Post-treatment changes in permanent retention

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Posttreatment movement of teeth in patients wearing a permanent fixed lingual retainer in the anterior mandible

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Abstract

Objectives. While permanent retention is today frequently the method of choice to stabilize orthodontic treatment outcomes, recent studies have increasingly reported posttreatment changes in tooth position during permanent retention. We conducted this study to analyze such changes in the anterior mandible, whether these follow an underlying movement pattern, and, aiming for a preventive strategy, whether any risk factors could be identified by comparing findings to the pretreatment situations.

Methods. We included 30 patients who had worn a fixed Twistflex retainer extending from canine to canine in the mandible. Casts reflecting the intraoral situations before orthodontic treatment (T0), directly upon completion of active therapy (T1), and 6 months into retention (T2) were scanned and superposed using Imageware Surfacer software. Posttreatment changes (T2−T1) in tooth position inside the retainer block were analyzed on 3D virtual models and were compared to pretreatment (T0) and treatment-related (T1−T0) findings to identify potential risk factors.

Results. Almost all patients revealed three-dimensional changes in tooth position within the retainer block. On comparing these movements, we repeatedly found the retainer blocks to have rotated in a labio-oral direction, with the center of rotation located at the first incisors. This pattern was associated with intercanine expansion and excessive overjet correction during the preceding orthodontic treatment. The canines underwent the most pronounced (rotational and translational) movements. In 13% of cases, these were so severe as to require another course of orthodontic treatment.

Conclusions. Permanent lingual retainers are safe but sometimes can induce tooth movement in their own turn. Risk factors seem to include intercanine expansion and excessive overjet correction during the preceding orthodontic treatment. Our recommendation is to consider the use of additional retention in specific cases.

Keywords: lingual retainer · orthodontic retention · Twistflex retainer

Introduction

Providing long-term stabilization of treatment outcomes is a particularly challenging task for orthodontists. Much research has gone into this issue, with a continuously increasing trend to use permanent retention systems that are independent of patient compliance. Despite these efforts, no recipe has yet been found to reliably prevent posttreatment changes. These may take the form of tooth positions relapsing toward the initial malocclusion, but another issue that is increasingly being discussed concerns changes in tooth position brought about by the retention system itself [4, 9, 30].

Great interest has been devoted to permanent retention of treatment outcomes since the early days of modern orthodontics. Investigations into the stability of orthodontic treatment outcomes revealed a marked tendency notably of upper and lower incisors to relapse into their previous positions unless appropriate measures of retention were taken [12, 13]. Very early it was realized that the concept advocated by Edward Angle to stabilize tooth positions by establishing a neutral occlusal relationship was not adequately effective in preventing posttreatment displacement of teeth. Hence Angle's critics suggested various concepts of improving the long-term stability of occlusal relationships. The approach proposed by Tweed sought to prevent relapse due to overexpansion of the dental arch by extracting premolars [3, 30].

To this day, however, these concepts do not seem to ensure long-term stability of the tooth positions achieved by orthodontic treatment. Hence more recent efforts have focused on appliances worn by patients beyond the stage of active orthodontic treatment. Studies have also increasingly looked into the reasons for orthodontic relapse, aiming to explore whether these insights might hold a prospect for more selective modalities of preventing relapse or, for that matter, any kind of change to which the occlusal relationship may be subjected after completion of treatment. A possible cause of relapse suggested in early reports by Reitan and others [3, 5, 19] was insufficient remodeling of the transgingival fiber apparatus to match the tooth movement, thus forcing the teeth to move back toward their original displacement after treatment. Accordingly, they suggested severing these fibers by periodontal surgery to prevent relapse. Other measures that have been discussed to ensure posttreatment stability would include overcorrection of the original tooth displacement or gentle modification of the lower intercanine distance (avoiding marked protrusion of the lower incisors) as part of the orthodontic treatment [2, 16, 24, 32].

From the evidence on numerous retention protocols in national and international publications, it is clear that permanent lingual bonded retainers are currently the most effective and predictable way of stabilizing tooth positions in the anterior mandible. Hence these retention protocols are today's gold standard [9, 23]. Recently, however, reports have increasingly been published on distinct changes in lower anterior tooth position during and despite the use of permanent lingual retainers, in some cases to the point of requiring a second course of orthodontic treatment [9, 18]. Interestingly, these changes are unrelated to the pretreatment tooth positions and thus should not be discussed in terms of orthodontic relapse. Rather, they must be independently regarded as a tooth movement related to the lingual retainers—and to the orthodontic treatments preceding their insertion—in ways that are currently not understood.

Facing a growing number of case reports in the presence of little scientific evidence, we designed this study to analyze the development of posttreatment changes during the use of permanent fixed lingual retainers. Our first aim was to systematically verify the actual incidence of this phenomenon and whether a consistent movement pattern could be identified. Subsequently these data were to be used for our next goal, which was to identify factors related to the preceding treatment regimens by comparing post- and pretreatment casts, thus verifying the presence of any treatment-related risk factors for future utilization by clinicians in assessing this risk and toward developing a strategy of preventing these posttreatment changes during permanent retention.

Materials and Methods

Patients. We retrospectively analyzed data of 30 consecutive patients treated at our institution (Department of Orthodontics, University of Bonn) in the period 2012−2015. Only patients were included who underwent ≥ 1 years of active multiband treatment followed by permanent retention in the anterior mandible, with no other appliance in the mandible and no extracted or congenitally missing anterior teeth. Retention was provided as described by Zachrisson et al. [32], using a Twistflex retainer (Dentaurum; Dentaflex 0.45 mm three-strand twisted steel wire) bonded to six lingual sites from canine to canine. All retainers were fabricated based on impressions in the laboratory of our department, and a silicone index was used for passive intraoral insertion. The preceding orthodontic therapies had been performed after conventional planning and included cases of both non-extraction and extraction of premolars. At the end of active treatment, the 30 (17 female and 13 male) patients were 24.52 ± 4.36 years old.

Digital visualization of tooth positions. For each patient, pairs of casts reflecting the pretreatment situation (T0) and the situation immediately upon completion of active treatment (T1) were available, plus a lower-jaw cast obtained after ≥ 6 months of retention (T2). Following digitization of the T1 and T2 casts with a laser scanner (Micromeasure70®; Microdenta Sensorik, Linden, Germany), 3D graphics software (Surfacer, v. 10.5; Imageware/Siemens PLM Software, Plano, TX, USA) was used to display the teeth and mucosal tissues as a 3D point cloud. Removing the gingiva—which is subject to dimensional changes [26, 27]—along with the retainer and the bonding sites reduced this display to the tooth surfaces required for tooth-position analysis.

Superposition of the virtual 3D models. To track the posttreatment movement of each anterior tooth during the period of retention, we superposed the T1 and T2 models. As the mandible features no anatomical structure that would be both unchangeable by orthodontic therapy and recordable by dental impression-taking [17], we based this superposition on the well-established method of "best surface matches" [15, 20]. In brief, the point clouds of the same molars scanned from T1 and T2 casts were projected onto each other using a surface-surface matching algorithm that works toward minimizing the distances between both clouds. These distances were described by a predefined function, the individual parameters of which were varied until the distance was effectively minimized for ideal congruence between both areas [10].

Measurement of tooth movements. To measure the actual changes in tooth position during permanent retention, teeth 33 to 43 of both superposed modes (T1 and T2) were segmented, then calculating the rotational and translational movement of each tooth at T2 as compared to T1 in all three dimensions by applying the surface-surface matching algorithm (see above) [10]. The coordinate system was defined such that the rotational components of tooth movement (°) were mesiodistal around the x-axis, orovestibular around the y-axis, and longitudinal around the z-axis (= tooth axis); and that the translational components (mm) were orovestibular along the x-axis, mesiodistal along the y-axis, and apicocoronal (intrusion/extrusion) along the z-axis (see Figure 4a) [10]. The mean method error involved was determined by applying the measuring process 10 times to an object based on 1° of rotation and 0.1 mm of translation.

Severity groups of posttreatment change. Based on the clinical appearance of the lower dental arches at T2, the patients were grouped into three severity groups. Grade 1 indicated mild or no change which did not require treatment, grade 2 moderate change which also did not require treatment but was documented and monitored, and grade 3 severe change noted by the orthodontist during the retention period which did require another course of active treatment. Additionally, a metric grading system was derived from the maximum values of rotational tipping measured for the various teeth. Developments in tooth position were considered stable if < 5°, moderate if ≥ 5°to ≤ 9°, and severe if > 9° irrespective of their directions.

Determination of treatment-related risk factors. To relate the outcomes to the initial situations prior to orthodontic treatment, manual measurements were performed on the T1 and T0 casts , including intercanine distance [1, 7, 8, 11] and overjet [7, 25]. The treatment-related changes of these parameters were obtained by calculating the difference between T0 and T1. Furthermore, the pretreatment space requirement diagnosed for each patient was measured and documented based on the T0 cast.

Statistical analysis. The results of the various measurements were entered and sorted in spreadsheet software (Excel; Microsoft Corporation, Redmond, WA, USA). Any statistically significant differences between results were identified by applying a t-test for independent samples, using statistical software (Graph Pad Prism 5; GraphPad Software, La Jolla, CA, USA). Differences were considered significant at $p \leq 0.05$.

Results

Posttreatment changes observed clinically and on virtual models. Comparing the situations at debonding (T1) and after 6 months of fixed lingual retention (T2), some patients did reveal a change in tooth position within the retainer segment (Figure 1). Notably the canines had moved relative to the first premolars by T2. This was confirmed after digitization of the T1 and T2 casts and superposition of the virtual models, which revealed that the retention-related posttreatment change was often characterized by the canines showing the greatest and the central incisors the smallest movement by T2. In the majority of cases, this movement exhibited a rotation-style pattern with the center of rotation in the area of the central incisors (Figure 2).

Incidence of posttreatment changes during permanent retention. Our qualitative and quantitative evaluation of severity of posttreatment changes (see Material and Methods) allowed us to classify patients as having undergone stable, moderate, or severe development during retention (Figure 3). The permanent lingual retainers had ensured stability of the tooth positions in 55.68% of cases. Moderate changes were seen in 30% and severe changes requiring another course of orthodontic treatment in 13.32% of cases.

Involvement of tooth types in the posttreatment changes. Superposition of each digitized and segmented tooth allowed us to determine the nature of the movement to which each lower anterior tooth had been subjected. Both the rotational and the translational components were analyzed in all three spatial planes. In-depth analysis revealed that the canines underwent the most pronounced rotation and translation.

Findings of rotational (tipping) movement. Figure 4a illustrates the coordinate system, which was defined such that rotational tooth movements were mesiodistal around the x-axis, orovestibular around the y-axis, and longitudinal around the z-axis. Figure 4b illustrates the mean rotational movements during retention, which were found to be most pronounced for the canines in the group of patients with severe posttreatment changes. These movements were clearly more pronounced in the mesiodistal (x: 6.96° ± 3.95°) and orovestibular (y: 5.13° ± 2.94°) planes than longitudinally (z: 3.3° ± 3.12°). In the group with severe changes, the mesiodistal (x) and orovestibular (y) rotational changes were significantly greater than in the group with moderate changes and in the stable group. No significant differences in longitudinal tooth rotation were noted (z).

Findings of translational (bodily) movement. Here the coordinate system (Figure 4a) expressed translational movements as orovestibular along the x-axis, mesiodistal along the y-axis, and apicocoronal (i.e. reflecting intrusion or extrusion) along the z-axis. Figure 4c illustrates the mean translational movements observed during retention. The greatest changes were again seen for the canines in the patient group with severe posttreatment changes. These movements were most pronounced in the orovestibular (x: 0.81 ± 0.59 mm) and mesiodistal (y: 0.95 ± 0.43 mm) planes. The results in the apicocoronal plane revealed extrusion of the canines (z: 0.52 ± 0.35 mm). Again, the differences between the severe and the stable group were statistically significant in all three planes, and the lateral and central incisors had moved far less than the canines.

Association of posttreatment changes with treatment-related factors. The casts obtained for all patients directly after (T1) as compared to before (T0) orthodontic treatment revealed significantly larger amounts of intercanine expansion (Figure 5a) and overjet reduction (Figure 5b) in the group with severe posttreatment changes. Thus our data suggest that patients with marked findings of intercanine expansion and/or overjet reduction during orthodontic treatment may be particularly at risk of changes in tooth position with a fixed lingual retainer in place. No differences between the three severity groups of posttreatment change were found based on the patients' pretreatment space requirements in the mandible (Figure 5c) or based on treatments that included extraction of premolars (Figure 5d).

Discussion

The issue of changes in tooth position occurring even while the patient is wearing a permanent retainer after completion of orthodontic treatment is of high clinical relevance. This is the first study to systematically evaluate this phenomenon, with results that substantiate the findings of recent observations and case reports [9, 21, 22]. A permanent fixed lingual retainer in the lower anterior segment is still one of the most effective ways to stabilize orthodontic treatment outcomes [23, 29, 31]. As our study demonstrates, however, tooth movement may occur even with such a retainer in place. Exactly how these changes come to pass is not currently understood.

Our findings are also consistent with previous case reports by showing very clearly that this specific phenomenon of posttreatment movement of anterior teeth is unrelated to the original malocclusion. Hence these changes should not be discussed in terms of relapse but should be regarded as a new development associated with the presence of the fixed lingual retainer. Judging from the available case reports and our own findings, this retainer—due to mechanisms that remain to be adequately documented—seems capable of inducing movement in its own turn, which, depending on the amount of movement, may result in a new malocclusion requiring another course of orthodontic treatment. More studies are needed to identify orthodontic therapies that involve a risk of generating posttreatment effects of this type.

Interestingly, our detailed analysis disclosed a rotational movement pattern of the six anterior teeth spanned by the retainer, with the center of rotation located at the central incisors. For reasons not currently understood, the retention protocol here described seems to result in ~~orthodontic~~ forces capable of rotating the entire block of teeth interconnected by the retainer, with one end of the block drifting in a lingual and the other end in a vestibular direction (see Figure 1). An explanation that comes to mind would be transverse relapse, with the force of narrowing being vented in the anterior mandible and causing rotation of the entire (rigidly interconnected) retainer block.

In a similar vein, authors have suggested that age-related anterior development of the mandible may be instrumental in the development of anterior crowding after orthodontic treatment [4]. According to this theory, an active force would emerge in the dental arch, due to physiological uprighting of the lower anterior teeth. Another potential cause that has often been discussed would be unnoticed iatrogenic activation of the retainer during bonding, resulting in an active permanent wire that might induce movement of any, and possibly all, of the teeth it interconnects [28].

Our results allowed us to specifically identify the amounts of intercanine expansion and overjet reduction as potential risk factors for posttreatment changes during permanent retention. Documented findings and considerations suggest that, in some cases, a removable plate appliance should be used in addition to the fixed retainer to ensure proper stabilization of the treatment outcome. It is reasonable to assume from the available findings—at least while scientific data to the contrary are not available—that the same factors on record as modifying the stability of orthodontic treatment outcomes will remain relevant even after a fixed lingual retainer has been inserted. In other words, repeatedly documented risk factors like mandibular anterior protrusion, mandibular intercanine expansion, or pronounced space requirements should not be ignored even in patients already wearing a permanent fixed lingual retainer [3, 5, 19].

Given the similarity of the tooth movements here reported to a rotational pattern, the retainer material might also be causative factor. Rotation of the entire block of teeth interconnected by the retainer might be favored by de-twisting of the retainer wire (Twistflex-Draht). At this point, we cannot conclusively say whether, and to what extent, such de-twisting might occur in the intraoral environment and whether the resultant forces/moments would be capable of generating such movement. Pertinent studies are, however, under way. The issue of whether the retainer material poses a risk will take biomechanical and clinical investigations to be settled for the future.

Despite the present data about the incidence of posttreatment tooth movement inside the span of lingual retainers, bonded retainers still may be considered an effective and safe method to stabilize outcomes of orthodontic treatment. What should be criticized is the fact that, in some cases, these retainers can induce tooth movement in their own turn. Exactly how this happens remains to be scientifically elucidated. Based on the results of our study, we recommend using a removable retention appliance in addition to a lingual retainer in cases exhibiting transverse expansion of the mandible and pronounced overjet correction during orthodontic treatment, as it is reasonable to expect better stability by combining a fixed lingual retainer with a removable retention appliance in the anterior mandible aimed at stabilizing the transverse arch dimension.

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Figure Legends

Figure 1 Intraoral views of a patient whose tooth positions visibly changed in the posttreatment period of wearing a permanent fixed lingual retainer. Compared to the left photograph taken at the end of active treatment (T1), moderate movement of the canines relative to the first premolars was seen following 6 months of retention (T2).

End of active treatment → Active treatment completed

6 month retention → 6 months into wearing a retainer

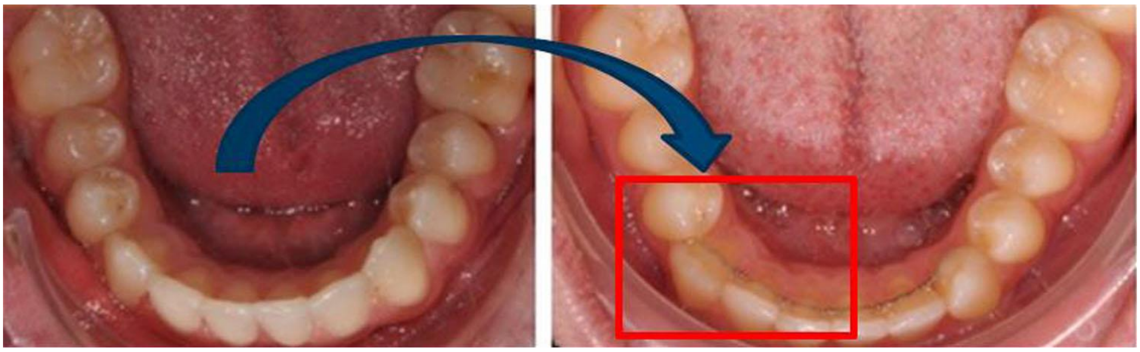

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Figure 2 Superposition of two virtual 3D models reflecting the situations in the same mandible at the end of active treatment (T1; brown areas) and after 6 months of wearing a permanent fixed lingual retainer in the anterior segment (T2; red areas). Movement of the area spanned by the retainer had been noticed clinically and is here illustrated in greater detail. Its rotational pattern is representative of the results of the present study, given a center of rotation in the area of the central incisors with resultant "swerving" of the canines.

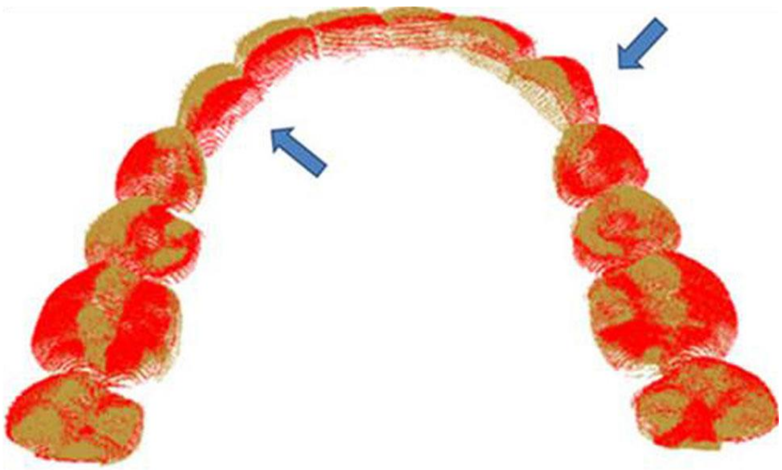

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Figure 3 Pie chart showing how the severity groups of posttreatment change defined for this study were distributed in our patient sample. Stable posttreatment results (rotational change < 5°) accounted for 56.68%, moderate change not requiring treatment (≥ 5°to ≤ 9°) for 30%, and severe change requiring treatment (> 9°) for 13.32% of cases.

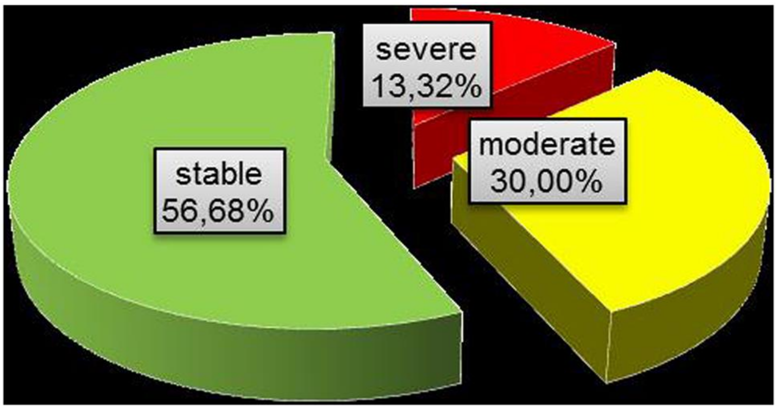

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Figure 4 (a) The coordinate system was defined such that rotational tooth movements were mesiodistal | orovestibular | longitudinal around x | y | z. Translational movements were orovestibular | mesiodistal | apicocoronal (i.e. reflecting intrusion or extrusion) along x | y | z. The bar charts illustrate the results for (b) rotational and (c) translational posttreatment tooth movements after the patients had been wearing a permanent fixed lingual retainer in the lower anterior segment for at least 6 months. Black horizontal lines crossing the bars indicate the method error. Asterisks (*) indicate significance ($p < 0.05$) for the patient group with severe posttreatment changes versus both the moderate and the stable groups. Hashes (#) indicate significance ($p < 0.05$) for the severe group versus the stable group.

Rotatory changes → Rotational changes

Translatoty changes → Translational changes

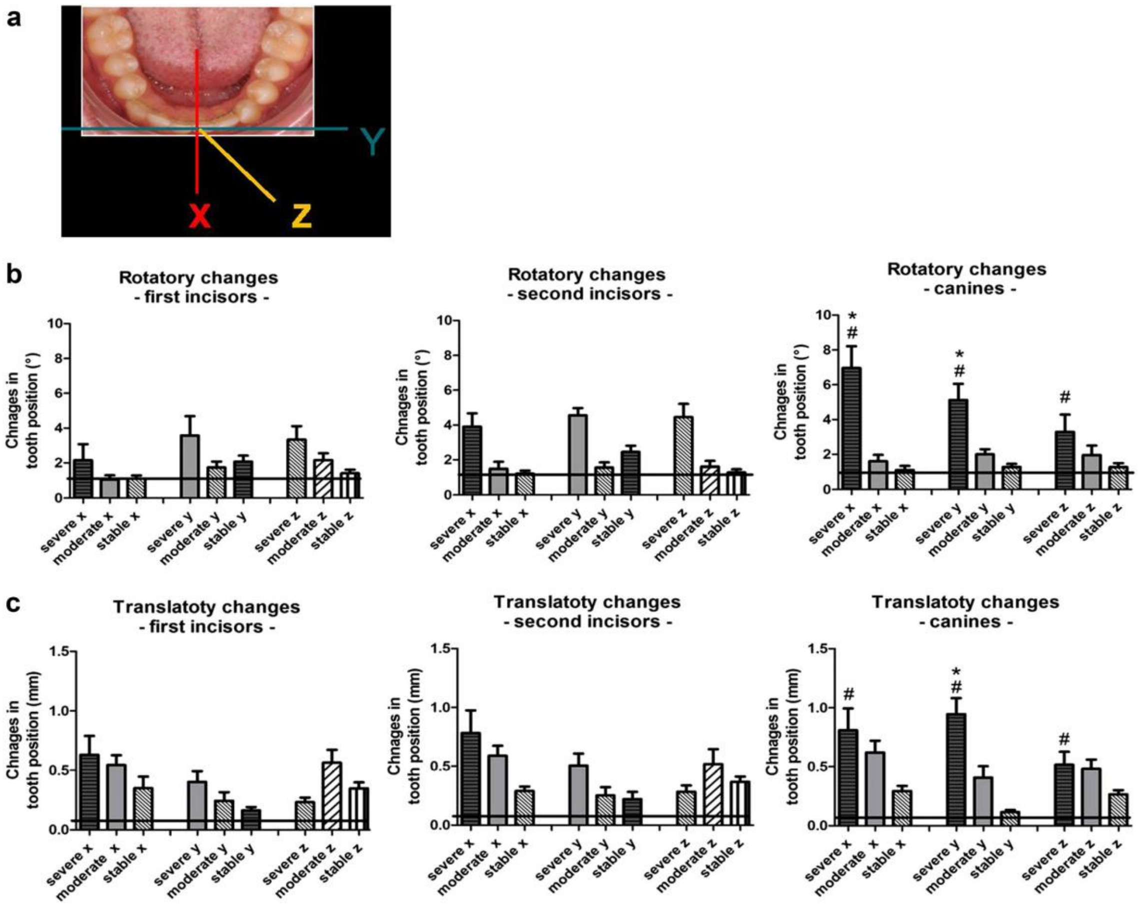

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Figure 5 Potential role of treatment-related factors (as reflected by T1−T0 differences) in the development of posttreatment tooth movement (as reflected by T2−T1 differences) associated with the use of a permanent fixed lingual retainer in the lower anterior segment. A role seems likely for both (a) intercanine expansion and (b) overjet reduction but neither for (c) the pretreatment space requirement nor (d) the inclusion of premolar extractions in the treatment plan. Hashes (#) indicate significance ($p < 0.05$) for the patient group with severe posttreatment changes versus the stable group.

Changes in intercanine dimension	→	Intercanine expansion
Changes in inter canine width (mm)	→	Intercanine expansion (T1−T0) in mm
Reduction of overjet	→	Overjet reduction
Changes in sagittal overjet (mm)	→	Overjet reduction (T1−T0) in mm
Mandibular space discripancy	→	Mandibular space requirement
(mm)	→	Space requirement (T0) in mm