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RELAPSE ONE WEEK AFTER BRACKET REMOVAL: A 3D SUPERIMPOSITIONAL ANALYSIS

Αλέξανδρος Δ. Παπαγιάννης

ΑΘΗΝΑ 2019

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ΑΘΗΝΑ 2019

Επιβλέπων Καθηγητής για την εκπόνηση της Μεταπτυχιακής Διπλωματικής Εργασίας κ. Ιωσήφ Σηφακάκης

Τριμελής Επιτροπή για την αξιολόγηση της Μεταπτυχιακής Διπλωματικής Εργασίας:

1. Δημήτριος Χαλαζωνίτης
2. Ιωσήφ Σηφακάκης
3. Ελένη Βασταρδή

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Περιεχόμενα

Περίληψη

Εισαγωγή: Η βραχυπρόθεσμη ορθοδοντική υποτροπή που εμφανίζεται μετά την αφαίρεση των ακίνητων ορθοδοντικών μηχανισμών μπορεί να σχετίζεται με τη μετακίνηση των δοντιών κατά τη διάρκεια της θεραπείας, και ίσως να αποτελεί ένδειξη της μακροπρόθεσμης υποτροπής.

Σκοπός: Η αξιολόγηση της άμεσης ορθοδοντικής υποτροπής μετά την αφαίρεση των ακίνητων ορθοδοντικών μηχανισμών, καθώς και της συσχέτιση αυτής με την αρχική κατάσταση.

Υλικά και μέθοδος: Το δείγμα αποτελείτο από 38 ασθενείς (19 αγόρια, 19 κορίτσια). Δύο αποτυπώματα πολυβινυλ-σιλοξάνης ελήφθησαν, το ένα αμέσως μετά την αφαίρεση των ακίνητων ορθοδοντικών μηχανισμών (T1), και το άλλο μια εβδομάδα αργότερα (T2), και ψηφιοποιήθηκαν στις τρεις διαστάσεις του χώρου. Κατά τη διάρκεια αυτής της περιόδου δεν εφαρμόστηκε κανένα σχήμα συγκράτησης. Η αλληλεπίθεση των ψηφιακών εκμαγείων έγινε σε δομές του βλεννογόνου της σκληρής υπερώας. Οι πρώτοι γομφίοι, οι κυνόδοντες και οι κεντρικοί τομείς της άνω γνάθου αποτέλεσαν τα υπό εξέταση δόντια. Καταγράφηκε η μετατόπιση του κέντρου γεωμετρίας του σχήματος, καθώς και η περιστροφή του κάθε δοντιού. Μελετήθηκε η υποτροπή που σημειώθηκε κατά την περίοδο (T1-T2). Επιπλέον, αξιολογήθηκε η μετακίνηση των δοντιών πριν τη θεραπεία (T0), μέχρι μετά τη θεραπεία (T1), και συσχετίσθηκε με την υποτροπή που παρατηρήθηκε. Η κανονικότητα της κατανομής των μετρήσεων ελέγχθηκε με τη δοκιμασία Shapiro-Wilk. Επελέγησαν μη παραμετρικές δοκιμασίες. Ο συντελεστής συσχέτισης του Spearman (r) χρησιμοποιήθηκε προκειμένου να αξιολογηθεί η συσχέτιση της μετακίνησης των δοντιών μεταξύ των περιόδων T0-T1 και T1-T2.

Αποτελέσματα: Παρατηρήθηκε ανιχνεύσιμη υποτροπή, η οποία σχετιζόταν με αλλαγές στη θέση των δοντιών κατά τη διάρκεια της θεραπείας. Όσον αφορά τους πρώτους

γομφίους (#16,26), παρατηρήθηκε υποτροπή στο εγκάρσιο επίπεδο (r=-0.38, P=0.020; r=-0.32, P=0.052 αντίστοιχα), στην εγγύς-άπω απόκλιση (r=-0.40, P=0.015; r=-0.34, P=0.034 αντίστοιχα), καθώς και στην προσθιοπίσθια κατεύθυνση (r=-0.31, P=0.061; r=-0.36, P=0.027 αντίστοιχα). Σχετικά με τους κυνόδοντες (#13,23), η άμεση υποτροπή περιεγράφηκε ως στροφή γύρω από τον επιμήκη άξονά τους (r=-0.55, P=0.003; r=-0.58, P=0.002 αντίστοιχα). Οι κεντρικοί τομείς (#11,21) υποτροπίασαν στην προσθιοπίσθια κατεύθυνση (r=-0.55, P=0.000; r=-0.48, P=0.03 αντίστοιχα), στο εγκάρσιο επίπεδο (r=-0.43, P=0.07; r=-0.32, P=0.047 αντίστοιχα), και παρουσίασαν στροφή γύρω από το επιμήκη άξονά τους (r=-0.53, P=0.001; r=-0.28, P=0.089 αντίστοιχα). Επιπρόσθετα, η απόκλιση της μύλης των κεντρικών τομέων μετά τη θεραπεία συσχετιζόταν με τη μετακίνηση του δοντιού κατά τη διάρκεια της θεραπείας κατά το προσθιοπίσθιο επίπεδο (r=-0.38, P=0.017; r=-0.37, P=0.024 αντίστοιχα).

Συμπεράσματα: Η άμεση ορθοδοντική υποτροπή μια εβδομάδα αμέσως μετά την αφαίρεση των ακίνητων ορθοδοντικών μηχανισμών μπορούσε να συσχετιστεί σημαντικά με τη μετακίνηση των δοντιών κατά τη διάρκεια της ορθοδοντικής θεραπείας. Οι συσχετίσεις που αναφέρθηκαν σε αυτό το άρθρο μπορούν να βοηθήσουν στην πιο ασφαλή πρόβλεψη της βραχυπρόθεσμης ορθοδοντικής υποτροπής, την αξιολόγηση της μακροπρόθεσμης ανάγκης για θεραπεία, καθώς και να οδηγήσουν σε περισσότερο εξατομικευμένα σχήματα συγκράτησης.

Abstract

Aim: The main objective of this research was to measure tooth movement one week post-treatment and assess potential correlation with changes invoked during treatment.

Materials and method: Thirty-eight patients were included in this study (19 males, 19 females). Two Polyvinyl Siloxane impressions were taken after bracket debonding (T1) and one week later (T2), and digitally scanned in 3-dimensions. No retention method was implemented during this period. The digital casts were superimposed on structures of the mucosa of the hard palate. Permanent molars, canines and central incisors were the teeth under study. Translation of the centroid, as well as the rotation of each tooth were documented. Relapse during (T1-T2) period was recorded. Furthermore, each tooth movement from the beginning (T0) until the end of treatment (T1) was assessed. The relapse observed was correlated to tooth movement during treatment. Descriptive statistics were computed. Data were tested for normality of the distribution (Shapiro-Wilk test). Non-parametric statistics were used. Spearman correlation coefficient (r) was used to evaluate correlation in tooth movement between T0-T1 and T1-T2.

Results: The relapse tendency was detectable and reflected changes in tooth position during treatment. Concerning the first molars, relapse was observed in the transverse direction (r=-0.38, P=0.020; r=-0.32, P=0.052 respectively), in tipping (r=-0.40, P=0.015; r=-0.34, P=0.034 respectively), as well as in the anteroposterior direction (r=-0.31, P=0.061; r=-0.36, P=0.027 respectively). For the canines, relapse was reported as rotation around their long axis (r=-0.55, P=0.003; r=-0.58, P=0.002 respectively). Regarding the central incisors, relapse was detected in the anteroposterior direction (r=-0.55, P=0.000; r=-0.48, P=0.03 respectively), transverse direction (r=-0.43, P=0.07; r=-0.32, P=0.047 respectively), and rotation around their long axis (r=-0.53, P=0.001; r=-0.28, P=0.089 respectively).

Furthermore, tipping after treatment was correlated with the anteroposterior tooth movement during treatment (r=-0.38, P=0.017; r=-0.37, P=0.024 respectively).

Conclusion: Immediate relapse one week after bracket removal could be substantially correlated to tooth movement during treatment. The associations reported in this article may help clinicians predict the short-term relapse more safely, evaluate the retention need in the long term, as well as guide them to more individualized retention schemes.

Introduction

There is insufficient evidence in the literature on which to base orthodontic retention protocols, and thus little agreement between clinicians (1). Among the areas that require further investigation are the the in-vitro and in-vivo behaviour of biomaterials and the quantification of individual relapse tendency. Regarding the first research line, the recent advances in medical technology have provided further insights (2). However, contemporary materials do not always ensure that successful treatment results are maintained in the long term. Even with bonded retainers in place, not only does relapse still occur (3) but also some unexpected post-treatment changes that cannot be explained by the pre-treatment malocclusion (4). As far as the second line is concerned, not enough light has been shed so far. Some malocclusions or movement types with high relapse tendency have been recognized (5). However, the relapse tendency may differ inter- and intra-individually and its quantification at a given time may be critical for clinical decision-making, regarding the appropriate retention appliance or cooperation in wearing.

Post-treatment tooth movement inevitably occurs; this is considered to be inherent to a system that has undergone major changes. The hypothesis tested here was that immediate relapse, within one week after bracket removal, is correlated to tooth position changes during orthodontic treatment, and might thus be an early sign of long-term relapse tendency. The main objective of this research was the quantification of the relapse movement of specific teeth short-term after debonding. Furthermore, the relapse tendency was investigated and correlated with tooth movement during treatment.

Materials and methods

The protocol of this research was approved by the Ethics Committee, School of Dentistry, National and Kapodistrian University of Athens. Written informed consent was obtained from all patients before the commencement of this study.

The sample comprised 38 patients (19 males, 19 females; mean age: 12.2, SD: 1.9, range: 7.7 to 17.6 years) treated at the Department of Orthodontics. The following inclusion/exclusion criteria were set:

- age between 7 and 18 years at the beginning of treatment,
- no missing, impacted teeth or other dental anomalies,
- Class I / II molar relationship,
- no congenital anomalies/syndromes,
- space deficiency and irregularity (Little's irregularity index) of no more than 6 mm in the maxillary/mandibular arch (6)
- non-extraction treatment plan with fixed edgewise straightwire appliances
- no orthopaedic appliances
- no patients treated in combination with orthognathic surgery
- Class I molar and canine relationship at the end of treatment with overjet ≤ 2 mm, overbite ≤ 3 mm, no crowding of the upper and lower dental arch and solid interdigitation of the buccal teeth

Mean treatment time was 3.0 years for all patients of our sample (SD: 1.1, range: 1.3 to 5.3 years).

In this research we focused on the maxillary arch because the palate serves as a reliable superimposition area that presents long term stability. Several studies have been

published reporting on the stability of the palatal rugae as reference for comparison of pre-treatment and post-treatment results (7,8,9). In the lower arch similar structures are lacking.

For the evaluation of the relapse tendency during the first week after bracket removal, two Polyvinyl siloxane imprints (Aquasil Ultra LV, Smart Wetting Impression Material, DENTSPLY) were taken, right after debonding (T1), and one week later (T2) at the delivery of the upper Hawley appliance. To assess the type and extent of initial tooth movement during the first week after debonding, the two impressions were scanned using a structured light 3D scanner (Identica, Medit Co., Ltd, Seoul, Korea), and the resulting digital casts were superimposed on structures of the mucosa of the hard palate. Central incisors, canines and first molars (#16,13,11,21,23,26) were the teeth under evaluation.

The palate configuration at the end of treatment (T1) was used as reference. Tooth movement was recorded between T1 and T2, as rotation and position change in all three dimensions of space, as described below. The superimposition mesh consisted of the whole hard palate, posteriorly limited by the line connecting the most distal point of the first molars at the gingiva level, and excluding a 4mm strip along the gingival margin. Since the palate is not expected to change appreciably during a week's period of time, this shape was considered to be appropriate for optimal superimposition. (Figure 1)

Furthermore, total tooth movement from the beginning (T0) until the end of treatment (T1) was also evaluated. Initial digital dental casts of the upper jaw were superimposed with the post treatment digital casts. As the palate may change substantially during treatment, the superimposition area for the T0 to T1 period was delineated anteriorly by the median 2/3 of the third rugae and laterally by two lines parallel to the midpalatal suture, extending posteriorly 5 mm from the third rugae; it also included a 6-mm wide stripe

on the midpalatal suture extending posteriorly to the level of a line connecting the lingual grooves of the 1st permanent molars at the gingival level (10). (Figure 2)

To quantify tooth movement in all three dimensions of space, each tooth in the initial state of each period (T0-T1, T1-T2) was used as reference object. (Figure 3) The X axis described changes in the transverse direction, the Y axis anteroposterior changes, and the Z axis changes in the vertical direction. The positive direction of each axis was set arbitrarily, and is graphically presented in Figure 4. After superimposing the digital casts, the axes of measurement were transferred to the centroid of each single tooth, used as reference (X,Y,Z: 0,0,0). The crowns of each tooth at the initial and final state were superimposed. The total movement of the tooth from the original to the final position was recorded as the translation of the centroid along the three axes, and rotation of the tooth around the axes. Superimpositions were based on the ICP (iterative closest point) algorithm (11). All superimpositions, as well as, the estimation of tooth movements, were performed using Viewbox 4 software (dHal software, Kifissia, Greece).

All statistical analyses were conducted with SPSS software (IBM Corp., NY, USA) and Microsoft Excel (Microsoft Corporation, Washington, USA). Descriptive statistics were computed for all variables. Data were tested for normality of distribution using the Shapiro-Wilk test. Due to multiple deviations from normality and small sample size, non-parametric statistics were used. Spearman correlation coefficient (r) was used to evaluate correlations in tooth position changes between T0-T1 and T1-T2.

Two weeks after the first analysis, eight patients at T1-T2 period, were randomly selected and analysed again by the same examiner. Intra-observer random and systematic error were estimated (12).

Results

Random intra-observer measurement error was 0.029 mm for translation (range: 0.017-0.048 mm) and 0.126 degrees for rotation (range: 0.038-0.222 degrees). No systematic error was detected.

Descriptive statistics of the magnitude of tooth movement during treatment (T0-T1), as well as a week's period of time after bracket removal (T1-T2) are presented in Table I and Table II respectively.

The relapse tendency observed during the T1-T2 period was detectable. Overall, the immediate relapse (T2-T1) did reflect the change in tooth position during treatment (T1-T0). There were certain types of movement for which the correlation in tooth movement followed the expected pattern and was significant at the statistical levels of 0.10 and 0.05.

More specifically, regarding the first right and left molars (#16, 26), relapse (negative correlation) was observed in the transverse direction (XP) (r=-0.38, P=0.020; r=-0.32, P=0.052 respectively), in tipping (XR) (r=-0.40, P=0.015; r=-0.34, P=0.034 respectively), as well as in the anteroposterior direction (YP) (r=-0.31, P=0.061; r=-0.36, P=0.027 respectively). (Figure 5) Torque relapse of the left molar (YR) (r=-0.31, P=0.020), did not appear to the right molar; the latter exhibited weak correlation concerning rotation around its long axis (r=-0.30, P=0.071). Other correlations were found statistically significant at $P<0.05$ for the right first molar, but were not between corresponding variables, i.e. (YP)-(ZR) (r=-0.35), (YR)-(XR) (r=0.33). (Table III)

As far as the canines are concerned (#13,23), relapse was reported as tooth rotation around its long axis (ZR) (r=-0.55, P=0.003; r=-0.58, P=0.002 respectively). (Figure 6) Regarding the right canine several tooth movements during treatment were statistically significantly, related to relapse at the level of $P<0.05$, i.e. anteroposterior position (YP) during treatment with relapse in the transverse direction (XP) and intrusion-extrusion (ZP)

(r=0.44, r=-0.41), as well as (XR)-(ZP) (r=-0.45) (Table VI). However, these correlations are difficult to explain clinically.

Regarding the central incisors (#11,21), relapse was detected in the anteroposterior direction (YP) (r=-0.55, P=0.000; r=-0.48, P=0.03 respectively), transverse direction (XP) (r=-0.43, P=0.07; r=-0.32, P=0.047 respectively), and tooth rotation around the long axis (ZR) (r=-0.53, P=0.001; r=-0.28, P=0.089 respectively). (Figure 7) Furthermore, tipping after treatment (XR) was correlated with the anteroposterior tooth movement during treatment (YP) (r=-0.38, P=0.017; r=-0.37, P=0.024 respectively). Additionally, right central incisor exhibited relapse in tipping (XR) (r=-0.33, P=0.044). Several other correlations, such as (YP)-(YR) (r=0.38) for the right central incisor, as well as (YP)-(XR) (r=0.34) and (YR)-(XR) (r=0.37) for the left central incisor, did not apply to any clinically observed relapse pattern. (Table V) In this study, thirteen patients had a diastema before treatment, and only one patient had pronounced labial frenum, not considered clinically significant. The relapse observed one week after, without the use of retainer was detectable (median: 0.16, SD: 0.24, range: 0.09 to 0.97 mm). However, this relapse was corrected in a short period, following the delivery of the retention appliance.

Discussion

This study had several limitations, mainly related to the superimposition procedure. Although the digital alignment of the T1 and T2 casts was reliable, due to the short time interval between the two records and the large area of superimposition, the T0 to T1 superimposition might suffer from palatal shape changes due to treatment and growth. We opted for the area recommended by Vasilakos et al. (10) as the most reliable and accurate. The digital procedure of measuring the casts and associated tooth movements showed high reproducibility.

A large post-treatment period would be ideal for more reliable evaluation of relapse movements, but it would be unethical to let treatment relapse. We, therefore, limited the observation period to the minimum, as is customarily required for construction of the maxillary retention appliance. However, even with this short observation period, measurable relapse, in some cases clinically detectable was found (Table II). This relapse was corrected in a short period, following the delivery of the retention appliance.

The relapse patterns observed on one side were consistent with the ones found on the other side. Nonetheless, there were some relapse patterns observed solely on one side and not on the other one. This can be mainly attributed to the fact that many patients exhibited differences on the right and the left side to the type and the degree of the malocclusion. It has to be stated at this point that the relapse was mainly guided by changes in tooth position during treatment. As a result, due to the small observation period, some relapse patterns might not be revealed. Correlations on one side existed on the other as well, however, they were weak and not statistically significant.

In this study we decided to evaluate only permanent central incisors, canines and first molars. Molar and canine position, as well as the anteroposterior position of the central incisors are important parameters in assessing dental relapse.

Orthodontists are still unable to reliably predict which patients are at risk of relapse, or the extent of such relapse. Accordingly, all patients should be treated as if they have a high potential to relapse (13,14,15). We had expected that rotation would be the movement most prone to relapse, and this was partially confirmed by the correlation coefficient values, especially for the anterior teeth (central incisors and canines). The tendency of rotated teeth to relapse after treatment following retention is well established. Animal studies have demonstrated that the extent of this relapse may reach 25% during the first 2 months after cessation of rotation movement (16). Early treatment, over-rotation, a long retention period, proper contouring of contact points and surgical procedures have been used to reduce relapse (17).

Retrospective studies have demonstrated that relapse of incisor crowding occurs in approximately half of the sample long term and more frequently in the mandible than in the maxilla (18,19). However, during this short observation period, no crowding relapse was seen. Several associated factors for the increase of incisor crowding have been described, such as severe pre-treatment incisor crowding, arch length deficiency, arch constriction and increased overbite (18), however none of the studied clinical factors (dental cast measurements at pre-treatment and at debonding) seem to be predictive of maxillary crowding relapse long term (19).

In the present sample, relapse was seen to the upper central incisors in the transverse and anteroposterior direction, sometimes resulting in opening of the midline diastema. Stability after maxillary midline diastema closure is traditionally believed to be difficult (20) and a removable retainer is deemed insufficient in these cases. Clinically significant relapse of the upper median diastema occurred in 60% of a sample wearing Hawley appliances (21). However, no pre-treatment predictors of relapse could be established for midline diastema

relapse. The only treatment change associated with diastema relapse was retroclination of the maxillary incisors, with increased tendency of relapse as inclination increased post-treatment (22). Relapse in the anteroposterior direction was observed for the central incisors and was correlated with tipping of the crown, to verify this claim, even in a week's time interval immediately after bracket removal. Regarding the inclination of upper incisors in treated Class II Division 2 cases, there was a mean relapse of 2 degrees 3.5 years post-treatment (23). The amount of relapse was independent of the type of the retention appliance (Hawley type retainer or lingual retainer) (23). In such cases, the inclination of upper and especially lower incisors showed some relapse post-retention. The overbite and the interincisal angle increased significantly post-retention (24).

Weak correlations between treatment changes and degree of relapse have been found only for overbite and inter-premolar distance in the maxilla, where treatment movement correlated with that of the relapse (14). A recent systematic review evaluated potential factors for predicting sagittal stability after orthodontic treatment in patients with Angle Class II malocclusion (25). Large changes during treatment in molar and canine relationships were the only two factors found to be positively associated with relapse, but with limited evidence. In the present study this pattern was verified, since relapse in the transverse direction was observed for the upper first molars, but not for the canines. Several characteristics regarding the pre- and post-treatment occlusion or the patient were found not to be predictive of relapse, however also with limited evidence (25).

The tendency of the expanded arch to relapse after treatment is well established. A long-term follow-up study found that arch width relapsed more frequently in the upper intermolar (25.8%) and lower intercanine region (23.9%) than in the lower intermolar (19.0%) and upper intercanine (13.8%) region (26). Pre-treatment and post-treatment

alignment as well as the kind of treatment and the amount of expansion were found to be influencing factors. Arch width relapse was found to be significantly correlated with an intermolar expansion of 4 mm or more and an intercanine arch width increase of 2.5 mm or more. The indication is overexpansion to be avoided (26).

Short treatment time is associated with higher relapse rate (14). It seems that treatment time may be more important than the extent of therapeutic movements and thus the severity of the malocclusion. A retention effect is established in the course of longer treatment (14). In the present study mean treatment time was approximately 3.0 years.

This attempt, to correlate the relapse movement of specific teeth short term after debonding with tooth movement during treatment three dimensionally, is part of a bigger project conducted in our Department. Further research will focus on the possible correlation of these short-term tooth movements with the long-term movement patterns. Predictors or associations may help clinicians to choose the appropriate retention scheme and determine the long-term prognosis of dental stability.

More specifically, certain movements proved to be more prone to relapse, and were associated to the initial tooth position. As a result, short term relapse, immediately after bracket removal, could be a predictor, leading to individualized retention schemes.

Furthermore, since there is no consensus among clinicians about the duration of the post-retention period, the degree of the micro-movements recorded long-term could be an indication about how strict the retention protocol followed should be. In case that significant relapse is seen, retention should be firmly continued. Otherwise, that may not be necessary.

Conclusions

- Immediate relapse one week after bracket removal could be substantially correlated to tooth movement during treatment.
- Short-term micro-movements after bracket removal may be correlated to long-term post-treatment relapse, thus providing the clinicians predictors for individualised retention protocols.

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FIGURES

Figure legends

Figure 1. The superimposition mesh for (T0-T1) period.

Figure 2. The superimposition mesh for (T1-T2) period.

Figure 3. Digital cast superimposition for (a) T0-T1 and (b) T1-T2 period, with colour map of the superimposition mesh. Green: T0 period, Grey: T1 period, Blue: T2 period.

Figure 4. Axes of the reference system. Vectors point in the positive direction.

Figure 5. Main relapse patterns of first molars (#16,26). Plots and graphics are indicative and depict correlation between corresponding variables pre- and post-treatment. Green: T0 period, Grey: T1 period, Blue: T2 period. The horizontal axis depicts changes during the post-treatment period (T1-T2), whereas the vertical axis changes invoked during orthodontic treatment (T0-T1).

Figure 6. Main relapse patterns of canines (#13,23). Plots and graphics are indicative and depict correlation between corresponding variables pre- and post-treatment. Green: T0 period, Grey: T1 period, Blue: T2 period. The horizontal axis depicts changes during the post-treatment period (T1-T2), whereas the vertical axis changes invoked during orthodontic treatment (T0-T1).

Figure 7. Main relapse patterns of central incisors (#11,21). Plots and graphics are indicative and depict correlation between corresponding variables pre- and post-treatment. Green: T0 period, Grey: T1 period, Blue: T2 period. The horizontal axis depicts changes during the post-treatment period (T1-T2), whereas the vertical axis changes invoked during orthodontic treatment (T0-T1).

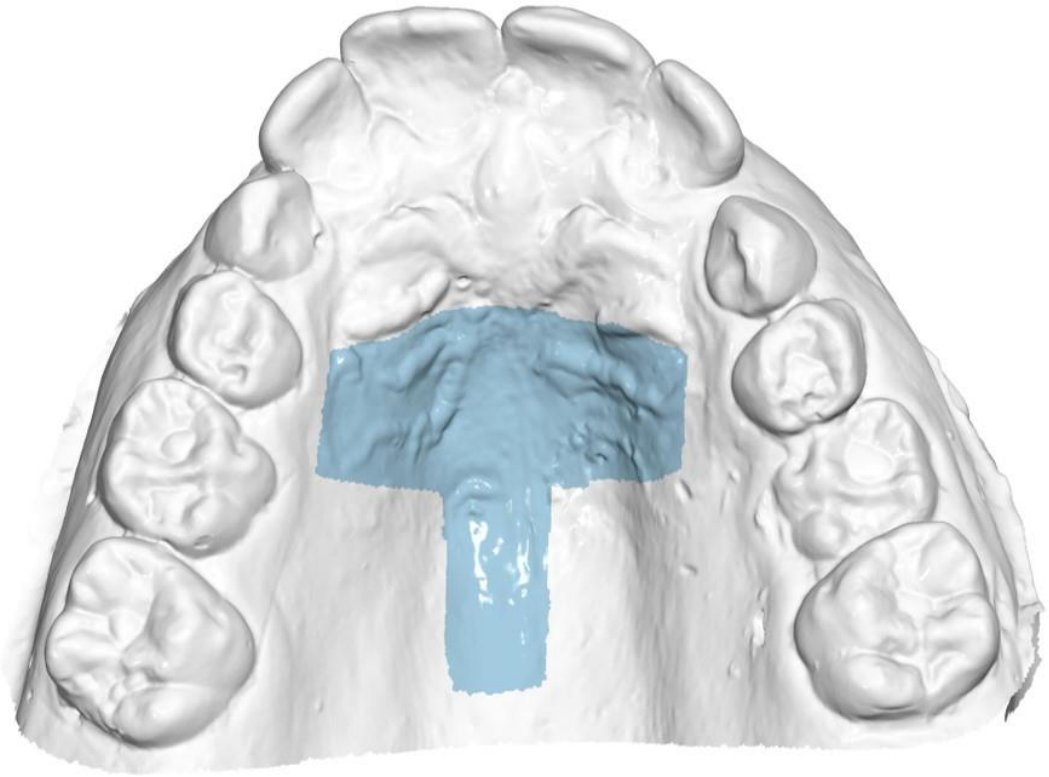


Figure 1. The superimposition mesh for (T0-T1) period.

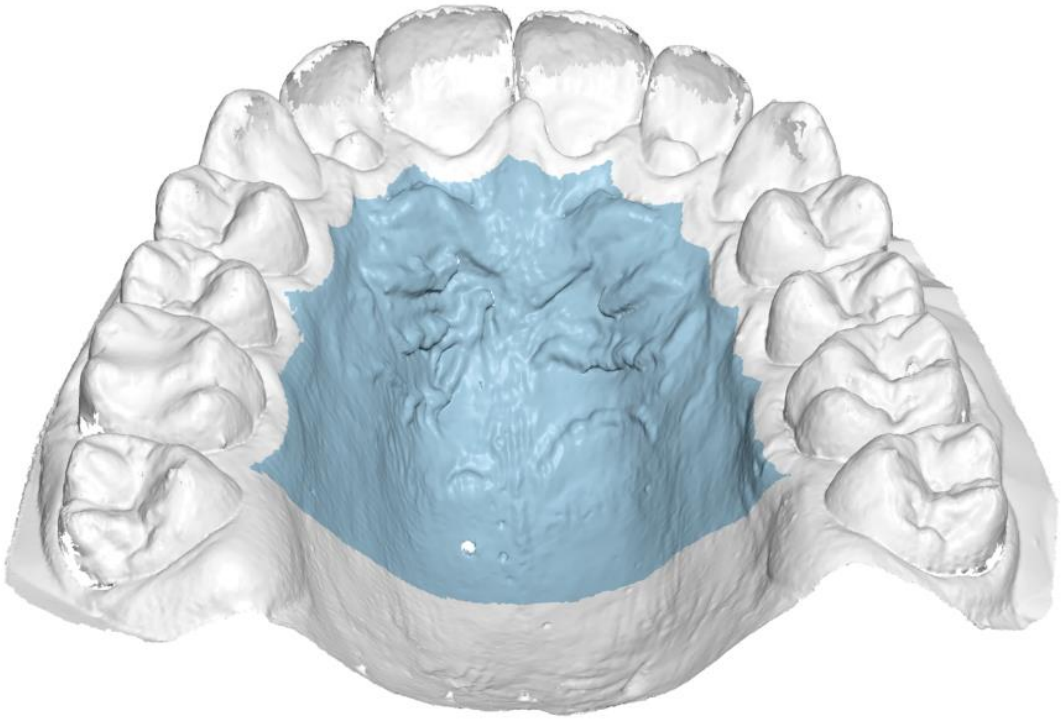
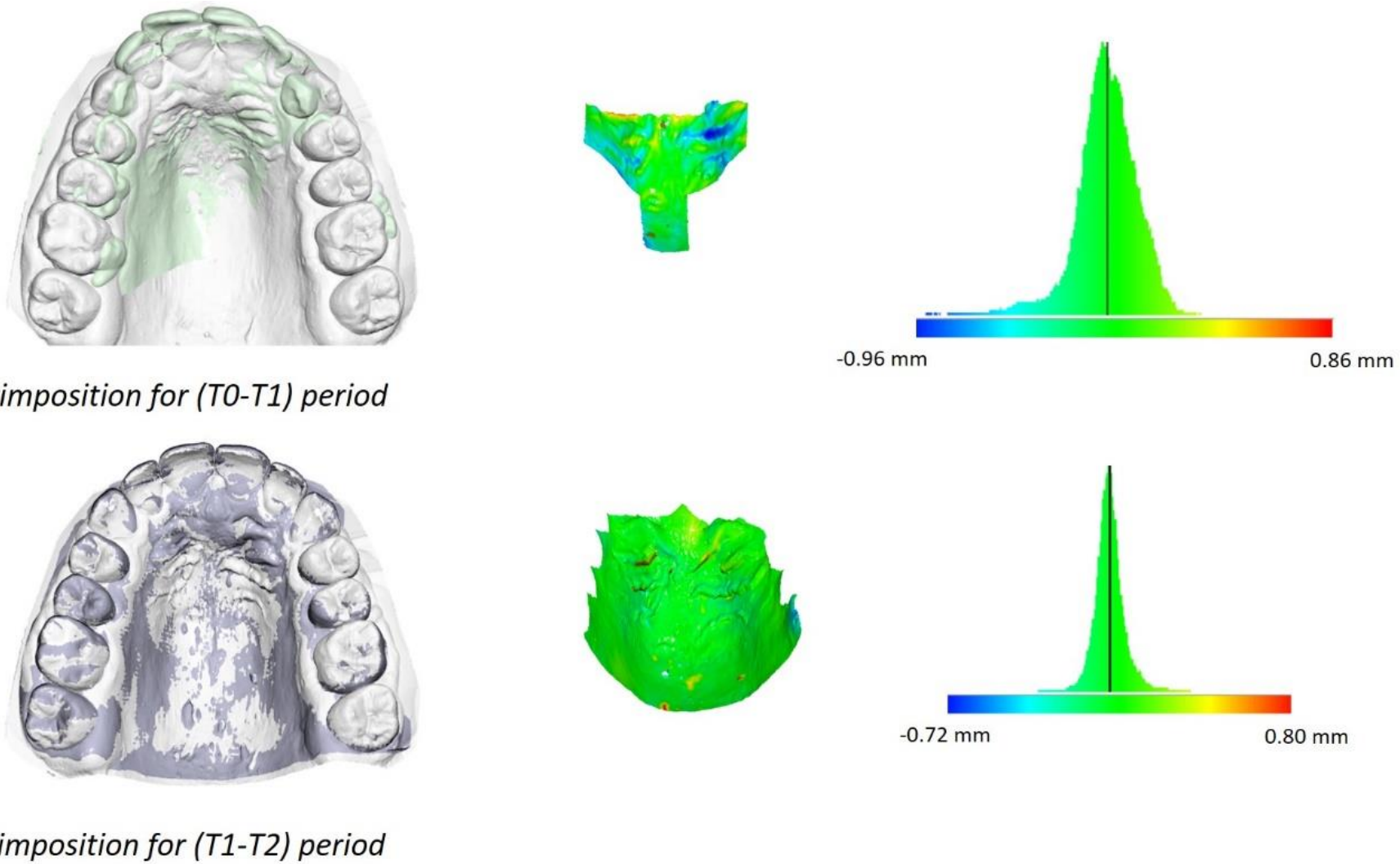


Figure 2. The superimposition mesh for (T1-T2) period.



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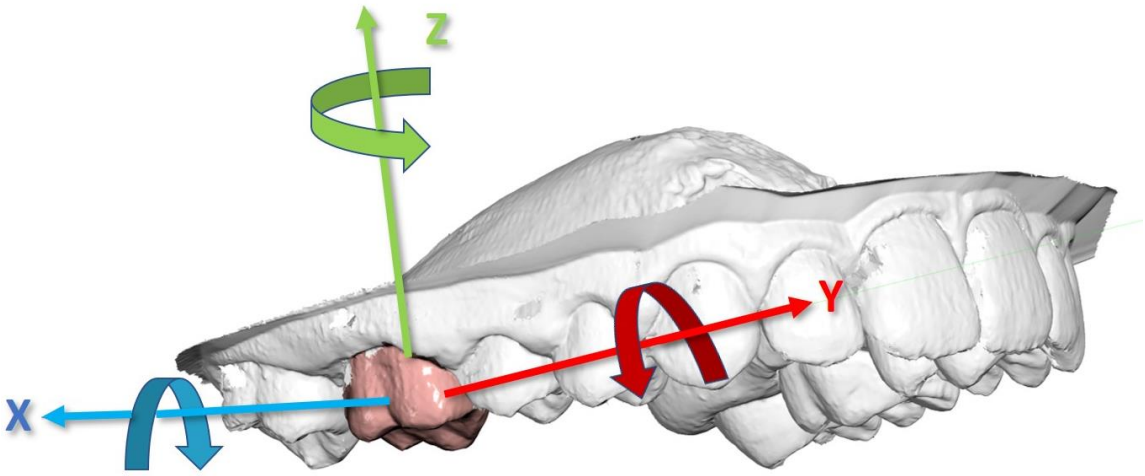

Figure 4. Axes of the reference system. Vectors point in the positive direction.

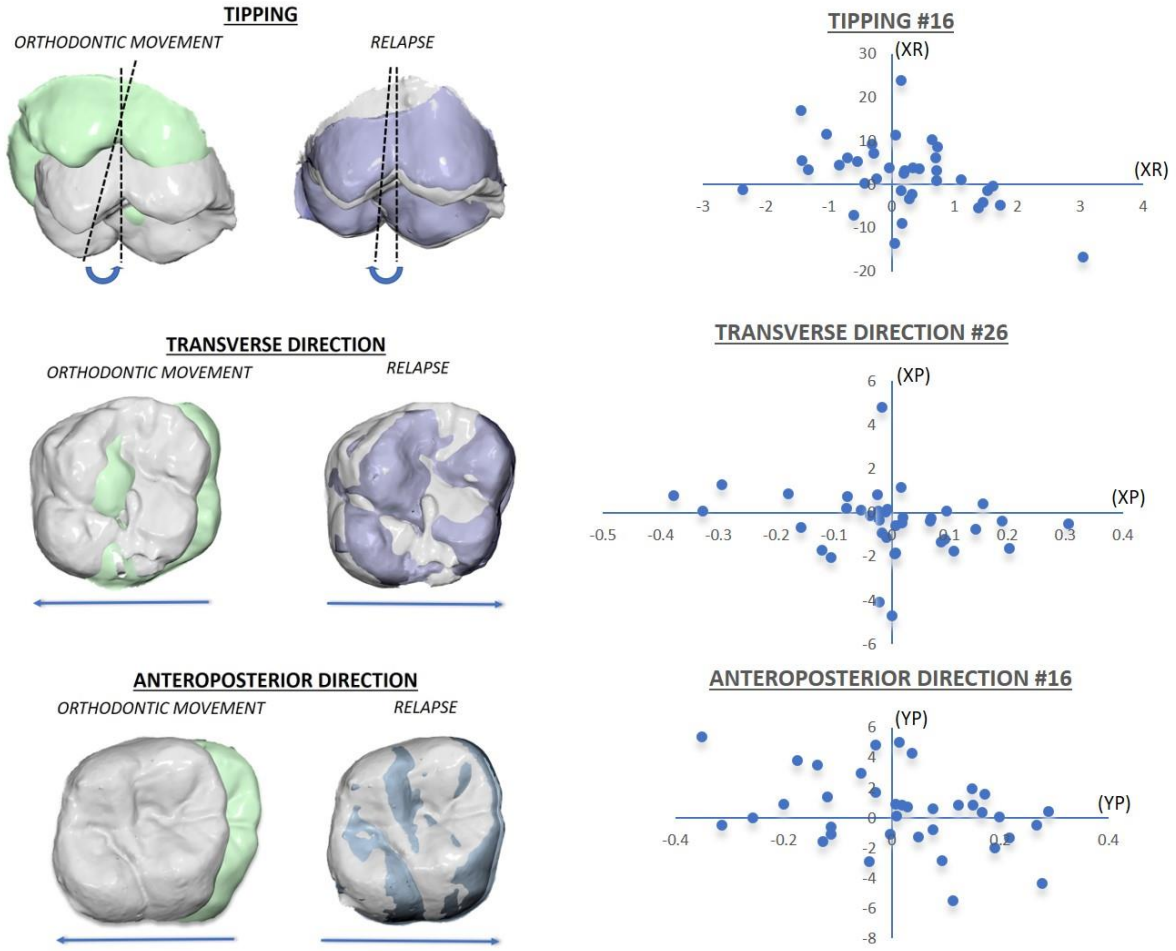

Figure 5. Main relapse patterns of first molars (#16,26). Plots and graphics are indicative and depict correlation between corresponding variables pre- and post-treatment. Green: T0 period, Grey: T1 period, Blue: T2 period. The horizontal axis depicts changes during the post-treatment period (T1-T2), whereas the vertical axis changes invoked during orthodontic treatment (T0-T1).

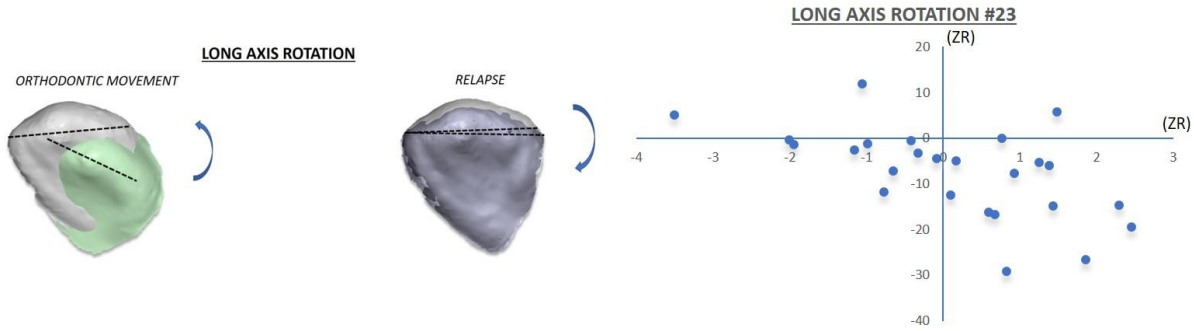

Figure 6. Main relapse patterns of canines (#13,23). Plots and graphics are indicative and depict correlation between corresponding variables pre- and post-treatment. Green: T0 period, Grey: T1 period, Blue: T2 period. The horizontal axis depicts changes during the post-treatment period (T1-T2), whereas the vertical axis changes invoked during orthodontic treatment (T0-T1).

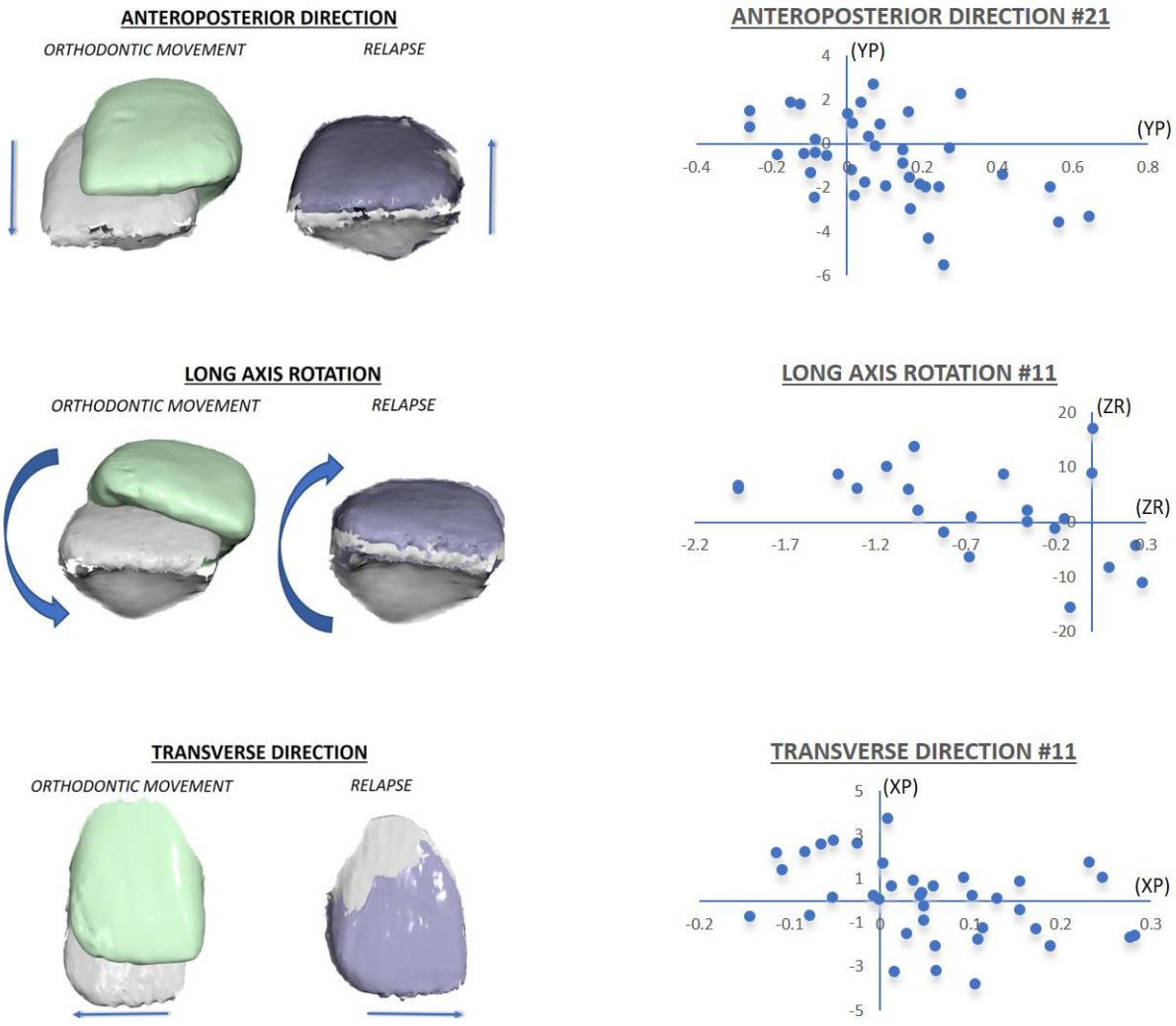

Figure 7. Main relapse patterns of central incisors (#11,21). Plots and graphics are indicative and depict correlation between corresponding variables pre- and post-treatment. Green: T0 period, Grey: T1 period, Blue: T2 period. The horizontal axis depicts changes during the post-treatment period (T1-T2), whereas the vertical axis changes invoked during orthodontic treatment (T0-T1).

TABLES

Table legends

Table I. Descriptive statistics of the magnitude of tooth movement (absolute values) during treatment (T0-T1). Position and rotation changes were measured in millimetres and degrees respectively. P: position; R: rotation.

Table II. Descriptive statistics of the magnitude of tooth movement (absolute values) one week after bracket debonding (T1-T2). Position and rotation changes were measured in millimetres and degrees respectively. P: position; R: rotation.

Table III. Spearman correlation coefficient (r) for the first molars (# 16, 26). P: position changes; R: rotation changes. Figures in bold are discussed in the text.

Table IV. Spearman correlation coefficient (r) for the canines (# 13, 23). P: position changes; R: rotation changes. Figures in bold are discussed in the text.

Table V. Spearman correlation coefficient (r) for the central incisor (# 11, 21). P: position changes; R: rotation changes. Figures in bold are discussed in the text.

Table I. Descriptive statistics of the magnitude of tooth movement (absolute values) during treatment (T0-T1). Position and rotation changes were measured in millimetres and degrees respectively. P: position; R: rotation.

T0-T1	16 X P	16 Y P	16 Z P	16 X R	16 Y R	16 Z R	26 X P	26 Y P	26 Z P	26 X R	26 Y R	26 Z R
25% quartile	0.34	0.69	0.78	2.46	1.40	3.03	0.25	0.54	0.45	2.32	1.49	1.61
50% quartile	0.62	1.27	1.58	4.34	4.35	6.81	0.76	1.41	1.75	4.34	2.76	4.07
75% quartile	1.01	2.92	3.09	8.84	7.23	12.58	1.41	2.15	3.25	9.01	6.76	9.16
maximum	3.88	5.50	5.95	23.90	13.78	25.62	4.80	4.79	7.24	24.45	11.80	19.31
	13 X P	13 Y P	13 Z P	13 X R	13 Y R	13 Z R	23 X P	23 Y P	23 Z P	23 X R	23 Y R	23 Z R
25% quartile	0.40	0.50	0.44	3.96	1.07	3.46	0.49	0.51	0.69	1.96	1.77	2.90
50% quartile	0.75	1.45	1.77	7.05	4.30	6.89	0.89	1.11	1.61	3.82	3.68	6.04
75% quartile	1.65	2.37	2.85	8.99	8.52	15.17	1.68	1.59	2.66	8.02	7.96	14.77
maximum	3.00	4.78	8.06	13.93	31.02	30.19	4.72	4.26	5.35	14.33	13.99	29.21
	11 X P	11 Y P	11 Z P	11 X R	11 Y R	11 Z R	21 X P	21 Y P	21 Z P	21 X R	21 Y R	21 Z R
25% quartile	0.58	0.82	1.10	4.29	2.23	2.10	0.45	0.72	0.66	4.09	1.23	1.47
50% quartile	1.23	2.00	2.33	9.31	4.13	6.45	1.00	1.53	1.97	8.00	3.69	5.48
75% quartile	2.10	2.52	3.07	16.23	7.62	9.24	2.45	2.05	3.46	15.23	5.82	10.34
maximum	3.79	3.77	6.32	43.52	16.01	17.03	3.56	5.52	6.00	38.85	14.00	23.73

Table II. Descriptive statistics of the magnitude of tooth movement (absolute values) one week after bracket debonding (T1-T2). Position and rotation changes were measured in millimetres and degrees respectively. P: position; R: rotation.

T1-T2	16 X P	16 Y P	16 Z P	16 X R	16 Y R	16 Z R	26 X P	26 Y P	26 Z P	26 X R	26 Y R	26 Z R
25% quartile	0.04	0.04	0.05	0.26	0.18	0.12	0.02	0.03	0.07	0.23	0.16	0.17
50% quartile	0.09	0.12	0.11	0.64	0.49	0.35	0.07	0.08	0.15	0.68	0.37	0.27
75% quartile	0.14	0.19	0.24	1.35	0.87	0.76	0.15	0.23	0.23	1.07	0.72	0.47
maximum	0.36	0.35	0.57	3.04	2.03	2.60	0.38	0.51	0.70	2.82	2.95	2.70
	13 X P	13 Y P	13 Z P	13 X R	13 Y R	13 Z R	23 X P	23 Y P	23 Z P	23 X R	23 Y R	23 Z R
25% quartile	0.04	0.06	0.05	0.27	0.30	0.26	0.04	0.05	0.04	0.29	0.26	0.56
50% quartile	0.08	0.12	0.12	0.54	0.73	0.68	0.08	0.08	0.09	0.61	0.64	0.96
75% quartile	0.16	0.21	0.20	1.06	1.05	1.50	0.15	0.16	0.18	1.07	1.15	1.63
maximum	0.36	0.39	1.03	2.65	2.40	3.13	0.26	0.58	0.68	2.45	2.69	3.51
	11 X P	11 Y P	11 Z P	11 X R	11 Y R	11 Z R	21 X P	21 Y P	21 Z P	21 X R	21 Y R	21 Z R
25% quartile	0.04	0.08	0.04	0.25	0.29	0.36	0.04	0.07	0.04	0.37	0.23	0.24
50% quartile	0.07	0.14	0.14	0.51	0.61	0.68	0.07	0.15	0.10	0.80	0.43	0.58
75% quartile	0.13	0.26	0.21	1.28	0.96	1.31	0.15	0.25	0.21	1.25	0.70	0.83
maximum	0.28	0.51	1.57	3.78	4.45	1.96	1.28	0.64	1.62	4.51	1.95	2.75

Table III. Spearman correlation coefficient (r) for the first molars (# 16, 26). P: position changes; R: rotation changes. Figures in bold are discussed in the text.

				T1-T2			
		16 X P	16 Y P	16 Z P	16 X R	16 Y R	16 Z R
	16 X P	**-0.381**†	-0.060	0.009	-0.190	0.121	-0.056
	16 Y P	-0.047	**-0.311***	0.012	-0.075	0.123	-0.030
	16 Z P	0.086	-0.077	-0.155	0.037	-0.138	0.111
	16 X R	-0.197	-0.277*	-0.155	**-0.397**†	0.330†	-0.278*
	16 Y R	0.178	-0.229	0.104	-0.114	-0.017	-0.023
	16 Z R	-0.041	-0.349†	-0.198	-0.160	0.052	**-0.300***
T0-T1		26 X P	26 Y P	26 Z P	26 X R	26 Y R	26 Z R
	26 X P	**-0.318***	0.038	-0.091	0.040	0.196	0.019
	26 Y P	-0.031	**-0.358***	-0.032	-0.158	0.010	-0.182
	26 Z P	-0.304*	0.139	-0.241	0.274*	0.068	-0.239
	26 X R	0.269	-0.216	0.103	**-0.344**†	-0.088	-0.145
	26 Y R	-0.044	0.327*	-0.173	0.110	**-0.377**†	-0.032
	26 Z R	-0.175	0.153	0.126	0.153	0.190	-0.098

‡ significant at 0.01 level, †significant at 0.05 level, * significant at 0.10 level

Table IV. Spearman correlation coefficient (r) for the canines (# 13, 23). P: position changes; R: rotation changes. Figures in bold are discussed in the text.

				T1-T2			
		13 X P	13 Y P	13 Z P	13 X R	13 Y R	13 Z R
	13 X P	-0.001	0.440†	0.199	0.309	-0.032	0.003
	13 Y P	0.065	-0.254	-0.188	0.019	0.299	0.177
	13 Z P	-0.287	-0.412†	-0.317	-0.448†	-0.071	-0.024
	13 X R	-0.207	-0.226	-0.266	**-0.496‡**	-0.077	0.003
	13 Y R	-0.048	-0.094	-0.115	-0.342*	-0.223	0.255
	13 Z R	0.114	0.207	0.366*	0.187	-0.273	**-0.547***
T0-T1		23 X P	23 Y P	23 Z P	23 X R	23 Y R	23 Z R
	23 X P	-0.292	-0.110	0.125	-0.228	0.058	-0.117
	23 Y P	0.010	-0.200	-0.178	-0.084	-0.225	-0.242
	23 Z P	0.318	-0.042	0.046	-0.217	-0.005	0.078
	23 X R	0.133	0.232	0.075	0.093	0.141	-0.131
	23 Y R	0.078	0.145	-0.076	-0.206	0.061	0.295
	23 Z R	0.132	-0.121	0.175	0.335	-0.145	**-0.582‡**

‡ significant at 0.01 level, †significant at 0.05 level, * significant at 0.10 level

Table V. Spearman correlation coefficient (r) for the central incisor (# 11, 21). P: position changes; R: rotation changes. Figures in bold are discussed in the text.

		T1-T2					
		11 X P	11 Y P	11 Z P	11 X R	11 Y R	11 Z R
T0-T1	11 X P	**-0.432‡**	0.019	0.281	0.253	-0.137	0.099
	11 Y P	0.109	**-0.549‡**	0.132	**-0.384†**	0.224	0.091
	11 Z P	0.099	-0.282*	-0.182	-0.262	0.062	-0.117
	11 X R	0.108	-0.291*	-0.092	**-0.329†**	0.142	0.093
	11 Y R	0.048	0.376†	0.053	0.151	-0.208	0.224
	11 Z R	0.127	-0.030	-0.079	-0.001	-0.012	**-0.525‡**
		21 X P	21 Y P	21 Z P	21 X R	21 Y R	21 Z R
	21 X P	**-0.324†**	0.190	-0.001	0.039	0.055	0.196
	21 Y P	0.208	**-0.475‡**	-0.127	**-0.365†**	0.061	0.116
	21 Z P	-0.001	-0.139	-0.102	-0.084	0.248	-0.197
	21 X R	0.294*	-0.338†	-0.207	-0.192	0.371†	-0.069
	21 Y R	-0.059	0.130	-0.046	-0.053	0.045	0.293*
	21 Z R	0.117	-0.065	0.045	0.076	0.059	**-0.280***

‡ significant at 0.01 level, †significant at 0.05 level, * significant at 0.10 level

APPENDIX

Right first molar movement (#16) in three-dimensions of space (X,Y,Z) during the orthodontic treatment period (T0-T1). P: position variables (mm), R: rotation variables (°), NA: not available data due to not erupted tooth

T0-T1	16 X P	16 Y P	16 Z P	16 X R	16 Y R	16 Z R
1	0.114	1.967	-2.104	2.883	-2.304	4.954
2	-0.135	-0.017	-1.164	1.172	6.130	5.994
3	0.312	0.837	1.154	1.459	3.207	-7.261
4	3.879	3.509	0.886	5.305	-8.984	-9.913
5	1.102	0.410	-1.855	2.196	2.607	2.539
6	-0.031	0.043	1.041	1.042	1.310	-1.425
7	-0.952	0.355	-3.203	3.360	6.143	5.005
8	-0.914	-1.323	-0.395	1.656	-16.830	4.713
9	-0.949	-4.331	-1.469	4.671	1.056	-1.381
10	-0.423	-1.981	1.261	2.386	-0.490	-3.696
11	1.474	-0.753	-3.120	3.532	3.394	2.518
12	-0.445	0.752	-1.778	1.981	-4.793	11.934
13	-0.334	3.807	-3.057	4.894	4.340	9.285
14	2.051	0.847	-3.875	4.466	11.275	-2.832
15	-0.351	0.867	-0.668	1.149	0.217	0.257
16	-0.238	-0.461	0.547	0.754	-1.413	-0.265
17	-0.949	-5.501	4.064	6.905	-13.667	-3.298
18	-1.668	4.294	-0.462	4.630	5.180	7.189
19	-0.315	1.403	-3.413	3.703	23.895	5.320
20	1.105	-0.508	-5.950	6.073	8.697	11.775
21	-0.331	0.921	-0.947	1.362	0.763	5.889
22	-0.624	-1.068	-4.248	4.424	5.526	10.876
23	1.067	-0.604	-0.671	1.398	11.497	13.776
24	0.317	-1.273	-0.479	1.397	-1.328	0.217
25	-0.352	1.555	-4.024	4.328	-5.339	-0.841
26	0.893	0.100	0.159	0.913	7.240	-0.094
27	0.483	-2.828	-1.101	3.073	-7.100	-1.067
28	-0.901	1.683	-3.266	3.782	-4.205	8.908
29	-0.618	5.373	-2.390	17.711	16.886	4.349
30	0.796	4.858	-1.575	5.168	10.236	-3.700
31	-0.916	5.037	-1.227	5.265	9.175	6.813
32	-1.549	0.884	-0.284	1.806	3.487	10.269
33	-0.617	0.619	-2.672	2.811	-1.364	2.736
34	0.791	2.947	-2.861	4.183	-3.429	0.233
35	-0.572	-2.896	-3.016	4.220	3.819	5.383
36	NA	NA	NA	NA	NA	NA
37	0.365	-1.567	2.044	2.601	3.096	-1.708
38	2.610	-1.054	0.300	2.831	3.753	0.163

Right canine movement (#13) in three-dimensions of space (X,Y,Z) during the orthodontic treatment period (T0-T1). P: position variables (mm), R: rotation variables (º), NA: not available data due to not erupted tooth

T0-T1	13 X P	13 Y P	13 Z P	13 X R	13 Y R	13 Z R
1	0.177	2.274	-2.968	-8.989	-19.146	15.239
2	-0.713	0.193	-2.040	-4.069	6.480	-3.346
3	NA	NA	NA	NA	NA	NA
4	0.727	1.926	-1.697	2.100	-8.797	2.432
5	NA	NA	NA	NA	NA	NA
6	-0.460	-0.502	-2.213	0.582	9.636	-7.997
7	NA	NA	NA	NA	NA	NA
8	1.318	-1.509	-4.742	-6.357	-1.518	-2.384
9	1.345	-4.777	-0.553	5.476	0.704	14.975
10	0.622	-1.784	-1.746	-4.664	-0.185	5.322
11	NA	NA	NA	NA	NA	NA
12	1.937	0.223	-2.943	-2.009	7.695	-1.572
13	-0.397	2.622	-0.101	3.924	-0.004	-6.135
14	-0.257	-0.262	-0.376	3.536	0.996	3.815
15	-0.408	0.762	0.163	9.803	3.674	-19.991
16	0.210	-0.469	-0.013	-0.982	0.211	-0.266
17	NA	NA	NA	NA	NA	NA
18	-0.996	4.025	2.565	13.933	7.198	2.787
19	NA	NA	NA	NA	NA	NA
20	NA	NA	NA	NA	NA	NA
21	0.252	0.227	-1.101	-3.116	-2.737	6.172
22	0.035	-2.035	-8.063	-7.876	7.552	-20.065
23	2.961	-1.394	1.716	8.017	4.918	-15.244
24	1.690	-1.692	-2.021	-7.420	-3.107	-14.272
25	-0.152	-0.139	-5.446	-6.339	1.315	7.308
26	0.543	-1.086	-0.105	-13.577	-11.351	22.353
27	-1.541	-1.957	-4.960	-11.006	31.022	-22.514
28	NA	NA	NA	NA	NA	NA
29	NA	NA	NA	NA	NA	NA
30	-0.872	3.336	-0.757	8.161	-4.992	9.137
31	-1.210	3.116	0.398	6.674	-10.025	6.374
32	-0.783	0.506	-2.318	-11.616	-9.946	30.192
33	1.839	-0.594	-3.956	-9.064	-6.075	6.310
34	NA	NA	NA	NA	NA	NA
35	3.000	-4.154	-2.446	-8.991	-1.928	-9.916
36	0.446	-0.830	0.055	8.129	-0.426	6.469
37	1.776	-1.042	1.786	5.152	-0.345	-2.837
38	-1.851	-2.397	1.532	8.904	1.297	8.453

Right central incisor (#11) movement in three-dimensions of space (X,Y,Z) during the orthodontic treatment period (T0-T1). P: position variables (mm), R: rotation variables (°),

T0-T1	11 X P	11 Y P	11 Z P	11 X R	11 Y R	11 Z R
1	-1.642	0.195	0.485	15.573	-4.840	2.344
2	-0.398	2.344	3.102	20.661	1.805	-1.125
3	-1.505	-2.338	2.991	-12.308	-9.335	8.912
4	0.134	2.054	-2.073	30.893	-16.012	-10.910
5	0.084	-2.485	-2.451	-1.966	11.946	-10.673
6	0.949	1.021	-0.869	9.609	-9.714	-8.272
7	2.257	-1.119	1.794	12.144	-1.002	-5.003
8	0.890	-2.285	-3.064	-6.531	2.605	-15.061
9	2.192	-1.971	2.799	18.211	2.370	-11.378
10	-1.218	-0.942	-2.352	5.044	7.308	-8.624
11	1.769	-3.757	-3.056	-16.265	-3.132	8.703
12	1.698	-2.033	-4.531	-21.515	6.639	-1.810
13	-0.708	-2.117	-2.302	-16.219	-5.521	3.368
14	-1.557	-3.094	1.688	-1.524	3.029	8.693
15	0.663	0.660	1.181	15.603	-5.346	-1.240
16	0.367	-0.553	-0.368	-0.829	-0.344	0.586
17	3.754	0.501	-2.840	-3.789	11.269	-15.527
18	-1.248	1.885	3.594	1.603	4.323	-0.907
19	-0.888	2.628	6.323	43.516	-6.367	0.792
20	2.739	-2.890	-0.658	-6.868	1.664	-6.283
21	0.241	-0.288	-1.222	-1.436	1.061	1.034
22	0.248	1.034	-1.728	9.394	0.268	-4.246
23	2.589	-2.324	4.824	23.937	-11.337	6.095
24	0.167	0.444	0.034	4.460	-3.933	6.069
25	-0.241	-1.722	-4.242	-9.221	0.929	8.346
26	0.661	-0.443	0.185	9.140	-6.901	2.195
27	-0.644	0.537	-0.331	5.801	-3.709	6.611
28	1.077	0.877	-1.577	19.612	0.690	-7.535
29	-3.189	-3.314	-3.056	-9.514	5.052	10.225
30	-3.230	0.315	0.261	5.562	-5.585	-1.802
31	-2.067	2.697	2.135	27.551	-10.166	0.146
32	-1.742	-1.142	-2.102	0.131	12.861	6.621
33	1.423	-1.587	-4.113	-10.924	-2.758	17.027
34	-3.785	2.257	-4.217	-4.666	-3.065	13.728
35	2.612	-3.665	-3.404	-12.025	1.774	-13.684
36	0.259	-3.191	2.618	2.342	-3.517	6.168
37	1.068	-2.329	0.329	-3.758	-8.567	2.226
38	-2.047	-3.765	2.751	4.812	3.608	-7.459

Left central incisor (#21) movement in three-dimensions of space (X,Y,Z) during the orthodontic treatment period (T0-T1). P: position variables (mm), R: rotation variables (°)

T0-T1	21 X P	21 Y P	21 Z P	21 X R	21 Y R	21 Z R
1	-1.626	-0.429	0.032	13.996	-0.466	-3.468
2	-0.124	1.828	2.728	22.420	-4.507	8.853
3	1.568	2.725	-2.647	15.251	1.960	-1.079
4	0.177	0.950	3.628	-5.798	-1.411	-5.109
5	0.275	-1.848	-1.928	-0.564	4.606	-9.568
6	1.601	1.507	-1.868	13.865	-2.453	-0.902
7	2.440	-0.546	1.578	12.509	2.552	-0.592
8	2.552	-1.393	-2.674	-5.576	-0.667	1.725
9	2.897	-1.724	2.670	11.160	-7.550	5.370
10	-0.604	-1.178	-2.536	-1.191	-5.396	14.848
11	2.625	-1.940	-2.020	-1.559	3.729	-10.504
12	2.499	-1.294	-3.981	-24.038	1.204	-15.991
13	-0.226	-2.416	-3.410	-17.270	-2.323	-0.828
14	-0.849	-3.306	1.817	-0.517	-3.947	3.284
15	0.675	1.473	1.138	22.418	1.932	-3.309
16	0.411	-0.467	-0.474	-1.126	-1.039	-0.316
17	3.207	2.270	-1.809	-7.346	-14.003	15.558
18	-0.507	1.893	3.286	5.878	-5.843	19.596
19	-0.448	1.912	5.995	38.850	1.237	5.918
20	3.556	-1.948	-0.397	-7.330	5.267	-2.402
21	0.348	-0.405	-1.074	-2.484	0.509	2.875
22	0.453	0.919	-1.797	4.123	4.399	-1.600
23	2.097	-2.331	4.261	24.247	6.638	-9.736
24	0.189	0.202	-0.603	8.652	-7.752	11.042
25	-0.059	-1.970	-3.838	-5.068	-0.631	-7.294
26	1.068	-0.080	-0.522	10.049	-5.597	-0.949
27	-0.843	0.325	-0.559	9.596	1.450	0.700
28	1.526	-0.261	-1.678	-11.678	9.988	-23.727
29	-1.936	-5.519	-4.167	-16.967	-12.210	22.210
30	-2.777	-0.175	-0.357	6.914	-5.727	6.213
31	-2.117	0.785	0.673	19.101	-6.342	9.195
32	0.537	-0.877	-0.364	4.838	1.367	-4.302
33	2.097	-1.545	-3.870	-14.573	-0.492	-10.792
34	-0.469	1.368	-5.375	-0.839	-3.642	-9.153
35	2.773	-2.946	-4.421	-15.224	-7.651	0.718
36	0.542	-3.549	2.055	2.723	0.495	-0.357
37	0.935	-1.906	0.158	-3.975	5.812	-5.593
38	-2.936	-4.292	2.782	4.845	-0.976	10.279

Left canine (#23) movement in three-dimensions of space (X,Y,Z) during the orthodontic treatment period (T0-T1). P: position variables (mm), R: rotation variables (º), NA: not available data due to not erupted tooth

T0-T1	23 X P	23 Y P	23 Z P	23 X R	23 Y R	23 Z R
1	NA	NA	NA	NA	NA	NA
2	-0.491	1.553	-0.113	0.397	9.053	-26.670
3	NA	NA	NA	NA	NA	NA
4	-1.704	0.555	-2.411	2.784	2.363	-0.319
5	NA	NA	NA	NA	NA	NA
6	NA	NA	NA	NA	NA	NA
7	NA	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA	NA
9	1.637	-0.836	0.303	13.804	-1.085	-29.212
10	-2.497	-1.536	-0.913	3.822	8.761	-16.131
11	NA	NA	NA	NA	NA	NA
12	0.814	1.501	-1.579	-9.816	2.738	-5.369
13	-0.942	0.583	-1.612	-0.131	5.897	-6.042
14	-1.563	-1.851	-0.022	13.247	-1.478	-1.294
15	NA	NA	NA	NA	NA	NA
16	0.315	-0.456	-0.279	-1.064	-0.779	-0.502
17	NA	NA	NA	NA	NA	NA
18	0.499	0.190	2.688	-5.909	0.567	-1.319
19	0.054	1.109	2.199	8.095	-3.296	11.912
20	NA	NA	NA	NA	NA	NA
21	-1.787	1.181	-1.307	3.150	13.630	5.703
22	0.107	1.635	-2.923	1.950	2.985	-7.198
23	0.992	-2.054	0.989	-5.587	1.639	-16.736
24	-0.889	0.168	-0.836	1.978	1.905	4.997
25	-0.229	-0.647	-4.166	-8.135	-3.681	-5.057
26	4.724	4.003	-1.782	-3.635	12.944	-3.245
27	0.288	-2.374	-1.965	-7.914	-2.066	-19.418
28	NA	NA	NA	NA	NA	NA
29	NA	NA	NA	NA	NA	NA
30	-3.351	0.798	-2.410	7.944	-6.913	-0.045
31	-1.073	-0.404	-2.739	5.330	-7.162	-4.459
32	0.486	0.436	-0.545	-3.955	9.404	-11.778
33	0.605	1.337	-2.641	-2.504	1.146	-2.545
34	NA	NA	NA	NA	NA	NA
35	1.647	-0.793	-5.351	-14.329	-5.395	-12.424
36	0.493	-1.405	-1.343	0.516	4.230	-14.852
37	-0.506	-0.475	0.410	-3.647	4.881	-7.680
38	-1.978	-4.259	3.028	1.858	13.986	-14.694

Left first molar (#26) movement in three-dimensions of space (X,Y,Z) during the orthodontic treatment period (T0-T1). P: position variables (mm), R: rotation variables (°)

T0-T1	26 X P	26 Y P	26 Z P	26 X R	26 Y R	26 Z R
1	-1.343	-0.638	-4.394	-2.319	-4.752	-1.955
2	0.181	1.520	-1.881	3.678	-4.494	-2.805
3	0.835	-2.010	-0.484	-0.642	3.097	-1.221
4	-0.154	0.789	0.405	-14.986	2.047	19.306
5	0.757	0.961	-3.485	-6.100	-11.801	7.378
6	-1.617	2.097	-1.812	3.439	-8.216	1.529
7	0.018	3.177	-3.110	5.249	0.727	2.035
8	-0.401	-0.402	-1.417	-8.730	-1.054	0.177
9	-1.885	1.462	-1.957	2.607	3.909	1.446
10	-0.347	-2.037	-0.015	-2.764	3.643	5.878
11	-4.071	4.205	-2.874	7.138	7.396	-4.206
12	1.275	1.963	-0.620	-6.751	-10.863	11.514
13	0.882	1.118	-3.209	-3.522	-2.652	3.564
14	0.147	-1.922	-3.762	13.778	-2.791	0.651
15	-0.500	0.170	-0.355	2.611	2.173	0.224
16	0.073	-0.212	0.301	-1.375	0.459	-0.295
17	-0.661	0.060	5.977	-12.259	2.394	-10.215
18	4.800	-0.102	-0.007	-0.162	2.454	13.202
19	0.418	1.735	-4.219	24.455	-1.059	-1.041
20	-0.466	3.993	-3.178	13.406	-0.528	8.974
21	1.134	1.381	-0.127	-0.821	-6.731	3.167
22	-0.262	1.461	-4.087	9.888	-11.254	-2.128
23	-1.846	-0.207	-1.693	10.760	-9.399	2.294
24	-0.211	0.575	-0.426	3.860	-1.036	7.091
25	-0.364	0.903	-3.388	-2.314	-0.873	7.390
26	-0.578	-0.500	-1.839	1.646	-0.526	8.949
27	0.121	-2.327	-0.512	-6.219	-0.907	3.936
28	-2.054	3.224	-0.704	4.810	-1.957	6.774
29	0.066	4.789	-3.049	13.853	-6.837	5.761
30	-4.686	3.037	-0.459	7.146	-8.058	9.719
31	-1.216	1.422	-7.240	9.856	-5.775	10.067
32	0.065	1.194	-0.078	-0.993	-2.592	1.634
33	-0.925	2.566	-2.494	-2.759	-2.176	-4.898
34	-1.768	0.555	-5.396	2.009	-5.514	10.388
35	-0.757	1.394	-1.359	6.461	-4.142	-10.356
36	0.782	0.081	-0.082	-1.010	-9.171	0.642
37	-1.117	-0.089	0.926	2.947	1.629	3.851
38	-1.713	-4.417	1.656	5.556	2.730	11.620

Right first molar (#16) movement in three-dimensions of space (X,Y,Z) during the post-treatment period (T1-T2). P: position variables (mm), R: rotation variables (º), NA: not available data due to not erupted tooth

T1-T2	16 X P	16 Y P	16 Z P	16 X R	16 Y R	16 Z R
1	-0.282	0.148	-0.114	0.331	0.807	0.128
2	-0.145	-0.257	-0.009	-0.703	-0.362	-0.905
3	0.089	0.149	-0.259	0.203	-0.298	-0.083
4	-0.014	-0.138	0.050	0.163	-0.295	-0.250
5	0.032	0.289	-0.019	0.188	-0.261	0.626
6	0.088	0.199	0.069	-0.238	0.141	0.306
7	0.040	0.166	-0.326	0.707	0.299	0.036
8	0.314	0.218	-0.291	3.044	-2.030	-0.919
9	-0.106	0.278	-0.001	1.101	0.494	0.055
10	-0.049	0.190	-0.449	1.616	-0.932	0.062
11	-0.054	0.076	0.567	-1.323	-1.485	-0.621
12	0.363	0.028	-0.006	1.732	-1.847	0.838
13	0.082	-0.174	-0.109	-0.836	0.536	1.482
14	-0.095	0.124	-0.147	0.062	0.652	-1.702
15	-0.135	0.019	0.078	-0.424	0.496	0.329
16	-0.125	-0.314	0.007	1.522	-0.219	-0.203
17	0.194	0.114	0.409	0.054	-1.083	1.083
18	-0.009	0.036	-0.217	-0.542	1.047	-0.253
19	-0.147	-0.119	-0.513	0.146	0.841	-0.880
20	-0.152	0.267	0.020	0.732	0.126	-0.280
21	0.073	0.006	-0.054	0.713	0.138	0.489
22	0.077	-0.003	0.154	-1.427	0.004	-0.473
23	0.092	-0.112	0.055	-1.033	-0.089	0.503
24	0.000	0.050	0.054	-2.361	-0.580	-1.104
25	0.099	0.172	0.088	1.379	-0.792	-0.108
26	-0.138	0.009	-0.013	-0.277	0.367	-0.042
27	0.026	0.092	-0.046	-0.607	0.177	0.195
28	-0.010	-0.029	0.145	1.453	-0.976	0.353
29	0.058	-0.351	0.149	-1.439	-0.901	-0.436
30	0.000	-0.030	-0.161	0.640	-0.044	0.377
31	0.062	0.014	0.267	-0.304	-1.185	-2.602
32	0.117	-0.200	-0.046	0.446	-0.309	-0.680
33	0.056	0.076	0.123	0.146	-0.047	0.049
34	0.016	-0.057	0.126	0.281	-0.099	-0.323
35	0.161	-0.042	-0.023	0.334	-0.181	0.000
36	NA	NA	NA	NA	NA	NA
37	-0.106	-0.127	-0.278	0.714	0.723	-0.067
38	0.025	-0.112	0.073	-0.039	-0.747	-0.690

Right canine (#13) movement in three-dimensions of space (X,Y,Z) during the post-treatment period (T1-T2). P: position variables (mm), R: rotation variables (°)

T1-T2	13 X P	13 Y P	13 Z P	13 X R	13 Y R	13 Z R
1	0.104	0.081	-0.202	1.883	0.303	-0.744
2	0.125	-0.253	-0.261	-0.273	-0.811	0.286
3	0.173	0.042	0.048	-0.539	-1.873	2.828
4	-0.046	0.033	0.013	0.418	0.793	-0.808
5	-0.021	0.205	0.018	0.784	0.306	-1.249
6	0.101	-0.132	0.048	-0.082	-0.746	-0.500
7	-0.158	0.068	0.202	0.056	-0.732	0.305
8	0.235	0.388	0.197	1.940	-1.258	-0.382
9	-0.054	0.281	0.248	-0.544	-1.383	-1.972
10	-0.017	0.166	0.161	0.982	-1.044	-0.044
11	0.267	0.233	-0.242	0.512	-1.051	-2.043
12	0.138	0.082	0.315	1.311	-2.396	1.435
13	-0.021	-0.137	-0.250	0.010	0.177	1.336
14	0.238	0.247	-1.033	-2.647	-0.598	0.177
15	-0.039	0.074	-0.264	-0.715	0.447	0.007
16	0.359	-0.132	0.069	2.177	-0.844	-2.106
17	-0.048	-0.068	0.047	0.287	0.826	-0.966
18	-0.172	-0.330	-0.081	-1.118	0.295	1.273
19	-0.016	0.148	-0.156	-0.678	-0.085	-0.151
20	0.177	0.153	0.021	-0.467	-0.806	-1.708
21	-0.010	-0.098	-0.104	-0.213	0.858	-1.371
22	0.005	0.169	-0.090	-1.110	-0.096	-0.131
23	-0.104	-0.043	-0.176	-2.417	-0.632	-0.690
24	-0.025	-0.104	-0.112	-1.050	1.238	1.159
25	0.142	0.227	0.232	0.790	-0.781	-1.799
26	-0.066	0.040	0.096	0.280	-1.063	-0.654
27	-0.157	-0.156	-0.014	0.210	0.599	0.333
28	0.128	0.122	0.140	0.844	-1.147	0.246
29	0.251	0.080	-0.149	0.499	-0.402	-0.426
30	-0.066	0.004	-0.029	0.019	-0.154	-0.377
31	0.155	-0.346	0.130	-0.127	-0.722	0.680
32	0.057	0.030	0.183	0.017	-0.358	-2.481
33	0.083	0.000	-0.025	0.536	0.736	-0.267
34	0.074	-0.021	0.052	-0.297	0.050	-0.042
35	0.016	0.027	0.013	1.570	-0.186	0.204
36	-0.038	0.114	0.093	-0.580	-0.098	-2.418
37	0.044	-0.117	-0.153	0.261	-0.210	0.104
38	0.063	-0.274	-0.117	-1.027	-1.535	-3.128

Right central incisor (#11) movement in three-dimensions of space (X,Y,Z) during the post-treatment period (T1-T2). P: position variables (mm), R: rotation variables (°)

T1-T2	11 X P	11 Y P	11 Z P	11 X R	11 Y R	11 Z R
1	0.277	-0.066	-0.197	-0.181	-0.055	1.787
2	0.155	-0.162	-0.554	-0.333	-0.949	-0.206
3	0.029	0.060	-0.276	-0.242	-0.763	-0.001
4	0.130	0.117	0.013	-0.214	0.072	0.277
5	-0.001	0.176	-0.050	0.316	0.066	1.302
6	0.037	-0.253	0.018	0.057	-0.879	0.092
7	-0.083	0.083	0.274	0.515	-0.877	1.444
8	0.154	0.515	-0.060	1.256	-0.526	1.330
9	-0.115	0.076	-0.146	-1.352	0.051	0.383
10	0.113	0.430	-0.451	0.349	-0.857	1.043
11	0.231	0.496	0.182	3.776	-1.060	-0.489
12	0.003	0.012	0.097	1.675	-1.774	0.448
13	-0.144	-0.119	-0.142	-1.005	-0.752	0.592
14	0.282	0.451	-1.569	-1.845	-0.507	-1.407
15	0.059	0.086	-0.209	0.264	-0.568	1.865
16	0.046	-0.290	0.152	-0.776	-2.149	-0.155
17	0.008	0.127	0.192	1.873	0.456	-0.122
18	0.172	-0.170	0.182	-0.097	-0.776	0.405
19	0.048	0.135	0.256	0.532	0.606	1.378
20	-0.052	0.244	0.010	-0.032	0.436	-0.683
21	0.044	0.021	0.047	-0.074	-0.602	-0.673
22	-0.007	0.079	-0.144	-0.764	-0.099	0.242
23	-0.065	-0.088	-0.212	0.505	-1.233	-1.962
24	-0.052	-0.156	-0.106	-0.557	0.251	-1.017
25	0.048	0.138	0.302	1.113	0.339	0.386
26	0.013	0.083	0.023	-0.175	-0.216	-0.361
27	-0.078	0.006	-0.021	0.337	0.622	-1.958
28	0.093	0.133	0.043	-1.552	-0.297	0.680
29	0.062	0.307	-0.239	0.374	-4.451	-1.138
30	0.015	0.266	-0.076	0.371	0.270	-0.821
31	0.188	-0.232	-0.034	-0.559	0.222	-0.360
32	0.109	0.220	0.178	0.257	-1.637	0.345
33	-0.109	0.216	-0.070	0.933	0.483	0.004
34	0.105	-0.049	-0.005	0.024	0.744	-0.984
35	-0.025	0.117	-0.032	0.494	-1.338	1.563
36	0.102	0.463	0.134	1.844	-0.638	-1.301
37	0.246	0.106	0.003	1.618	1.539	-0.967
38	0.061	0.281	-0.057	1.848	0.998	0.479

Left central incisor (#21) movement in three-dimensions of space (X,Y,Z) during the post-treatment period (T1-T2). P: position variables (mm), R: rotation variables (°)

T1-T2	21 X P	21 Y P	21 Z P	21 X R	21 Y R	21 Z R
1	0.202	-0.115	-0.062	0.600	-0.302	1.435
2	0.167	-0.124	-0.496	-0.973	0.611	0.052
3	0.125	0.071	-0.281	-0.431	1.249	0.421
4	-1.285	0.015	-1.618	0.043	0.052	-0.069
5	-0.019	0.192	-0.063	0.311	0.647	0.801
6	0.062	-0.259	-0.101	-0.822	0.256	-0.319
7	-0.071	-0.055	-0.179	1.228	0.308	0.165
8	-0.187	0.412	-0.156	2.456	-0.433	0.178
9	-0.242	0.048	-0.091	-0.268	0.081	-0.776
10	-0.042	0.012	0.017	0.939	-0.433	-1.861
11	0.122	0.539	0.026	2.816	-0.757	-0.474
12	0.038	-0.098	-0.148	-0.724	0.113	0.948
13	-0.233	-0.086	-0.030	-0.360	-1.393	0.025
14	0.041	0.643	-0.651	-0.714	1.232	-0.423
15	-0.073	0.162	-0.239	0.025	-0.602	0.216
16	-0.275	-0.185	-0.040	-4.508	-1.948	-0.315
17	-0.059	0.302	0.205	0.910	-0.368	2.748
18	0.151	-0.151	0.034	0.950	-0.228	-0.889
19	0.026	0.038	0.266	0.598	0.258	-0.361
20	-0.121	0.245	0.094	-0.288	-1.022	-0.647
21	-0.022	-0.084	-0.096	-0.833	0.098	0.249
22	-0.056	0.086	-0.225	-1.099	0.230	0.224
23	-0.163	0.020	-0.211	0.667	0.339	0.652
24	0.054	-0.085	-0.100	-0.202	0.275	0.632
25	-0.018	0.210	0.301	2.162	-1.035	-0.548
26	-0.041	0.076	0.019	0.032	0.623	-0.765
27	0.018	0.058	-0.009	0.984	-0.330	0.755
28	0.022	0.147	-0.038	-0.196	-0.584	-0.607
29	-0.016	0.258	-0.155	1.320	-0.543	-0.328
30	-0.121	0.271	-0.102	0.748	-0.679	-1.230
31	0.019	-0.258	-0.048	0.785	-0.761	-1.415
32	-0.144	0.148	-0.133	-0.546	-1.431	-0.813
33	-0.043	0.166	-0.092	1.321	-0.152	1.973
34	0.035	0.002	0.043	-0.367	-0.155	0.014
35	-0.110	0.168	-0.025	1.825	0.181	-0.334
36	0.104	0.564	0.264	2.386	0.570	-1.118
37	-0.162	0.102	0.107	1.311	0.077	0.698
38	0.065	0.215	-0.006	0.853	0.596	0.163

Left canine (#23) movement in three-dimensions of space (X,Y,Z) during the post-treatment period (T1-T2). P: position variables (mm), R: rotation variables (°)

T1-T2	23 X P	23 Y P	23 Z P	23 X R	23 Y R	23 Z R
1	-0.137	0.046	-0.042	0.400	-0.507	-0.154
2	0.111	-0.060	-0.396	-1.092	-0.146	1.853
3	0.086	0.129	-0.143	0.712	-0.073	-1.668
4	-0.017	0.130	0.098	0.131	1.845	-2.004
5	-0.037	0.047	0.043	0.798	0.136	0.114
6	0.162	-0.210	0.109	-0.038	1.151	-1.627
7	0.060	0.035	0.122	0.695	0.766	0.614
8	-0.146	0.259	0.127	2.403	1.688	1.420
9	-0.139	0.103	0.075	-0.986	1.071	0.821
10	0.069	0.109	-0.677	-0.015	-1.185	0.596
11	-0.046	0.310	-0.424	-0.142	-0.012	1.653
12	-0.193	0.060	-0.054	0.793	0.195	1.247
13	-0.154	-0.314	0.027	-1.445	0.592	1.384
14	-0.085	0.199	0.284	0.246	1.815	-0.988
15	-0.027	0.065	-0.111	-0.447	0.190	-0.459
16	0.054	-0.389	-0.013	-0.137	-0.042	-0.422
17	0.013	-0.055	0.043	0.576	0.517	0.895
18	0.217	-0.129	-0.041	-1.879	-0.511	-1.945
19	0.038	-0.135	0.057	0.862	-2.685	-1.060
20	-0.028	-0.038	-0.006	0.112	-0.632	1.578
21	-0.074	0.025	0.020	2.060	0.640	1.486
22	-0.051	-0.021	-0.061	-0.613	-0.240	-0.651
23	-0.184	0.052	-0.158	-0.297	1.001	0.673
24	-0.091	0.010	-0.175	0.274	-0.902	-3.509
25	-0.071	0.341	0.194	1.461	-0.273	0.168
26	-0.148	0.079	0.049	-0.615	0.231	-0.331
27	-0.191	-0.098	-0.004	2.452	-1.406	2.456
28	0.031	0.125	0.037	-0.270	0.308	0.008
29	-0.117	0.077	-0.003	-1.257	1.875	2.071
30	0.034	0.033	-0.211	0.592	-1.245	0.759
31	-0.261	-0.058	-0.270	-0.425	1.168	-0.085
32	-0.156	0.050	-0.179	-0.758	-0.647	-0.777
33	-0.118	-0.150	-0.112	1.059	-0.693	-1.156
34	0.036	0.067	0.227	-0.586	0.353	0.725
35	0.011	-0.172	-0.046	-1.134	0.894	0.097
36	-0.063	0.576	0.251	0.897	0.920	1.431
37	0.115	-0.064	-0.022	-0.340	0.493	0.928
38	0.020	-0.018	-0.035	-0.451	0.388	2.291

Left first molar (#26) movement in three-dimensions of space (X,Y,Z) during the post-treatment period (T1-T2). P: position variables (mm), R: rotation variables (°)

T1-T2	26 X P	26 Y P	26 Z P	26 X R	26 Y R	26 Z R
1	0.085	0.086	0.011	0.068	0.295	0.299
2	-0.079	0.028	-0.016	-0.850	0.205	0.132
3	-0.025	0.253	-0.170	0.407	-0.594	-0.351
4	-0.037	0.123	-0.067	1.521	-0.063	-0.406
5	-0.077	-0.024	0.107	0.696	0.364	0.285
6	0.204	-0.064	0.231	0.225	0.012	-0.249
7	-0.011	-0.019	-0.192	0.230	-0.059	0.187
8	0.191	0.019	-0.525	2.817	-0.714	2.701
9	0.005	0.202	0.108	1.050	-0.374	0.187
10	-0.021	0.229	-0.697	1.783	-0.759	-0.223
11	-0.022	0.463	-0.321	-0.077	-1.596	0.491
12	-0.294	-0.001	-0.121	0.828	2.947	0.738
13	-0.179	0.326	0.408	-0.666	0.127	1.154
14	-0.007	0.513	0.267	-0.561	0.293	0.599
15	0.306	0.005	0.215	-0.809	-0.925	0.236
16	0.095	-0.266	-0.043	1.178	-1.102	0.471
17	-0.157	0.027	0.225	0.138	0.616	-0.147
18	-0.017	0.112	0.196	-0.815	0.424	-0.005
19	0.158	-0.172	-0.278	2.472	0.086	-0.472
20	0.018	-0.005	0.107	0.035	-0.158	-0.358
21	0.016	0.029	-0.060	1.048	0.342	0.055
22	0.068	-0.113	0.073	-0.883	-0.163	0.392
23	0.007	0.015	0.105	0.310	0.300	-0.163
24	0.019	-0.131	0.026	-0.312	-0.003	0.446
25	0.066	0.222	-0.095	1.930	-0.987	-0.167
26	0.006	0.050	0.068	0.276	-0.027	0.436
27	-0.052	-0.009	0.208	-0.023	0.562	0.808
28	-0.106	0.007	0.246	0.981	0.960	0.069
29	-0.327	-0.036	0.100	-1.145	0.619	-0.232
30	0.000	0.067	-0.418	0.540	-0.310	-0.227
31	0.092	-0.227	0.216	0.053	-0.288	0.363
32	-0.023	0.041	-0.277	1.339	-0.410	-0.543
33	-0.017	-0.368	0.068	-0.941	0.812	0.053
34	0.107	0.095	0.216	-0.137	0.103	0.173
35	0.145	-0.282	-0.040	-0.483	-0.580	0.213
36	-0.377	0.480	-0.031	1.541	0.896	-0.552
37	-0.010	0.033	-0.204	0.426	0.292	0.207
38	-0.120	0.083	0.075	0.094	0.637	0.040