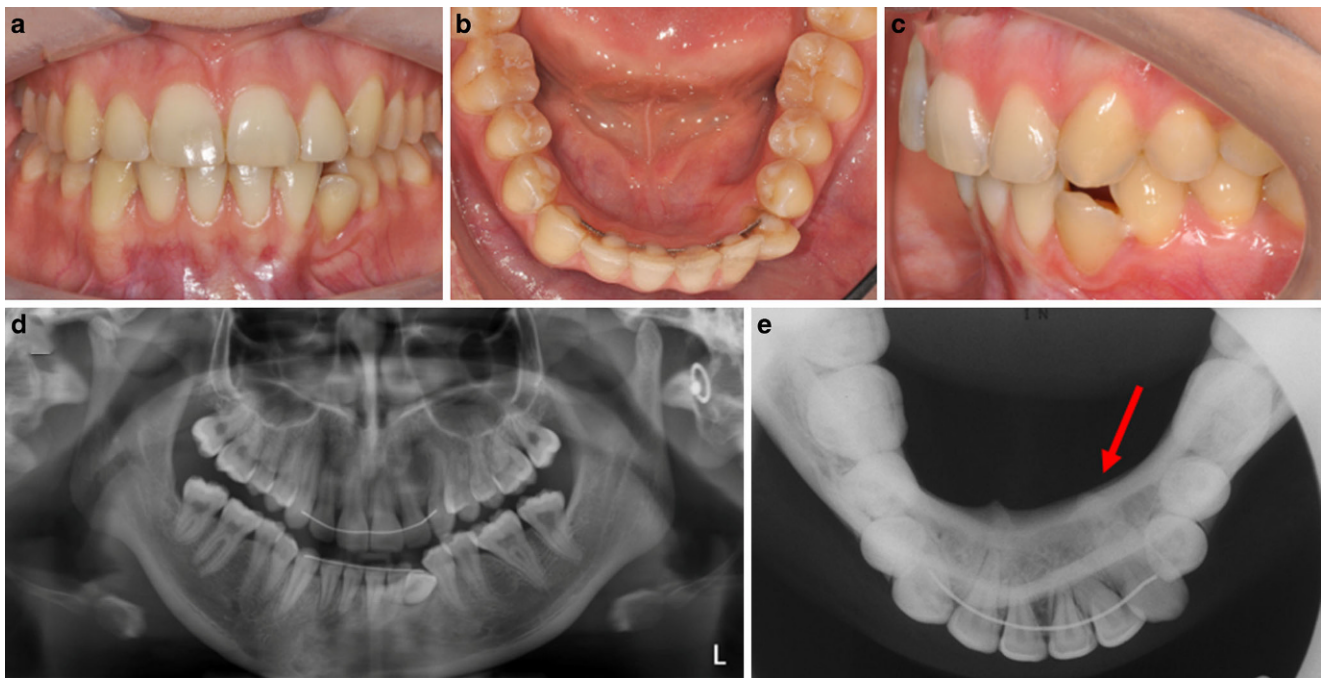
Fig. 1 Representative example of a 20-year-old woman with retainer-induced misalignment of the lower left canine. Intraoral views (**a–c**), orthopantomograph (**d**) and an occlusal radiograph of the mandible (**e**). The lower left canine shows severe proclination with an intact twistflex retainer (**a–c**), while the tooth root appears outside of the bony housing (**e**, *red arrow*)

Abb. 1 Exemplarische Darstellung einer Patientin mit retainerassoziierter Zahnfehlstellung des unteren linken Eckzahns. Intraorale Ansichten (**a–c**), Orthopantomogramm (**d**) und Unterkieferaufbissaufnahme (**e**) einer 20-jährigen Patientin, die sich mit einer unerwünschten Zahnstellungsänderung des unteren linken Eckzahnes bei intaktem Twistflex-Retainer vorstellte. Beim Zahn 33 zeigt sich eine extreme Proklination (**a–c**) mit resultierendem Austritt der Wurzel aus dem knöchernen Tegument (**e**, *roter Pfeil*)

Participants

All patients attending the Department of Orthodontics at University Bonn, Jena and Aachen, Germany, for routine orthodontic examinations between 2017 and 2019 were assessed for eligibility. The study was designed as a retrospective pilot investigation on routinely collected patient data to determine the impact of retainer debonding on tooth movement. Since this is a pilot study with no prior similar investigation, no sample size calculation was possible beforehand. The inclusion criteria were completed fixed orthodontic treatment, current fixed lingual retainer (flexible round spiral wire) in the upper and/or lower jaw and visible misalignment (≥0.5 mm tipping from the regular occlusion as confirmed by three-dimensional (3D) measurements of the routinely taken dental casts) of one or more teeth included in the retainer. Exclusion criteria were broken or damaged retainers, retainers with broken bonding pads and patients which reported retainer failures. Fig. 1 illustrates a typical finding of undesired retainer-associated misalignment in a 20-year-old woman.

Clinical examination

Standard dental examinations were conducted using a dental light, mirror and a dental probe. Based on Bonn, Jena and Aachen university hospital standard operating procedures, the existing retainers were removed to discontinue the present forces. Therefore, a dental probe or needle holder was used and the remaining composite was debonded with a hard metal polisher (Comet Dental, Lemgo, Germany). After 14 (±1) weeks another routine consultation was performed to study possible realignment of the dentition (t1).

The following parameters were recorded as part of the standard treatment protocol:

- Orthodontic study models (stone plaster, BonDur®, Wiegelmann Dental, Bonn, Germany) and routine intraoral photos were made at the retainer debonding (t0) and follow-up (t1) appointment.
- The dental casts were digitalized with a model scanner (orthoX® scan, Dentaurum, Ispringen, Germany) and the obtained STL files were superimposed using 2D/3D dental imaging software (OnyxCeph³™ 3D Pro, version 3.2.32 38, Image Instruments, Chemnitz, Germany) to detect positional changes of the teeth. The analysis was

performed based on previous studies that had demonstrated the accuracy and validity of digital models obtained with the orthoX®scan in evaluating and conveying tooth positions [29, 30].

Superimpositions of the virtual 3D casts

All superimpositions were performed with the software "Aligner 3D module" (OnyxCeph³ᵀᴹ 3D Pro, version 3.2, Image Instruments, Chemnitz, Germany). The scanned study models were segmented digitally and a crown-specific coordinate system was defined. Next, the virtual casts of t1 and t0 were superimposed using a "best fit method" which was based on an iterative closest point (ICP) matching algorithm. In this algorithm, each point of the 3D point cloud of the digitized model is matched several times with the closest corresponding point of the 3D point cloud of the segmented model. The aim was to achieve ideal congruence between the premolars and molars of the two models as their position was assumed to be stable.

Afterwards, the software was able to calculate differences between the two models. In brief, the software computed an additional iterative closest point (ICP) matching algorithm only for the crowns of the misaligned teeth. Therefore, the individual crown coordinate system with the following axes was used: the mesial/distal (m/d) axis from the mesial to the distal point of the crown, the tooth axis from mesial–distal midpoint to the apical point of the crown and the vestibular axis which is orthogonal to the inclination and rotation axes. The following crown landmarks were used: the mesial, the distal, the incisal and the apical reference point. Translation and rotation components were applied along or around these coordinate system axes and measured in millimeters and in degrees (Fig. 2).

The following movements were examined:

- Angulation—measured around the vestibular axis (surface normal of the plane from the m/d axis and tooth axis). If the angulation is positive, the incisal point is turned mesially and the apex towards the distal.
- Inclination—measured around the inclination axis (mesial reference point to distal reference point axis). If the inclination is positive, the incisal point is turned outwards and the apex to the center.
- Rotation—measured as change in the angle of rotation around the tooth axis (m/d axis center point to apex point). If the rotation is positive, the labial point is rotated mesially.

Regarding the translational movements, the three translation components (m/d, apical and vestibular component) were measured separately along the corresponding coordinate axis of the described crown coordinate system—these measurements are invariant regarding the position. Regarding the rotational movements, it is important consider the origin of the coordinate system (m/d crown center) and the application order.

Patients were examined in the department of orthodontics by one clinician. All superimpositions were performed by one trained and calibrated examiner. The calibration procedure was performed with 10 superimpositions prior to the beginning of the analysis. Afterwards, a dentist analyzed the virtual models twice on different days to ensure the reproducibility of the data. The intrarater reliability was ($\kappa_{intra} = 0.934–0.996$). The average measuring difference was 0.19° and 0.02 mm.
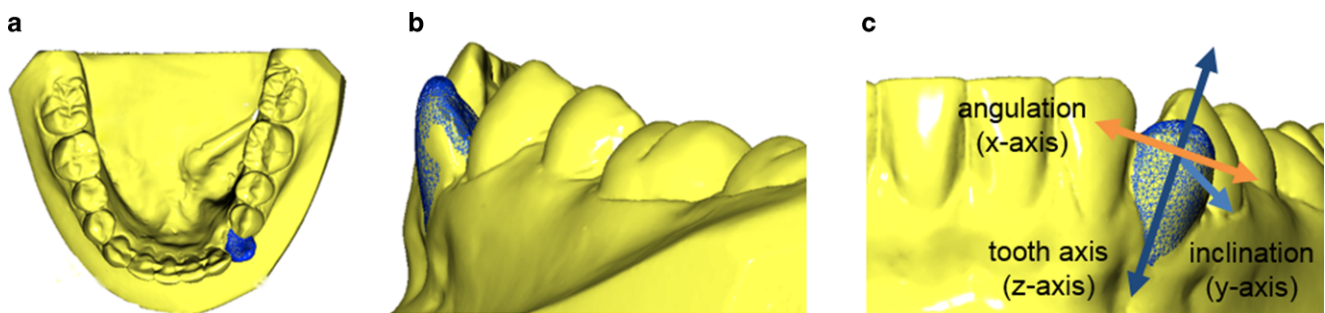

Fig. 2 Three-dimensional analysis of undesired tooth movement. Exemplary illustrated virtual superimposition of dental casts in a patient with undesired tooth movements of the lower left canine in the presence of a twistflex retainer. *Yellow areas* show tooth 33 at retainer debonding (t0), *blue areas* show spontaneous realignment of tooth 33 after 3 months (t1) from occlusal (**a**), left (**b**), and frontal (**c**) views. Changes in tooth position are described for the x-, y-, and z-axis (**c**)

Abb. 2 3-D-Analyse unerwünschter Zahnstellungsänderungen. Exemplarische Darstellung einer digitalen Überlagerung eines unteren linken Eckzahns einer Patientin mit unerwünschter Zahnstellungsänderung unter permanenter Retention mit einem Twistflex-Retainer in der Ansicht von okklusal (**a**), links (**b**) und frontal (**c**). Verglichen wird die Zahnstellung bei Retainerentfernung (t0; *gelb unterlegt*) und nach einer Beobachtungszeit von 3 Monaten (t1; *blau unterlegt*) in der x-, y- und z-Achse

Statistical analysis

Data were recorded in Microsoft Excel files (Microsoft Office 365, Microsoft Corporation, Redmond, WA, USA) and transferred to the Statistical Package for Social Sciences (IBM® SPSS® Statistics, IBM Corporation, Armonk, NY, USA) and GraphPad Prism (version 7, GraphPad Software, San Diego, CA, USA) for analysis. Fig. 2 was designed using cephalometric software (Viewbox 4 Software 4.1.0.1 BETA, dHAL Software, Kifissia, Greece). The primary outcome was extent of tooth movement determined by superimposition for tooth tipping (degree) and tooth movement (millimeters). The primary outcome was compared between the different groups using a nonparametric Kruskal–Wallis test. The significance level for all statistical tests was set at $p \leq 0.05$. Results are shown as absolute values.

Results

Clinical examination

A total 23 teeth (12 upper teeth: 10 incisors, 2 canines; 11 lower teeth: 7 incisors, 4 canines) were analyzed as baseline at retainer debonding (t0) and 14 (±1) weeks later (t1). Fig. 3 illustrates the results of dimensional changes on both rotational and translational levels. Retainer debonding led to alterations in all analyzed teeth.

Digital analysis of tipping movements

Mean overall tipping was $1.11 \pm 0.82°$ in the mesial/distal direction (angulation, x-axis), $2.02 \pm 1.9°$ in the buccal/lingual direction (inclination, y-axis) and $1.28 \pm 0.99°$ around the tooth axis (z-axis) in both jaws at t1.

Mean tipping was more pronounced in the upper (U) as compared to the lower jaw (L) regarding angulation (U: $1.38 \pm 0.93°$ vs. L: $0.83 \pm 0.60°$) and inclination (U: $2.68 \pm 2.41°$ vs. L: $1.30 \pm 0.77°$); however, the difference was not statistically significant ($p \geq 0.05$). Mean rotation was very similar in the upper or lower jaw (U: 1.27 ± 1.09 vs. L: 1.29 ± 0.93; Fig. 3a).

Digital analysis of bodily movements

Mean overall movement in both jaws was 0.30 ± 0.31 mm in the mesial/distal direction (angulation, x-axis), 0.10 ± 0.13 mm in the buccal/lingual direction (inclination, y-axis) and mean in- or extrusion was 0.22 ± 0.24 mm (z-axis) at t1.

Mean movement was more pronounced in the upper jaw regarding angulation (U: 0.15 ± 0.16 mm vs. L: 0.05 ± 0.04)
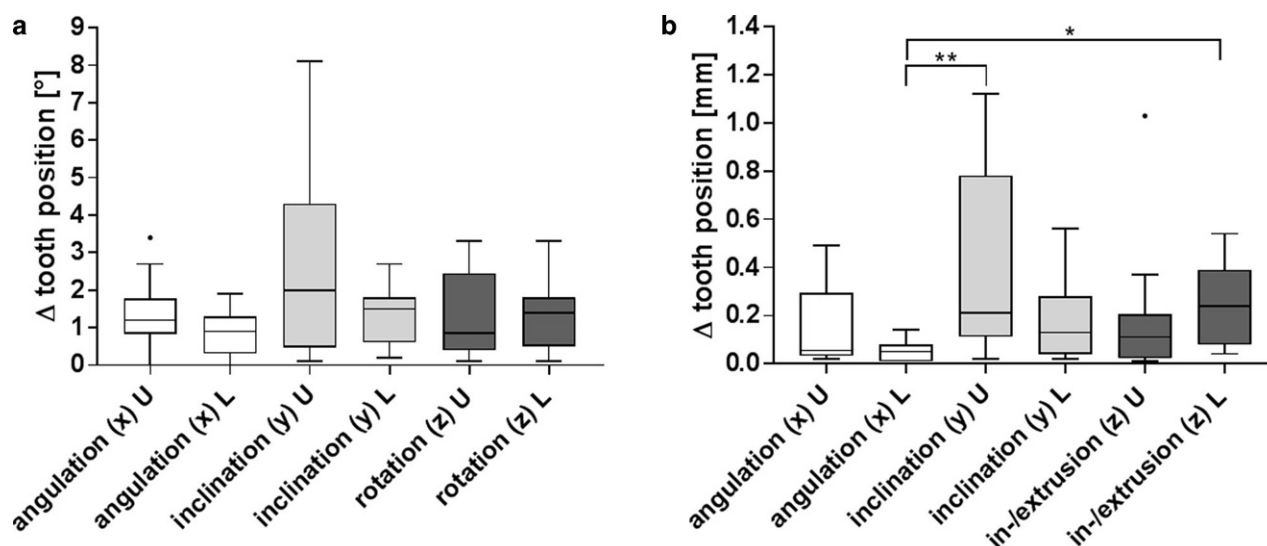

Fig. 3 Results of virtual superimpositions of upper and lower jaws with retainer-associated undesired tooth movements. Box and whisker plot of the results of three-dimensional superimpositions of upper (U; $n = 12$) and lower teeth (L; $n = 11$) with undesirable changes in tooth position in the presence of twistflex retainers. Tooth position at retainer debonding (t0) was compared to tooth position after 3 months (t1). Differences in tooth tipping and tooth movement are described for the x-, y-, and z-axis in degree (**a**) and millimeters (**b**); *$p \leq 0.05$ and **$p \leq 0.01$ (Kruskal–Wallis test)

Abb. 3 Ergebnisse der digitalen Überlagerung von Ober- und Unterkiefern mit unerwünschten retainerassoziierten Zahnstellungsänderungen. Box-Whisker-Plot der Ergebnisse der 3-D-Überlagerungen oberer (U; $n = 12$) und unterer Frontzähne (L; $n = 11$) mit unerwünschten Zahnstellungänderungen unter Versorgung mit Twistflex-Retainern. Verglichen wurde die Zahnstellung am Tag der Retainerentfernung (t0) sowie nach einer Beobachtungszeit von 3 Monaten (t1). Unterschiede in der Zahnstellung wurden in Grad (**a**) und Millimeter (**b**) für die x-, y- und z-Achse angegeben; statistisch signifikante Unterschiede wurden mit *$p \leq 0,05$ und **$p \leq 0,01$ markiert (Kruskal-Wallis-Test)

Fig. 4 Exemplary illustration of retainer induced misalignment of the upper left central incisor. Occlusal (**a,d,g**), right (**b,e,h**), and frontal views (**c,f,i**) of a 20-year-old woman who presented with undesirable position changes of the upper left central incisor in the presence of an intact twistflex retainer. **a–c** The patient at 15 years of age on the day of retainer insertion *alio loco*, **d–f** at 20 years of age shortly before retainer debonding, and **g–i** 13 weeks after debonding. After retainer debonding there was a remarkable spontaneous realignment of 21; however, the original position after bracket debonding could not be achieved (**a–c**)

Abb. 4 Exemplarische Darstellung einer retainerassoziierten Zahnfehlstellung des oberen linken zentralen Frontzahns. Intraorale Ansichten von okklusal (**a,d,g**), rechts (**b,e,h**) und frontal (**c,f,i**), 20-jährige Patientin, die sich mit einer unerwünschten Zahnstellungsänderung des oberen linken zentralen Frontzahnes bei intaktem Twistflex-Retainer vorstellte. **a–c** zeigen die Patientin im Alter von 15 Jahren am Tag der Retainerinsertion *alio loco*, **d–f** zeigen die Patientin im Alter von 20 Jahren kurz vor Retainerentfernung und **g–i** zeigen eine spontane Zahnstellungskorrektur nach 13 Wochen. Die Stellung von 21 verbesserte sich spontan, die initiale Zahnstellung nach Entfernung der Multibracketapparatur konnte jedoch nicht vollständig erreicht werden (**a–c**)

Table 1 Results of the virtual superimposition of an upper left central incisor of a 20-year-old woman shown in Fig. 4 before and after retainer debonding. Differences in tooth position are described for the x-, y-, and z-axis in degree and millimeters

Tab. 1 Ergebnisse der virtuellen Überlagerung eines linken oberen zentralen Schneidezahns einer 20-jährigen Patienten (Abb. 4) vor und nach Retainerentfernung. Kippende Zahnbewegungen werden in Grad, körperliche Zahnbewegungen in Millimetern in der x-, y- und z-Achse angegeben

Tooth type	Movement	Axis	Δ T0–T1
21	*Tipping movement*		
	Angulation	x	1.8°
	Inclination	y	8.1°
	Rotation	z	0.2°
	Bodily movement		
	Angulation	x	0.05 mm
	Inclination	y	0.2 mm
	Intrusion	z	1.03 mm

and inclination (U: 0.41 ± 0.38 mm vs. L: 0.18 ± 0.16 mm). Mean in- or extrusion was higher in the lower arch (U: 0.19 ± 0.29 vs. L: 0.25 ± 0.18) but the difference between jaws was not statistically significant ($p \geq 0.05$). There were statistically significant differences between mean angulation in the lower and mean inclination in the upper jaw ($p \leq 0.01$) and mean angulation and in-/extrusion in the lower jaw ($p \leq 0.05$; Fig. 3b).

Furthermore, individual patients were analyzed for tooth movement after debonding. In Fig. 4, undesired dental misalignment after completed orthodontic treatment (*alio loco*) and subsequent spontaneous realignment after retainer debonding in a 20-year-old woman is shown. In addition, Table 1 summarizes the realignment results of the left upper central incisor in the same patient.

Discussion

This study evaluated the impact of retainer debonding on tooth position in fixed retainer misalignment cases. The present pilot investigation demonstrates that twistflex re-

tainers can be associated with severe changes in tooth position of incisors and canines as previously shown. However, for the first time we provide quantitative evidence that misaligned teeth attached to fixed retainers show tooth movement when those retainers are debonded. Our observations therefore underline the idea that retainers might be able to induce active force onto teeth which could be responsible for iatrogenic tooth movements.

According to other groups it can be estimated that approximately 2.7–5% of patients with retainers made from multistranded wires are affected by unexpected tooth movements during the orthodontic retention phase [21, 31]. Katsaros et al. reported mostly on torque differences between lower incisors and buccal tipping of lower canines, which was also observed in this study [21]. In a similar case, Pazera et al. described a severe lingual crown torque of a lower canine in a patient with an intact retainer resulting in dehiscence of the buccal bone and massive gingival recession [24].

Other groups have also described iatrogenic tooth movements of entire retainer-blocks in the lower jaw [28]. The authors showed that fixed retainers were able to cause forces that moved the teeth at one end in a lingual and at the other end in a buccal direction, whereas the center of rotation was located close to the central incisors [28]. One possible explanation for this observation was that the affected arches had been expanded before and underwent a relapse in the transverse dimension during the retention phase causing rotation of the entire (rigidly interconnected) retainer block [28].

In these reports factors including inter canine expansion, lower incisor protrusion and mandibular anterior protrusion are discussed to be potential risk factors for posttreatment changes during permanent retention [5, 28, 32]. Therefore, several authors consider additional removable appliances in addition to fixed retainers in cases of intended dental arch expansion [28].

Other reasons for unwanted tooth movements associated with fixed retainers are deformations that occur during the manufacturing and bonding process. Also, the impact of chewing forces to activate an initially passive retainer are discussed [4, 27].

All patients of the present investigation were provided with twistflex retainers. Some authors assume that highly flexible 6-point twistflex retainers appear to be the most likely to produce inadvertent tooth movement [16]. Egli et al. examined unwanted tooth movements in patients with multistranded 6-point retainers that were bonded directly or indirectly. However, patients with indirectly bonded retainers showed less unexpected tooth changes as compared to patients with directly bonded retainers [33]. It can be assumed that the risk of activation during the bonding process plays a significant risk factor.

In this context, high-precision computer aided design/computed aided manufacturing (CAD/CAM) retainer systems made of nickel–titanium [34, 35] or zirconium [36] seem to be a promising alternative. A perfect fit might prevent unwanted wire deformations during bonding. Future investigations have to clarify whether these modern systems cause fewer unwanted tooth movements.

Another reason for the development of unwanted tooth movements might be that multistranded wires tend to detwist [28]. In a long-term study, Renkema et al. did not detect any severe changes in tooth position when patients wore rectangular stainless steel 2-point retainers bonded only to the canines [22]. Adverse tooth movements are also not described in patients with retainers constructed out of one-strand round stainless steel wires bonded only on the canines [37]. However, in these patients moderate incisor crowding appeared within 5 years as part of relapse or normal growth [22, 31], which could negatively affect patients perception of the treatment results.

However, there are limitations of this retrospective study. First, the sample size was small as unwanted tooth movements is a rare but serious finding in orthodontic patients. Future investigations need to analyze larger study populations in order to investigate the scientific background of the observe tooth movements. Second, there was a lack of prior treatment charts and it was therefore not possible to specify to which degree the demonstrated tooth movements were part of a relapse to the original position. Therefore, future randomized clinical trials are necessary to understand the exact mechanisms of unwanted tooth movements during the orthodontic retention phase. Understanding causative reasons for detected differences in the upper and lower jaw could also influence and individualize treatment decisions for clinical practice.

Taken together, the present data show that in general some tooth movement can be expected when fixed retainers are debonded in cases of retainer-associated misalignment.

Conclusions

The present analysis indicates that in some cases fixed retainers can be considered active and therefore debonding might reduce further malalignment of affected teeth. In these cases, retainer debonding might especially in the upper front help to improve tooth alignment and reduce further orthodontic treatment need. With respect to these findings, future studies are necessary to gain additional information on risk factors leading to unwanted posttreatment changes in tooth position in the retention phase. Based on our findings, routine examination of alignment in patients with fixed retainers and debonding/retainer reinsertion in

cases of observed initial malalignment should be recommended for clinical practice.

Compliance with ethical guidelines

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Hier steht eine Anzeige.