Variations in maxillary second molar position of untreated subjects with normal occlusions: a long-term observational study

Veronica Giuntini, DDS, PhD[1]

Michele Nieri, DDS, PhD[2]

Cecilia Goracci, DDS, PhD[3]

Antonio C. Ruellas, DDS, PhD[4]

James A McNamara, Jr, DDS, PhD[5]

Lorenzo Franchi, DDS, PhD5[6]

1. Associate Professor, Department of Experimental and Clinical Medicine, The University of Florence, Italy.

2. Research Fellow, Department of Experimental and Clinical Medicine, The University of Florence, Italy.

3. Associate Professor, Department of Medical Biotechnologies, University of Siena, Policlinico Le Scotte, Siena, Italy.

4. Associate Professor, Department of Orthodontics and Pediatric Dentistry, University of Michigan School of Dentistry, Ann Arbor, MI 48109.

5. Thomas M. and Doris Graber Endowed Professor of Dentistry Emeritus, Department of Orthodontics and Pediatric Dentistry, School of Dentistry; Professor Emeritus of Cell and Developmental Biology, School of Medicine, The University of Michigan, Ann Arbor, Michigan. Private practice of orthodontics, Ann Arbor, Michigan.

6. Associate Professor, Department of Experimental and Clinical Medicine, The University of Florence, Italy; Thomas M. Graber Visiting Scholar, Department of Orthodontics and Pediatric Dentistry, School of Dentistry, The University of Michigan, Ann Arbor.

Running Head: Three-dimensional evaluation of maxillary second molars

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1111/OCR.12522

Address all correspondence to:

Dr. Lorenzo Franchi

Department of Experimental and Clinical Medicine

Università degli Studi di Firenze

Firenze, Italy

Phone: +39 055 7945602

Email: lorenzo.franchi@unifi.it

DR LORENZO FRANCHI (Orcid ID : 0000-0002-3262-6492)

Article type : Research Article

Variations in maxillary second molar position of untreated subjects with normal occlusions: a long-term observational study

Abstract

Introduction: The purpose of the present study was to evaluate the long-term variations in maxillary second molar position in untreated subjects with normal occlusion. **Setting and Sample Population** A sample of 39 subjects (18 females and 21 males) selected from the University of Michigan Growth Study (UMGS) was followed longitudinally with digital dental casts at 3 observation times: T1, when the maxillary permanent second molars were fully erupted, T2, last observation available in the longitudinal series (38 subjects) and T3 at least 20 years after T2 (12 subjects). **Materials and Methods:** Digital measurements were recorded with an open-source software. Outcome variables were sagittal and transverse inclinations of the upper second molars. Two mixed effect models were performed. **Results:** The maxillary second molars had a distolingual inclination at T1, T2, and T3. Sagittal and transverse inclination showed progressive significant uprighting from T1 through T3 ($P<0.001$). From T1 to T2 the adjusted difference in sagittal crown inclination was 8.0° (95% C.I. from 6.5° to 9.6°; $P<0.001$). From T2 to T3 the adjusted difference was 5.5° (95% C.I. from 3.0° to 8.1°; $P<0.001$). From T1 to T2 the adjusted difference in transverse crown inclination was 1.9° (95% C.I. from 0.4° to 3.5°; $P=0.011$). From T2 to T3 the adjusted difference was 6.0° (95% C.I. from 3.4° to 8.5°; $P<0.001$). **Conclusions:** Along with age, maxillary second molars showed a progressive significant uprighting with a decrease in the distal and lingual inclinations.

Keywords: Maxillary second molars; Sagittal and transverse inclination; Digital dental casts; Normal occlusion.

Introduction

The evaluation of the position of the maxillary permanent second molars has important clinical implications because these teeth may be responsible for premature contacts and occlusal interferences during function. Second molars may produce working, balancing and protrusive interferences and may hamper the attainment of anterior guidance during function.(1, 2)

When evaluating the treatment results of candidates for the *American Board of Orthodontics*,(3) the most common mistakes were related to the position of the maxillary second molars. Nearly 80% of the problems with buccolingual inclination occurred with the maxillary and mandibular second molars. Nearly 50% of the problems with alignment involved the second molars, and the most common marginal ridge discrepancies (more than 55%) occurred between the maxillary and mandibular first and second molars.(3)

The three-dimensional position of the crown maxillary second molars on dental casts has been assessed both in cross-sectional samples of adolescents and young adults.(4-18) Andrews(4) found that maxillary second molars presented with a very slight mesial angulation or tip (mean value +0.4°), while these teeth showed a lingual inclination (torque) of -8.0°. Currim and Wadkar (5) and Kannabiran et al.,(6) using the same methods described by Andrews,(4) reported for Indian young adult subjects with normal occlusion a mesial inclination (+3.0° and +4.2°, respectively) and a lingual crown inclination (-9.9° and -14.5°, respectively) of the maxillary second molars.

Lombardo et al.(7) performed digital measurements on 3D virtual casts of young adult Caucasian subjects with ideal occlusion. Digital measurements were based on the same anatomical reference points and planes as those used by Andrews.(4) They reported a distal angulation (-3.9°) and a lingual inclination (-5.5°) of the maxillary second molars.(7)

Recently a study (8) using digital measurements in a sample of adolescents found that the maxillary second molars presented with a more accentuated distal angulation (-18.9°) and a lingual inclination of -10.6° with respect to that reported for young adults.(5-7) The authors concluded that the finding of distal crown inclination, in contrast with Andrews observation of a mesial crown inclination, suggests that a revision in tip prescription for pre-adjusted brackets might be considered.

To our knowledge, no previous study has analyzed the longitudinal changes of sagittal crown inclination (angulation or tip) and transverse crown inclination (torque) of the maxillary second molars. In particular, it would be interesting to analyze the longitudinal changes of the position of the upper second molars in the transition from adolescence to adulthood. Therefore, the aim of the present investigation was to assess the longitudinal long-term variations of maxillary second molar position in untreated subjects with normal occlusion.

Materials and Methods

This paper followed the STROBE statement.(9)

This paper reports the results of a retrospective observational long-term study that analyzed a sample of digital dental casts of orthodontically untreated subjects with normal occlusions that were derived from the archive of the University of Michigan Growth Study (UMGS).(10,11) The casts of the University of Michigan Growth Study had been converted previously to digital format using the 3Shape R700 model scanner (ESM Digital Solution Ltd., Dublin, Ireland). This study was exempted from review by the Medical School Institutional Review Board of the University of Michigan (HUM00160161).

To be included in this study, subjects had to have no previous orthodontic treatment, bilateral Class I molars, and regular arch forms with no or minimal crowding. For all subjects at least 2 longitudinal observations had to be available. The first one (T1) was taken when the maxillary permanent second molars were fully erupted. The second observation (T2) corresponded to the last observation available in the original longitudinal series. The third time point (T3) corresponded to a long-term observation at least 20 years after T2. The T3 observation was obtained when an attempt was made to recall University of Michigan Growth Study subjects in the 1990s for a long-term follow-up study.(12,13)

Measurements

Digital measurements of the upper second molars were performed with an open source software (3D Slicer, https://www.slicer.org/wiki/Documentation/4.x/Acknowledgments) and measured using the same anatomical reference points as described by Andrews.(4)

The 3D surface model (.stl file) was loaded in 3DSlicer, and the model was oriented using a fixed 3D coordinate system provided by the software, with three orthogonal planes indicated with yellow, red, and green colors (Fig. 1). These planes were used as a reference to orientate the surface models of each subject. The transforms tool was used to move the model based on defined landmarks and planes. The maxillary occlusal plane was identified with three anatomical points: interincisal point and mesiopalatal cusp tip of each maxillary first molar.(14,15) The midsagittal plane passed through the median palatal raphe and the middle point between right and left rugae.

The model was oriented until the midsagittal plane coincided with the yellow plane, and the occlusal plane with the red plane (Fig. 1). This process was repeated for each subject, thus accomplishing a common orientation within the 3DSlicer coordinate system for all digital models.

Sagittal crown inclination

The facial axis of the clinical crown (FACC), shown as the black line in Figure 2, was obtained by joining two landmarks (the most occlusal, O, and the most cervical, C, points) within the groove on the buccal surface of the upper second molars. The sagittal crown inclination was the angle between FACC (viewed from the buccal surface) and the green line constructed perpendicular to the occlusal plane.(4,5)

For the sagittal crown inclination, the angle (pitch) between the FACC and the occlusal plane, was calculated using the Q3DC tool in Slicer. The angle was positive when the occlusal portion of the FACC was mesial to the gingival portion. In contrast, the value of the sagittal crown inclination was negative when the occlusal portion of FACC was distal to the gingival portion.

Transverse crown inclination

The transverse crown inclination was measured by the angle between the FACC and a yellow plane constructed perpendicular to the occlusal plane (viewed from the coronal view; Fig. 3). The angle (roll) between the FACC and the occlusal plane was calculated by the software (Q3DC tool in Slicer). The angle was positive when the occlusal portion of the tangent line was buccal to the gingival portion and negative when the occlusal portion of the tangent line was lingual to the gingival portion.

For the assessment of intra-observer agreement, the same examiner (A.R.) remeasured 30 subjects after a wash-out period of two weeks. Intraclass Correlation Coefficient (ICC) values were calculated for each variable. Absolute error also was assessed with Dahlberg's formula.

All subjects fulfilling the inclusion criteria were included in the study.

Statistical analysis

A mixed-effects model was applied. In this analysis the outcome variable was sagittal crown inclination (or transverse crown inclination), the subjects represented the random effect, while the explanatory variables were the time point (T1 vs T2 vs T3) and the arch side (right vs left). In the event of statistical significance, Tukey's HSD test for multiple comparisons of the difference between T1 and T2 and T2 and T3 was carried out with a 95% confidence interval (C.I.). The level of significance was set at $P<0.05$. A sensitivity subgroup analysis was carried out including only the 11 subjects with longitudinal data at T1, T2, and T3. To assess the assumption of the models, graphical residual analyses were performed. All statistical computations were performed with statistical software (JMP version 13.0.0, SAS Institute Inc, Cary, NC, USA and MedCalc version 19.6.4, MedCalc Software Ltd., Ostend, Belgium).

Results

ICC values were above 0.80 for all the variables, with most values being close to or above 0.90, thus indicating a very good intra-rater reliability. Absolute error varied between a minimum of 1.4° for the transverse inclination right and a maximum of 1.9° for sagittal inclination right and left.

From the parent sample of 708 subjects of the University of Michigan Growth Study, the digital dental casts of a group of 187 subjects with Class I occlusion were screened. For each subject fulfilling the inclusion criteria (39 subjects, 18 females and 21 males), the entire longitudinal series of annual dental casts was checked. Thirty-eight of the 39 subjects presented an observation at T2 while 12 subjects had also digital casts at T3 (Table 1). The descriptive statistics for the T1-T2, T2-T3 and T1-T3 intervals are reported in Table 1.

The maxillary second molars presented a distal inclination at T1, T2, and T3. This inclination showed progressive significant decreases from T1 through T3 ($P<0.001$; Table 2). From T1 to T2 the adjusted difference in sagittal crown inclination was 8.0° (95% C.I. from 6.5° to 9.6°; $P<0.001$; Table 3). From T2 to T3 the adjusted difference was 5.5° (95% C.I. from 3.0° to 8.1°; $P<0.001$; Table

3). From T1 to T3 the adjusted difference was 13.5° (95% C.I. from 11.0° to 16.1°; P<0.001; Table 3). There was also a significant difference in the arch side (right vs left) of -3.7° (95% C.I. from -4.9° to -2.5°; P<0.001).

The maxillary second molars presented a lingual inclination at T1, T2, and T3. This inclination showed progressive significant decreases from T1 through T3 (P<0.001; Table 2). From T1 to T2 the adjusted difference in transverse crown inclination was 1.9° (95% C.I. from 0.4° to 3.5°; P=0.011; Table 3). From T2 to T3 the adjusted difference was 6.0° (95% C.I. from 3.4° to 8.5°; P<0.001; Table 3). From T1 to T3 the adjusted difference was 7.9° (95% C.I. from 5.4° to 10.4°; P<0.001; Table 3). The difference in the arch side (right vs left) was -0.9° (95% C.I. from -2.1° to 0.4°; P=0.166).

The sensitivity analysis on 11 subjects confirmed the results of the main analysis. From T1 to T2 the adjusted difference in sagittal crown inclination was 8.6° (95% C.I. from 6.0° to 11.2°; P<0.001). From T2 to T3 the adjusted difference was 5.9° (95% C.I. from 3.2° to 8.5°; P<0.001). From T1 to T2 the adjusted difference in transverse crown inclination was 3.7° (95% C.I. from 0.6° to 6.9°; P=0.016). From T2 to T3 the adjusted difference was 5.3° (95% C.I. from 2.2° to 8.5°; P<0.001).

In the analysis of the residuals, there were not departures from homoscedasticity and normality.

Discussion

The objective of the present study was to assess the longitudinal long-term changes of the sagittal and transverse inclinations of maxillary second molars in untreated subjects with normal occlusion. Both sagittal and transverse crown inclination of the maxillary second molars changed significantly in both the short and long term. In particular, the maxillary second molars showed a progressive significant uprighting with a decrease in the distal and lingual inclinations (Supplementary Figure 1).

In the short term, the distal and lingual inclinations decreased by 8.0° and 1.9°, respectively. In the long term (from T2 to T3) the distal and lingual inclinations decreased by 5.5° and 6.0°, respectively. The cause of this uprighting of the maxillary second molars, however, is unclear. We can speculate that a role could be played by the eruption of the third molars and/or by the occlusal forces generated by the associated musculature. It should be stressed that the relatively high standard deviations and confidence intervals for the values in sagittal and transverse crown inclinations for the T1-T2, T2-T3, and T1-T3 intervals, suggest a high interindividual variability.

The results of the current investigation at T3 were similar to those reported by Lombardo et al. in Caucasian adults.(7) In fact, Lombardo et al.(7) reported a distal inclination of -3.9° versus -6.4° of the current study, while the lingual inclination was -5.5° versus -4.8° of the present investigation.

The studies of Currim and Wadkar (5) and of Kannabiran et al. (6) were performed in young adult Indian populations (mean age 18.7 and 21.5 years, respectively). In contrast to the values at T3 in the present study, Currim and Wadkar (5) and Kannabiran et al. (6) reported a mesial inclination (+3.0° and +4.2°, respectively) and a more accentuated lingual inclination (-9.9° and -14.5°).

It should be noted that Currim and Wadkar (5) and Kannabiran et al. (6) performed manual measurements on physical dental casts similar to Andrews' method,(4) while both the current study and Lombardo et al.(7) evaluated the inclinations of the maxillary second molars by using a digital method on digital dental casts. In addition, the difference between the results of the current investigation at T3 and those of Currim and Wadkar (5) and Kannabiran et al.(6) can be explained in part by the different population and by the differences in chronologic age. In fact, the results of the present study showed that both sagittal and transverse inclination of the maxillary second molars changed with maturation.

It is interesting to note that our sample showed values for sagittal and transverse inclinations that differed from the values of both Roth™ (Straight-Wire® Synthesis™, ormco.com) and MBT™ (3M™ MBT™ appliance system, 3m.com) straight wire prescriptions (0° of sagittal inclination and -14° of transverse inclination). Specifically, in our sample the values for sagittal inclination always were negative also in the adult stage at T3 and never reached the 0° value. On the contrary, the values for transverse inclination also were always less negative in the adolescent stage at T1. The clinical implications could be that the distal inclination of upper second molars in both adolescents and adults may be reduced in patients treated with MBT™-prescription brackets, with the extrusion of the distal surface.

Lino et al.(16) pointed out that such extrusion could determine premature contacts and occlusal interferences; they recommended that to minimize this risk, changes in the bracket prescription of maxillary second molars may be required. Additionally, the results of the current investigation suggest that different sagittal and transverse inclination values (tip and torque) for the maxillary second molars with straight-wire prescriptions might be advisable for different age-groups. These results indicate a divergence from the values recommended in the pre-adjusted appliances. Thus, a re-assessment of the prescriptions for angulation and inclination for the maxillary second molars is suggested. Therefore, the use of customized orthodontic treatment systems that have been proposed recently in the literature (17) could be recommended.

A limitation of the current study was that the sample size at T3 showed a remarkable reduction. It should be considered that a high number of dropouts is expected when performing a long-term longitudinal study on untreated subjects. Another limitation was the lack of longitudinal observations in the age range between 20 and 40 years. Moreover, the occlusal plane, that was chosen as a reference, could have modified along with time. Finally, when analyzing an historical cohort of subjects, a secular trend cannot be excluded.

Conclusions

The results of the present study showed that both sagittal and transverse crown inclination of the maxillary second molars changed significantly in both the short and long term. In particular, the maxillary second molars showed a progressive significant uprighting with a decrease in the distal and lingual inclinations.

Acknowledgments

Conflict of interest statement: none of the authors declare any conflict of interest.

Authors' contributions

Veronica Giuntini: conception and design.

Michele Nieri: data analysis and interpretation of data, writing of the manuscript.

Cecilia Goracci: conception and design.

Antonio C. Ruellas: measurer.

James A. McNamara Jr.: conception and design, editing of the manuscript.

Lorenzo Franchi: conception and design, writing of the manuscript.

Data availability

Data are available on request from the authors.

References

1. Cohen WE. A study of occlusal interferences in orthodontically treated occlusions and untreated normal occlusions. *Am J Orthod*. 1965;**51**: 647-89.

2. Oltramari PV, Conti AC, Navarro Rde L, Almeida MR, Almeida-Pedrin RR, Ferreira FP. Importance of occlusion aspects in the completion of orthodontic treatment. *Braz Dent J*. 2007;**18**: 78-82.

3. American Board of Orthodontics. Why case reports do not pass the ABO Phase III clinical examination. Am J Orthod Dentofacial Orthop 1996;**110**: 559-60.

4. Andrews L F. Straight wire. The concept and appliance. San Diego: L.A. Wells Co.; 1989.

5. Currim S, Wadkar PV. Objective assessment of occlusal and coronal characteristics of untreated normals: a measurement study. *Am J Orthod Dentofacial Orthop*. 2004;**125**: 582-8.

6. Kannabiran P, Thirukonda GJ, Mahendra L. The crown angulations and inclinations in Dravidian population with normal occlusion. *Indian J Dent Res*. 2012;**23**: 53-8.

7. Lombardo L, Perri A, Arreghini A, Latini M, Siciliani G. Three-dimensional assessment of teeth first-, second- and third-order position in Caucasian and African subjects with ideal occlusion. *Prog Orthod*. 2015;**16**: 11.

8. Goracci C, Ruellas AC, Nieri M, Crouch S, McNamara JA, Jr, Franchi L. Three-dimensional evaluation of maxillary second molar position in untreated patients with normal occlusion: Implications for preadjusted appliance prescriptions. *Journal of Orofacial Orthopedics*. 2021.

9. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;**61**: 344-9.

10. Riolo ML, Moyers RE, McNamara JA, Jr, Hunter WS. An atlas of craniofacial growth: Cephalometric standards from The University School Growth Study, The University of Michigan. Ann Arbor: Monograph 2, Craniofacial Growth Series, Center for Human Growth and Development, The University of Michigan; 1974.

11. Moyers RE, van der Linden FPGM, Riolo ML, McNamara JA, Jr. Standards of Human Occlusal Development. Ann Arbor: Monograph 5, Craniofacial Growth Series, Center for Human Growth and Development, The University of Michigan; 1976.

12. Carter GA, McNamara JA, Jr. Longitudinal dental arch changes in adults. *Am J Orthod Dentofac Orthop*. 1998;**114**: 88-99.

13. West KS, McNamara JA, Jr. Changes in the craniofacial complex from adolescence to adulthood: A cephalometric study. *Am J Orthod Dentofac Orthoped*. 1999;**115**: 521-32.

14. Sjögren AP, Lindgren JE, Huggare JA. Orthodontic study cast analysis--reproducibility of recordings and agreement between conventional and 3D virtual measurements. *J Digit Imaging*. 2010;**23**: 482-92.

15. Nouri M, Abdi AH, Farzan A, Mokhtarpour F, Baghban AA. Measurement of the buccolingual inclination of teeth: manual technique vs 3-dimensional software. *Am J Orthod Dentofacial Orthop*. 2014;**146**: 522-9.

16. Lino AB, Vigorito JW. Evaluation of the vertical alterations of the upper second molars after the alignment and leveling phase using the MBT technique. *Dental Press J Orthod*. 2013;**18**: 115-20.

17. Grauer D, Wiechmann D, Heymann GC, Swift EJ, Jr. Computer-aided design/computer-aided manufacturing technology in customized orthodontic appliances. *J Esthet Restor Dent*. 2012;**24**: 3-9.

Table and Figure legends

Table 1. Demographics for the longitudinal sample at T1, T2, and T3 and for the T1-T2, T1-T3, and T2-T3 intervals.

Table 2. Descriptive statistics and statistical comparisons for the 2 analyzed variables.

Table 3. Descriptive statistics and statistical comparisons for T1-T2, T2-T3, and T1-T3 changes for the 2 analyzed variables.

Figure 1. Model orientation in the 3D measurement software using a fixed 3D coordinate system.

Figure 2. The facial axis of the clinical crown (FACC) was obtained by connecting the most occlusal (O) and the most cervical (C) landmarks within the groove on the buccal surface of the maxillary second molars. The sagittal inclination was the angle formed by the FACC as viewed from the buccal surface, and the line perpendicular to the occlusal plane.

Figure 3. The transverse inclination of the maxillary second molars was measured by the angle between the FACC, viewed from the coronal view, and the occlusal plane.

Supplementary Figure 1. Progressive reduction of the sagittal inclination of the maxillary second molars from T1 through T3 in the dental casts of a clinical case.

Table 1. Demographics for the longitudinal sample at T1, T2, and T3 and for the T1-T2, T1-T3, and T2-T3 intervals

Time	Subjects	Females	Teeth	Mean Age (Years)	Std dev	Min; Max
T1	39	18	77	14.3	1.1	12.7; 17.0
T2	38	18	76	16.4	1.3	14.0; 18.7
T3	12	4	23	47.9	4.4	40.1; 57.3
Interval	Subjects	Females	Teeth	Mean Interval (Years)	Std dev	Min; Max
T1-T2	38	18	76	2.2	1.3	0.7; 5.0
T2-T3	11	4	22	30.4	4.6	23.1; 39.3
T1-T3	12	4	23	33.0	5.1	24.2; 44.3

Table 2. Descriptive statistics and statistical comparisons for the 2 analyzed variables.

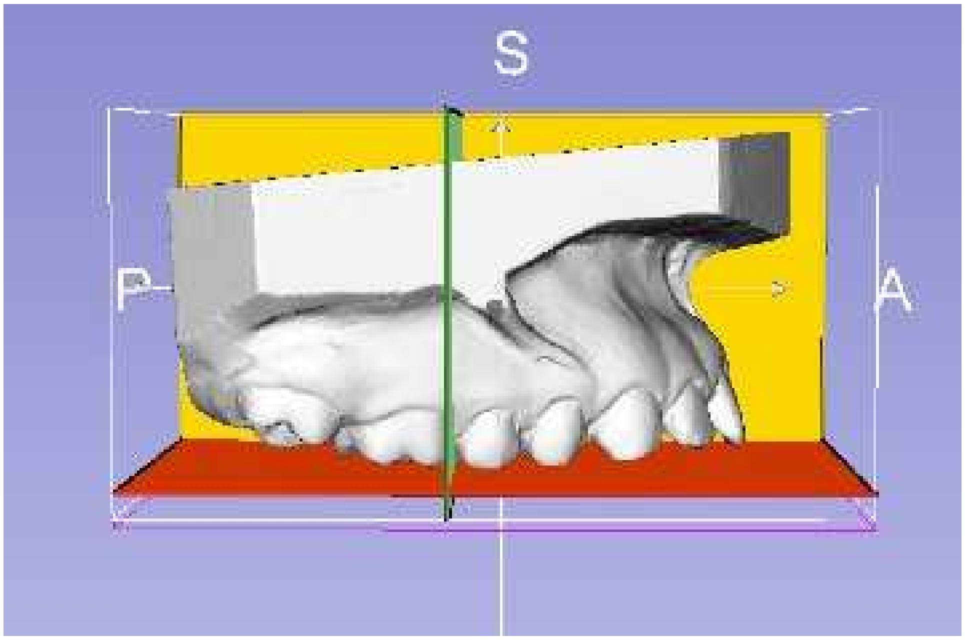
Variable	T1 N=77	T2 N=76	T3 N=23	P value
Sagittal crown inclination (std dev)	-18.7 (6.6)	-10.7 (5.9)	-6.4 (4.7)	<0.001
Transverse crown inclination (std dev)	-12.6 (7.1)	-10.8 (7.6)	-4.8 (8.6)	<0.001

N = number of teeth

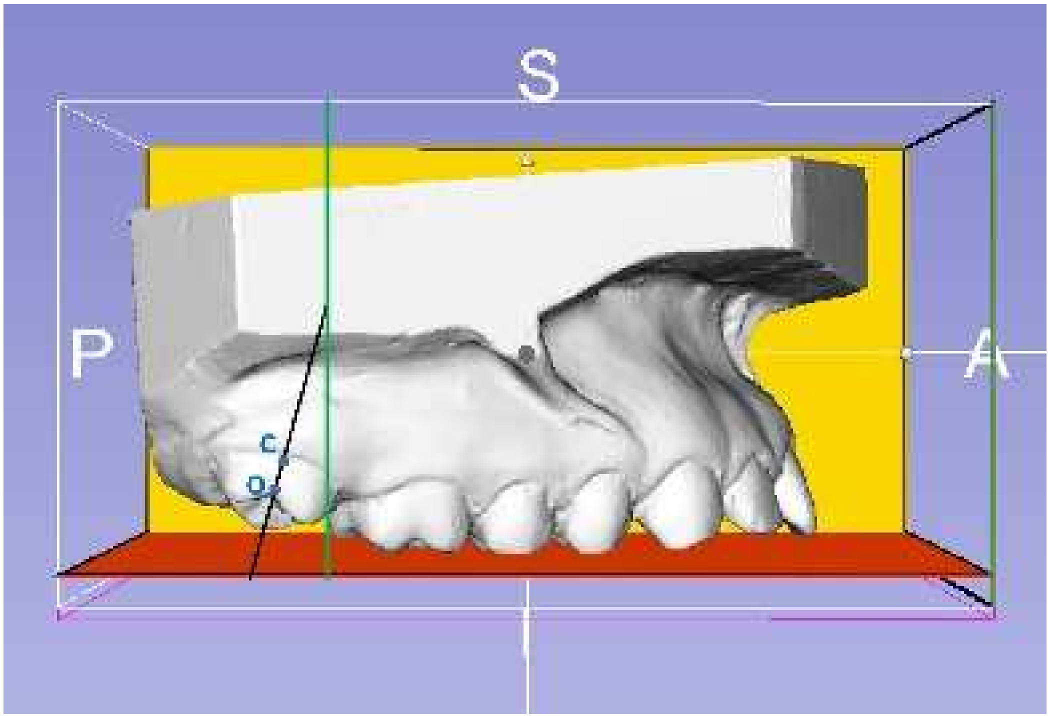
Table 3. Descriptive statistics and statistical comparisons for T1-T2, T2-T3, and T1-T3 changes for the 2 analyzed variables.

Sagittal crown inclination (degrees)	N	Mean Unadjusted (SD)	Mean Adjusted	P value	Confidence Interval
Change T1-T2	76	8.1 (4.7)	8.0	<0.001	6.5 - 9.6
Change T2-T3	22	5.8 (4.7)	5.5	<0.001	3.0 - 8.1
Change T1-T3	23	14.0 (5.8)	13.5	<0.001	11.0-16.1
Transverse crown inclination (degrees)					
Change T1-T2	76	2.0 (4.4)	1.9	0.011	0.4- 3.5
Change T2-T3	22	5.1 (6.5)	6.0	<0.001	3.4 - 8.5
Change T1-T3	23	8.7 (7.5)	7.9	<0.001	5.4 -10.4

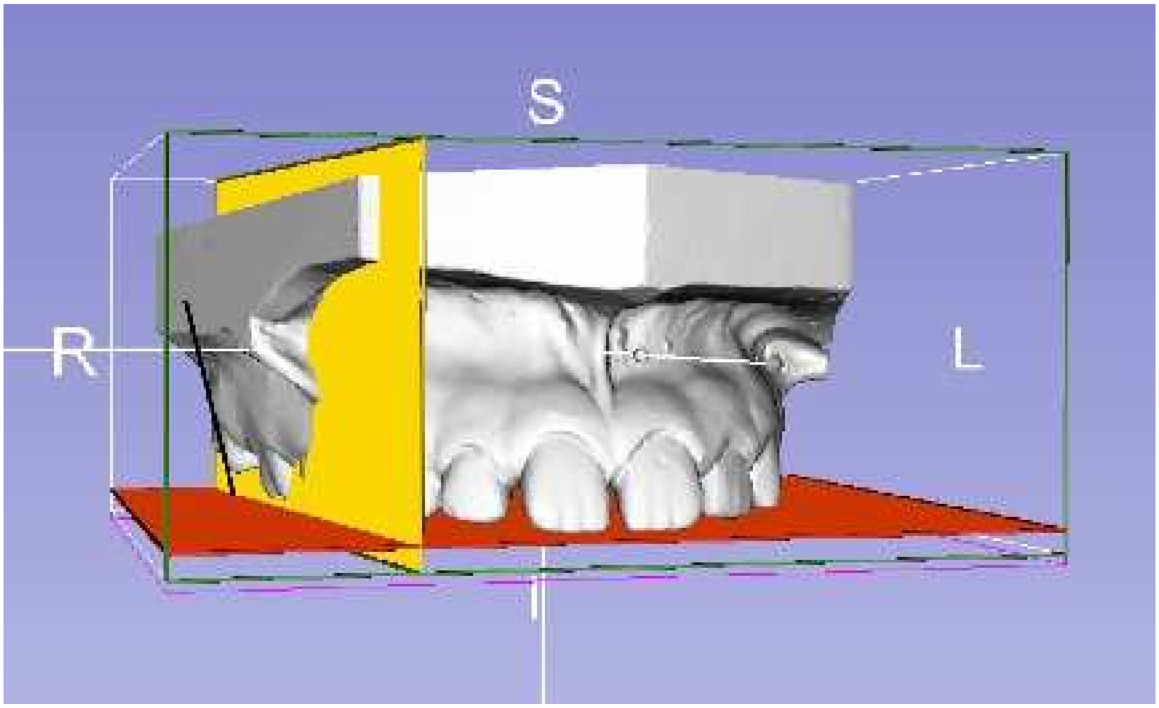
N = number of teeth



ocr_12522_f1.jpeg



ocr_12522_f2.jpeg



ocr_12522_f3.jpeg