Panoramic evaluation of mesiodistal axial inclinations of maxillary anterior teeth in orthodontically treated subjects

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Introduction: The objectives of this study were to evaluate, through panoramic radiographs, the mesiodistal axial inclinations of the maxillary anterior teeth at the beginning and end of nonextraction orthodontic treatment, and to compare the results with the mesiodistal axial inclinations of a control sample with normal (acceptable) occlusions. Methods: The experimental sample consisted of 40 white patients (20 male, 20 female; mean age, 14 years) with Class I malocclusions who were treated orthodontically with a standard edgewise (not preadjusted) technique without extractions. The mean treatment period was 1.6 years. The control sample comprised 42 white subjects (14 male, 28 female; age range, 12-17 years) with untreated normal (acceptable) occlusions. Panoramic radiographs were taken of the patients at the beginning (T1) and end (T2) of treatment. The mean values of the mesiodistal axial inclination at T1 were compared with the mean values at T2, and both were compared with the mesiodistal axial inclinations of the control sample. Results: The mesiodistal axial inclinations of the maxillary anterior teeth of the experimental group at T1 were different from those of the control group for 50% of the evaluated teeth. In contrast, the inclinations at T2 were consistent with the normal anatomical configuration of the controls. Conclusions: The panoramic radiograph is an effective tool for evaluating the mesiodistal axial inclinations of maxillary anterior teeth. (Am J Orthod Dentofacial Orthop 2006;130:56-61)

Normal occlusion depends on proper axial inclination, especially of the maxillary anterior teeth, which have the longest crowns. Furthermore, the degree of incisor tip determines the amount of mesiodistal space they consume and, therefore, has a considerable effect on posterior occlusion and anterior esthetics. Tuverson demonstrated this with a diagnostic wax setup and showed that 2 mm of excess space could be absorbed by angulating upright maxillary incisors. Occasionally, teeth are overangulated, and space is gained by correction to normal angulation.

A major objective of orthodontic treatment is to normalize tooth positions in 3 planes of space, with the goal of approaching predefined cephalometric or occlusal standards. The mesiodistal axial inclination (tip) of permanent teeth should also be considered in an occlusion analysis. Andrews determined the mean values of tooth crown angulation and chose this condition as 1 of the 6 keys to be evaluated in an ideal static occlusion.

At the beginning and end of orthodontic treatment, axial inclinations should be checked both clinically and radiographically. A patient with a properly treated occlusion, viewed radiographically, should have the same root arrangement after treatment as a patient with normal occlusion. The panoramic radiograph is the method most often used to provide information about the teeth and their axial inclinations and to evaluate root parallelism after orthodontic treatment. Ursi et al suggested acceptable norms of tooth axial inclinations for adolescents with untreated normal occlusions. However, studies examining panoramic radiographs as a means of investigating changes in axial inclination after orthodontic treatment are lacking in the literature. Therefore, 2 main questions arise: (1) do the axial inclinations of maxillary anterior teeth in patients with malocclusions differ significantly from those of pa-
tients with normal untreated occlusions and (2) does orthodontic treatment change the axial inclination of maxillary anterior teeth to suggested norms? The purposes of this study were to evaluate, with panoramic radiographs, the mesiodistal axial inclinations of the maxillary anterior teeth at the beginning (T1) and end (T2) of nonextraction orthodontic treatment and to compare the results with the mesiodistal axial inclinations of a control sample with normal (acceptable) occlusions.

MATERIAL AND METHODS

The experimental sample consisted of 80 radiographs of 40 patients (20 male, 20 female) from a private dental office. All patients were white, with an initial mean age of 14 years (range, 11-17 years). Radiographs were taken at T1 and T2. The sample was selected according to the following criteria:

1. All radiographs were taken with the same machine by the same operator.
2. All patients had Angle Class I malocclusions (canine and molar relationships), maximum overbites of 3 mm, maximum overjets of 1 mm, and no more than 4 mm of crowding.
3. All subjects were treated orthodontically with a standard edgewise technique without extractions by the same clinician.
4. The maxillary incisor brackets were angulated, as proposed by Holdaway,11 mesiodistally 3°, and the maxillary canine brackets were angulated 5°.
5. All permanent teeth were present with the possible exception of third molars (no loss or agenesis of any permanent teeth).

A control sample was obtained from the files of the University of São Paulo (Bauru) Growth Study. It comprised 42 white subjects (14 male, 28 female) ranging in age from 12 to 17 years. All subjects had untreated normal (acceptable) occlusions, with a full complement of teeth (except third molars), Class I canine and molar relationships, maximum overbites of 3 mm, and maximum overjets of 1 mm.

Panoramic radiographs were taken under standard conditions4,5-10 with a cephalostat, with the clinical Frankfort horizontal plane parallel to floor and the facial midline plane in a vertical position.8

For each patient in the experimental group, panoramic radiographs were taken at T1 and T2; for subjects in the control group, only 1 radiograph was used. The mean period between T1 and T2 was 1.6 years. No additional panoramic radiograph was taken during treatment.

The inferior outline of the orbits and the contours of the anterior maxillary teeth were traced on acetate paper over each radiograph by 1 investigator (R.R.A.P.), and the tracings were verified by another (A.P.). The reference line used passed through the most inferior points of the right and left orbits.2,12 The angles formed by the upper reference line and the long axes of the teeth (longest extension of the root canal) were measured on each radiograph. Figure 1 shows the anatomic structures, references lines, and angular measurements used in this study.

Statistical analysis

All statistical analyses were performed with a commercial statistical package (*SIGMA STAT, Statistical Software for Windows, version 1.0, SPSS, Chicago, Ill) Means and standard deviations for each tooth were calculated to enable characterization of both groups. A nonparametric test was chosen because the data were nonhomogeneous and might not have been normally distributed, perhaps because the number of the subjects was small. Therefore, all comparisons were carried out by the Mann-Whitney U-test. Significance was defined as $P < .05$ and $P < .01$.

To assess the error of localizing the reference points and the manual procedure, 20 randomly selected radiographs were retraced and remeasured by the same examiner (R.R.A.P.) about 4 weeks later. The casual errors were assessed by using Dahlberg’s formula, and the systematic errors were ascertained by using paired t tests.13 The casual error of the method (Dahlberg’s formula) did not exceed 0.70°. Paired t tests did not show statistically significant differences for systematic errors ($P < .05$).

RESULTS

The mean values of the mesiodistal axial inclination at T1 and T2, the significance tests of comparisons between T1 and T2, and both comparisons to the mesiodistal axial inclination of the normal control sample are shown in Tables I, II, and III and in Figure 2.
The results demonstrated statistically significant differences between the mean values at T1 and T2 for the maxillary left central and lateral incisor and left canine. The comparison of the treated group at T1 and the control group also demonstrated statistically significant differences for mesiodistal inclinations of the same teeth (maxillary left central and lateral incisor and left canine).

The mean values of the treated group at T2 were compared with the mesiodistal axial inclinations of the control sample, and the results did not show statistically significant differences (Table II).

### DISCUSSION

Panoramic radiographs are routinely used in orthodontic practice to provide important information about teeth, axial inclinations, maturation periods, and surrounding tissues. Therefore, panoramic radiographs seem to be an indispensable orthodontic screening tool. However, as in any radiographic method, the dimensions of structures in panoramic radiographs are magnified. Larheim and Svanaes emphasized that horizontal measurements were unreliable. Angular measurements, such as axial tooth inclinations, are not as variable.

Accurately assessing mesiodistal tooth inclination with panoramic radiograph is possible. To prevent distortion and magnification of the images, we were careful to obtain a standard exposure and to ensure proper patient posture. We evaluated only maxillary anterior teeth, because panoramic radiograph images of other regions, especially the premolar area, might be of dubious value, as McKee et al stated.
Evaluating the axial inclinations of teeth has significant relevance to orthodontics. Orthodontic treatment objectives include obtaining functional occlusion, esthetics, and stability. A criterion for obtaining a functional occlusion is to have ideal axial inclinations of all teeth after active treatment. Another goal of orthodontic treatment is to establish appropriate axial inclinations of the teeth with near parallel roots. This has special significance for orthodontically closed extraction sites, which are more prone to open if adjacent teeth are not parallel.1-7

To our knowledge, no study in the literature has evaluated, through panoramic radiographs, the mesiodistal axial inclinations in patients with malocclusions. Mlynarska-Zduaniak16 established means and standard deviations of inclination of the axes of the teeth and the buds of permanent teeth in panoramic radiographs in normal occlusions in the early period of tooth exchange. This has special significance for orthodontically closed extraction sites, which are more prone to open if adjacent teeth are not parallel.2-7

In response to our first question, the results demonstrated statistically significant differences between the mean values at T1 from those with normal untreated occlusions (Table II). Consequently, orthodontic treatment should change these tooth inclinations to achieve functional occlusion and stability. The results also showed that treatment successfully changed the mesiodistal axial inclinations of the teeth once there were statistically significant differences between the mean values at T1 and T2 (Table IV).

Clinical considerations

Correct mesiodistal inclination of teeth after orthodontic treatment has been attempted by several methods. From artistic loops in rectangular archwires, welding brackets to bands in angulated position as suggested by Holdaway,11 to the direct bonding of brackets following the same principles, the search for simplification with no loss of quality is ongoing.

Despite these resources, individuality often prevails, and some adjustments are required. Thus, special attention should be given to positioning the brackets, because the teeth might have adequate mesiodistal axial inclinations at the onset of treatment and thus require customization of the appliance. Thus, attachments should be positioned parallel to the incisal edges when there is good tooth positioning, with a view to maintaining the initial axial inclination. With regard to treatment with the straight-wire technique, which makes use of programmed brackets with ideal angulations, customization of the appliance might be adequate. Further investigations are required to evaluate axial inclinations after orthodontic treatment with the straight-wire technique.

Furthermore, mesiodistal tooth inclinations should be evaluated at posttreatment, to control possible orthodontic relapses. A longitudinal panoramic radiograph clinical study is being conducted to investigate mesiodistal axial inclinations in orthodontically treated patients with 4 first premolar extractions to verify whether mesiodistal axial inclinations at T2 remained stable 5 years later, and whether the changes in the axial inclinations in the anterior mandibular teeth could be an important factor that affects crowding.

CONCLUSIONS

After assessing mesiodistal axial inclinations on pretreatment and posttreatment panoramic radiographs and comparing them with control radiographs, we drew the following conclusions.

- The mesiodistal axial inclinations of maxillary anterior teeth at T1 were different from those observed in a normal occlusion for 50% of the evaluated teeth.

<table>
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<tr>
<th>Table IV. Mann-Whitney test for treated group at T1 and T2 comparison</th>
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<tr>
<td>Tooth</td>
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<td>Maxillary right lateral incisor</td>
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<td>Maxillary left central incisor</td>
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<td>Maxillary left lateral incisor</td>
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<td>Maxillary left canine</td>
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NS, Not significant; *P = 01.
• Inclinations at T2 were consistent with the normal anatomical configuration of untreated normal subjects.
• The panoramic radiograph proved to be an important and valuable tool for assessing mesiodistal axial inclination. This radiograph should be evaluated before treatment so that teeth with incorrect inclinations can be corrected. Furthermore, if a panoramic radiograph is taken before appliances are removed, changes in axial inclination can easily be made.

REFERENCES

COMMENTARY
The significance of appropriate mesiodistal angulations of the teeth in completed orthodontics patients has been highlighted by many clinicians.1-4 It has been reported that the final spatial orientation of each tooth should be such that it can best withstand the forces during function.3-5 There are no absolute rules that can be assumed when describing tooth inclinations; however, statistical data in anatomical specimens and non-orthodontic normal occlusions have been collected and analyzed.3-4 Andrews4 might have been the first to give a quantitative assessment of tooth angulation as a key for normal occlusion. This concept played a role in the development of the straight-wire appliance.

The significance of corrected angulation in 3 planes is now universally accepted, and several related parameters have been studied. These include periodontal health,6 proper interproximal contact establishment, tight posterior occlusion, no spaces, occlusal force distribution, and retention and stability.4,5,7-9 The American Board of Orthodontics has included assessment of mesiodistal angulation as a parameter for evaluating finished cases for orthodontists aspiring to be board certified.10 The authors state that the relevance of this project arises from the need for objective quantification of changes in axial inclinations from orthodontic treatment.

The authors did not formulate a stringent methodology for a sound project design. The inclusion criteria for the experimental group mandate screening for Bolton discrepancies, skeletal asymmetries, history of trauma, history of previous interceptive orthodontic treatment, and dilacerations, because these factors might be confounding variables. An evaluation of the Bolton discrepancy is essential in subject selection for this study because minor tooth-size discrepancies are masked by variations in mesiodistal angulations at the end of treatment.11 The study by Tuveron12 was cited to substantiate this, but the authors did not include it in their selection criteria. In a more precise study, Hussels and Nanda13 discussed the quantitative effects of incisor angulation on arch length. Any skeletal asymmetries should have been recorded during initial subject selection because all measurements were based on a plane along the inferior border of the orbits. Either trauma or previous orthodontic treatment can influence axial inclination and should have been addressed in the patient histories for the experimental sample. These should have served as exclusion criteria. Crown-root angulations in the mesiodistal plane should also be assessed before starting treatment. Although dilacerations are extreme deviations in crown-to-root angula-