Original Article

Canine angulation in Class I and Class III individuals: A comparative analysis with a new method using digital images*

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Abstract

Objectives: This study aimed to determine the mesiodistal angulation of canine crowns in individuals with Class III malocclusion in comparison with Class I individuals. **Methods:** Measurements were taken from digital photographs of plaster models and imported into an imaging program (Image Tool). These procedures were repeated to assess random method error (Dahlberg's formula), and analyze reproducibility by intraclass correlation. The sample consisted of 57 patients with complete permanent dentition, untreated orthodontically and divided into two groups according to their malocclusion: Group I consisted of 33 patients with Class I malocclusion, 16 males and 17 females, mean age 27 years; Group II comprised 24 patients with Class III malocclusion, 20 males and 4 females, mean age 22 years. **Results:** Random error for canine angulation ranged from 1.54 to 1.96 degrees. Statistical analysis showed that the method presented an excellent reproducibility ($p<0.01$). Results for canine crown angulation showed no statistically significant difference between maxillary canines in the Class I and Class III groups, although canine angulation exhibited, on average, 2 degrees greater angulation in Class III individuals. Mandibular canines, however, displayed a statistically significant difference on both sides between Class I and Class III groups ($p = 0.0009$ and $p = 0.0074$). Compared with Class I patients, angulation in Class III patients was lower in mandibular canines and tended to follow the natural course of dentoalveolar compensation, routinely described in the literature. **Conclusion:** The results suggest that dental compensation often found in literature involving the incisors region, also affects canine angulation, especially in the lower arch.

Keywords: Mesiodistal angulation. Canine. Class III malocclusion. Class I malocclusion.

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INTRODUCTION

Inclination and angulation have been the subject of orthodontic studies since the days when Angle[4] systemized orthodontic treatment by developing the edgewise appliance, where inclinations and angulations are controlled through bends in the archwires, which are inserted in bracket slots.

Some time ago, orthodontists realized the advantages of bracket angulation,[10] but no consensus has been reached concerning the appropriate amount of angulation for each tooth. Thus, the possibility arose of designing individual brackets for each type of tooth, employing archwires with no bends, or manufacturing brackets tailored for each individual patient.

A key step in this direction was the study on "The Six Keys to Normal Occlusion," describing six common characteristics of 120 models of optimal natural occlusion, which should be the goals of orthodontic treatment.[2] In this study, the second key concerns tooth crown angulation. By analyzing the angle formed by the intersection of the buccal axis of the clinical crown with a line running perpendicular to the occlusal plane and passing through the center of the clinical crown, it was found that clinical crowns are usually angulated mesially at varying degrees, depending on the group of teeth being examined. In this study, dental crown angulation was determined by measuring the angle formed between clinical crown and occlusal plane. Models were cut beforehand in the center of the clinical crowns with the aid of a plastic protractor. A recent study examined 61 study models with normal, natural occlusion in Brazilians,[12] and showed that most individuals exhibited only one to three occlusion keys. The most frequently observed characteristics were curve of Spee (100%), tight proximal contacts (42.6%) and proper dental crown inclinations (34.4%). Mesial angulation of dental crowns was found in 27.9% of the sample.

The Straight-Wire technique makes use of brackets preadjusted or tailored for each individual tooth, allowing each tooth to be ideally positioned until treatment completion. Since its inception, the original proposal[2] provided, in addition to the use of standard brackets in many patients, for the use of different prescriptions to suit the different types of malocclusion, treatments and the desired or possible positioning of the teeth after treatment. In other words, the tailoring of a customized orthodontic appliance according to the features of each malocclusion. The concept of normality and the potential of orthodontics have been redefined since the 1970s, when these precepts were formulated.

Originally, compensations[3] were related to inclinations (torque) on incisor brackets to compensate for the skeletal discrepancies that had not been addressed in their entirety during orthodontic treatment. In the case of Class III malocclusion, a buccal torque was applied to maxillary incisors and a lingual torque on mandibular incisors. Changes induced in the arches derive from dental compensation in cases of skeletal malocclusion, as reflected in the buccolingual tipping of the teeth in the opposite direction of the skeletal error. Thus, many cases of mild skeletal Class III malocclusion, that do not require surgical treatment, could be solved simply by performing dental compensation at the end of treatment. Achieving such outcome would require case customization since each patient has unique skeletal and dental characteristics.[5] Thus, manipulating canine angulation can play an important part in compensating for orthodontic skeletal error.

One of the many changes made to the original system calls for modifying canine angulation in cases of compensation. Angulations of 8° and 5° for maxillary and mandibular canines, respectively, in treating Class I malocclusion, were changed to 11° on maxillary canines while mandibular canines were left with no angulation whatsoever in treatments aimed at compensating for Class III malocclusions.[5] The purpose of these changes was to increase or maintain the perimeter of the upper arch and reduce or maintain the perimeter of the lower arch, thereby encouraging the creation of an anterior positive overjet, introducing greater compensation and increasing the potential for malocclusion correction, despite the skeletal error.

Despite growing interest in modifying tooth angulation and inclination described by the study on the six keys to normal occlusion[2], few studies have examined the reliability of the measurements when employing a particular method. Although several methods have been described for measuring tooth inclination (torque),[2,6,9,13,14] few investigations have evaluated the error inherent in the method used to analyze tooth angulation.[14]

A recent study[6] described a new method to measure tooth angulation and torque using volumetric computed tomography (VCT). To this end, tomographic slices were made of the anterior teeth of two individuals with facial patterns II and III, respectively. After evaluation, it was concluded that computed tomography (CT) can be a useful means for evaluating tooth torque and angulation, greatly contributing to research involving tooth positioning as well as orthodontic treatment customization since it enables professionals to check tooth positioning on an individual basis. Furthermore, it is a distortion-free test. However, these tooth angulation measurements on models and CTs should be made with caution because these are relatively new methods that still require further studies to prove their efficacy and, particularly, reliability. The risk radiation and high cost of CT scans should also be emphasized.

A device was recently introduced, which was specifically designed to measure the angulation and inclination of dental crowns.[14] Plaster models were attached to a table and the long axis on the crown of each tooth was determined. Once each model had been correctly positioned and attached, the table was rotated in L shape until the long axis of each tooth crown coincided with a marking made centrally in a magnifying glass, which was fixed to the table. The number of gear teeth, rotated from its zero point (previously defined during device calibration), corresponded to the value of each angle, as it was measured. Reproducibility was confirmed by analysis of systematic error using Student's t-test. The random error observed in tooth angulation measurements ranged between 0.30 and 1.33. With the advent of this new device it became possible to establish mean angulation and inclination values for dental crowns of Brazilian patients with normal occlusion. The results revealed a mean angulation of 7.13° for maxillary canines and 2.43° for mandibular canines.

Compensatory orthodontic treatment of Class III malocclusions requires the identification of these initial compensations, which are present prior to treatment and should be maintained or enhanced whenever possible. Thus, it seems reasonable to believe that canine crown angulation facilitates incisor positioning and promote natural dental compensation in Class III malocclusion cases. This occurs when maxillary canines are angulated more mesially, allowing maxillary incisor proclination, while mandibular canines should be uprighted, enabling mandibular incisor retroclination and preventing or minimizing anterior crossbite.[5] However, what seems like clinical evidence, and is built into the prescriptions of brackets used in cases where it is possible to maintain or increase any compensation naturally observed in Class III individuals, actually requires further scientific assessment to support or not the changes incorporated into the orthodontic appliances used for this purpose. Simple methods to allow orthodontists to identify whether or not these natural compensations do exist, or even to quantify them reliably, would enable clinicians to expand this concept in a scientifically sound manner.

MATERIAL AND METHODS

The sample used in this study was selected from private orthodontic practices and consisted of 57 patients in the stage of permanent dentition.

With the purpose of conducting a comparative analysis of permanent canine angulations among Class I and Class III individuals, the sample was divided into two groups. The first group was comprised of 33 Class I patients with incipient orthodontic problems, i.e., cases where orthodontic treatment would be limited to minor movements (closure of diastema, mild crowding, posterior molar crossbite, among others), without previous orthodontic treatment (Fig 1). The second group consisted of 24 individuals with Class III malocclusion (Fig 2). Patients with tooth loss, agenesis, bimaxillary protrusion, syndromes and moderate or severe crowding were excluded from the sample because these factors might affect canine angulation.

Canine angulations were obtained from standardized digital photographs of each quadrant of the initial plaster models of the sample patients, taken with a digital camera (Canon Rebel 6.0 megapixels, Tokyo, Japan) with a 18-55 mm lens. (Fig 3). These models were placed on a glass plate (A), at a distance of 20 cm from the camera (B). At the bottom of each model a black device was placed with a marking in the center, used as reference to centralize the canines (C). The camera lens was laid on a wax plate in order to optimize lens direction (D).

A total of 228 photographs were taken and exported to a computer program (Adobe Photoshop 7.0) in order to draw the occlusal plane (Fig 4). Those images were subsequently imported into an imaging program (UTHSCSA ImageTool™ software, University of Texas Health Science Center, San Antonio, Texas, USA) where permanent canine angulations were measured. The occlusal plane was drawn from the midpoint between the

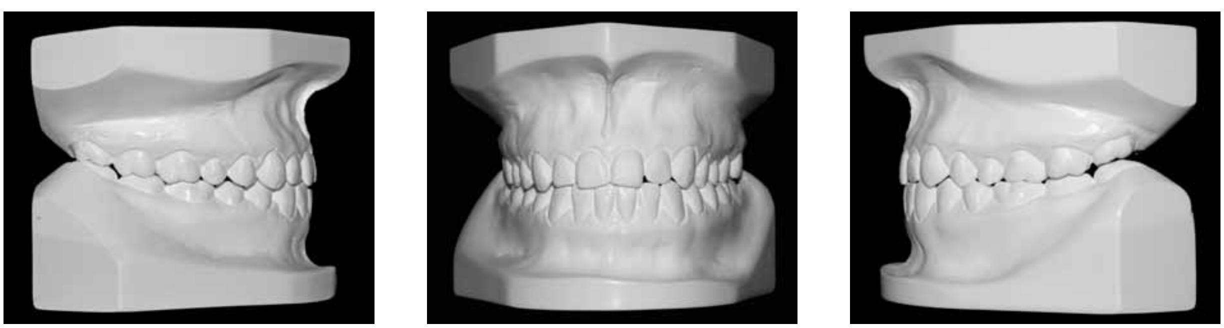

FIGURE 1 - Plaster models of a Class I individual with incipient malocclusion, used in the sample.

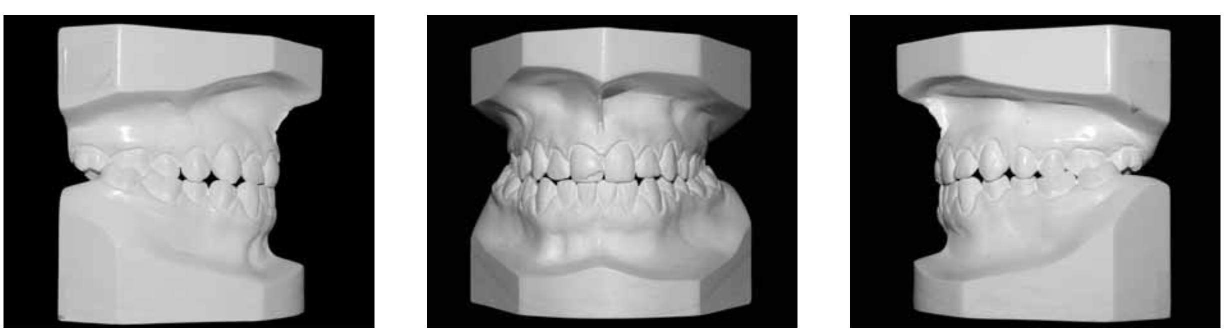

FIGURE 2 - Plaster models of a Class III individual included in the sample.

central incisors to the mesiobuccal cusp of the first permanent molar. Subsequently, Image Tool was used to trace the long axis on the clinical crown of the canine, and from the intersection of these two lines (occlusal plane and long axis) the angulation value for the clinical crown on the plaster model was obtained (Fig 4).

To analyze the method error, the initial plaster model quadrants of all patients were photographed again 30 days later and all the steps previously described were repeated to obtain new canine angulation measurements.

The random error was calculated according to Dahlberg's formula ($S^2=\sum d^2/2n$) and an analysis of the reproducibility of the measurements was performed using the intraclass correlation test, both with a confidence level of 95%. One outlier with a value far below the other measurements taken for tooth 43, in the Class III group, was excluded from the evaluation.

Means, standard deviations, mean differences, analysis of the normal distribution and independent t-test were used to detect differences between canine angulations in the Class I and Class III groups.

RESULTS

At first, normal distribution was observed for canine angulations in both groups ($p> 0.05$) (Table 1). Random error difference ranged from 1.54 to 1.96 between measurements (Table 1). Regarding the reproducibility analysis (intraclass correlation), statistical analysis revealed excellent method reproducibility

Canine angulations in both groups were analyzed by comparing the measurements of each canine in the Class I groups with its analogue in the Class III group.

Results showed that mean angulations of right maxillary canines in the Class I group ($x=7.92°$) were not statistically different ($p=0.22$) when compared with the means for the same teeth in the Class III group ($x=9.97°$) (Table 2).

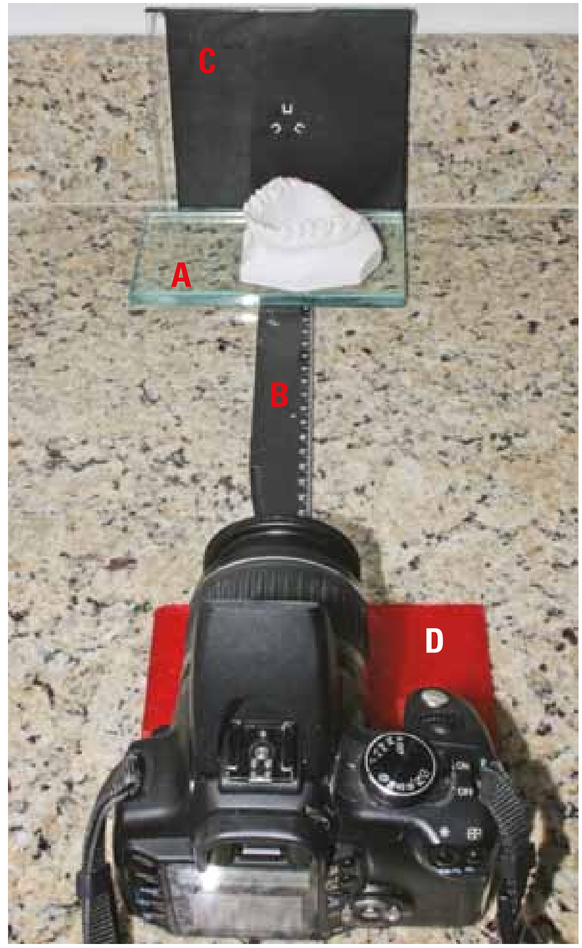

FIGURE 3 - Method used for standardizing photographic snapshots of the plaster models: A= 10 mm glass plate, B= 20 cm millimeter ruler, C= black plastic plate with mark indicating the center of the object (back sleeve of a compact disc/CD), D= wax plate.

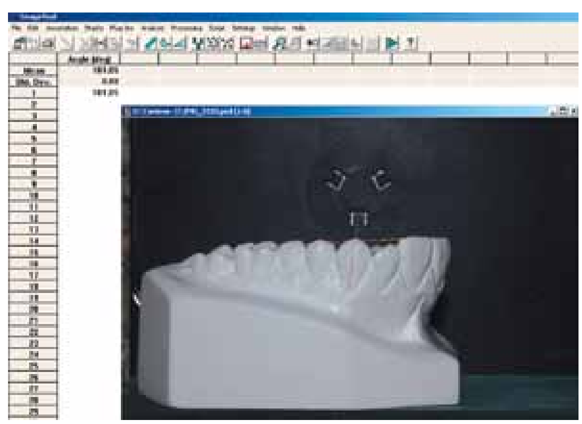

FIGURE 4 - Photograph of the study model exported to the imaging program used to obtain the canine angle measurements.

TABLE 1 - Random error (Dahlberg's formula), method reproducibility (intraclass correlation) and normal distribution analysis of values obtained for canine angulations in Class I and Class III groups.

	CLASS I				CLASS III			
Tooth	13	23	33	43	13	23	33	43
Random error	1.77	1.74	1.73	1.55	1.54	1.96	1.53	1.65
Intraclass correlation	0.91**	0.92**	0.94**	0.96**	0.95**	0.93**	0.93**	0.96**
Level of reproducibility	EXC	EXC	EXC	EXC	EXC	EXC	EXC	EXC
Normal Distrib. (P value)	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05	>0.05

** p<0.01; EXC= Excellent reproducibility.

TABLE 2 - Angulation means (angle complement), standard deviations (SD), mean differences and p value (independent t-test) in groups I and Class III.

	CLASS I		CLASS III		CLASS I X CLASS III	
Tooth	Mean	SD	Mean	SD	Diff. between means	p-value
13	82.08 (7.92°)	5.81	80.03 (9.97°)	6.61	2.04	0.22(ns)
23	81.87 (8.13°)	6.10	79.90 (10.1°)	6.89	1.97	0.26(ns)
33	86.73 (3.27°)	6.99	92.78 (-2.78°)	5.48	-6.04	0.0009**
43	86.22 (3.78°)	7.87	91.67 (-1.67°)	7.60	-5.45	0.0074**

ns= non-significant; ** p<0.01.

Mean angulations of left maxillary canines in the Class I group (x=8.13°) were not statistically different either (p=0.26), when compared with the means for the same teeth in the Class III group (x=10.1°) (Table 2).

Furthermore, mean angulations of right mandibular canines in the Class I group (x=3.78°) were statistically different (p=0.007) when compared with the means for the same teeth in the Class III group (x=-1.67°) (Table 2). Mean angulations of left mandibular canines in the Class I group (x=3.27°) were also statistically different (p=0.0009) when compared with the means for the same teeth in the Class III group (x=-2.78°) (Table 2).

In summary, the clinical crowns of maxillary canines were similarly turned mesially in both groups, although slightly more pronounced in Class III individuals. Moreover, mandibular canines in the Class I group had their clinical crowns turned mesially, while their analogues in the Class III group were either upright or had their clinical crowns turned distally (Figs 5 and 6).

DISCUSSION

The primary aim of this study was to examine whether there were differences in permanent canine angulations among individuals presenting with Class I and Class III malocclusions using a simplified method that made use of photos scanned from plaster models and exported to an image manipulation program for simple angle reading (Image Tool).

There have been few studies on the degree of reliability of measurements taken from models, perhaps because this was originally considered a direct method. However the modifications used in this study showed that the method used to measure canine crown angulations, as well as being very simple to use, is remarkably reproducible, displaying a random error of less than 2° (Table 1).

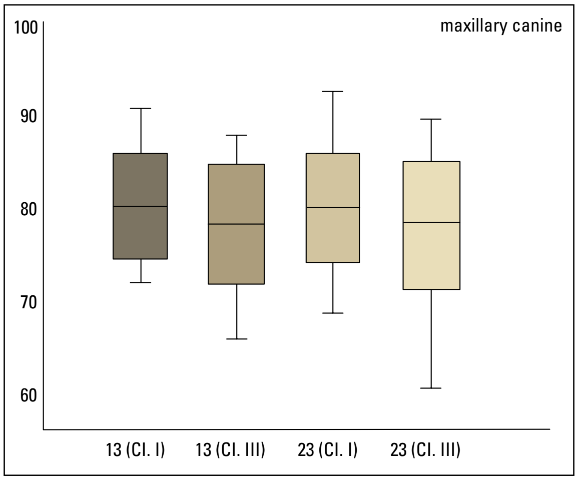

FIGURE 5 - Boxplot for values of maxillary canine angulations in the Class I (Cl. I) and Class III (Cl. III) groups.

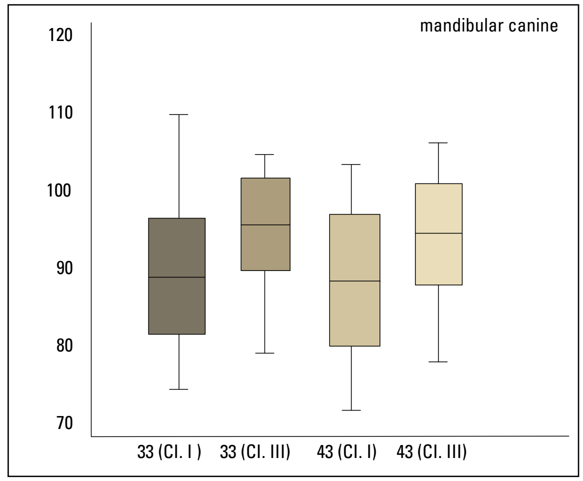

FIGURE 6 - Boxplot for values of mandibular canine angulations in the Class I (Cl. I) and Class III (Cl. III) groups.

A few methods have been described to measure tooth angulation, some are simple to employ such as measurements taken directly from the models using a plastic protractor,[2] while others require major technological resources, such as computed tomography.[6]

Thanks to advances in technology, dentistry has benefitted from modern computer programs that simplify diagnosis. Grounded in this premise, this study employed a computer imaging program capable of accurately reading canine angulation from standardized digital photographs of plaster models. This methodology differs from the original proposal that led to the development of preadjusted brackets.[2] One major difference refers to the occlusal plane, which in this study is represented by a line linking the midpoint between the incisors and the mesiobuccal cusp of the first molar. This plane is not always parallel to that of Andrews, notably in cases of malocclusion.

Correctly defining the mesiodistal angulation of teeth after treatment has been the goal of many researchers. The values found by Andrews[2] and described as normal, 11 degrees for maxillary canines and 5 degrees for the mandibular canines, both positive, were crucial factors in the development of a fully programmed orthodontic appliance called Straight-Wire. It was designed to impart to brackets certain features to ensure that teeth would be properly positioned at the end of orthodontic treatment.

However, given that the occlusal and skeletal characteristics of each patient are unique and individual, all cases should not be finished in the same manner. Thus, some adjustments in the original Straight-Wire concept became necessary. Since this realization, many orthodontists have begun to customize brackets according to their clinical experience in view of the morphological diversity inherent in the dentofacial complex. Most of these changes were introduced without any scientific support.

Even Andrews[3] incorporated some changes into the torque of incisor brackets to compensate for the skeletal discrepancies that had not been addressed in their entirety during orthodontic treatment. In the case of Class III malocclusion, more buccal torque was applied on maxillary incisors and more lingual torque on mandibular incisors. Based on Andrews'[3] ideas, other authors[5] have advocated brackets with different angles and inclinations for Class I, II and III malocclusions. These brackets appeared after changes were made to Andrews'[3] brackets. The main variations to the original model relate to canine angulations to facilitate the torque compensation applied to the central incisors while keeping incisor torque compensations.

Class III malocclusion is significantly different from sagittal malocclusions to the extent that in most cases patients present a natural dental compensation. Thus, in cases of Class III malocclusion, maxillary incisors are more angulated than in Class I malocclusion. Class III malocclusion brackets were therefore prescribed whenever this problem proved amenable to being solved by means of dental compensation, through orthodontic treatment alone, without the need for surgery.[5] For this purpose, an 11° angulation was applied to maxillary canines (three degrees above standard) and 0 degree to mandibular canines (five degrees below standard). These changes aimed to increase the perimeter of the upper arch and reduce the perimeter of the lower arch to help develop an anterior positive overjet or the maintenance of any pre-existing compensation.

The results achieved in this study disclosed that maxillary canine angulation was similar in both groups, although canine angulation was slightly increased, by nearly 2 degrees, in the Class III group (Table 2, Fig 5). The results for mandibular canines revealed statistically significant differences between the two groups, with smaller canine angulation in Class III subjects ($p = 0.0009$ for tooth 33 and $p = 0.0074$ for tooth 43). Therefore, the results highlighted differences in natural canine angulation in Class I vs. Class III individuals, thereby lending support to the prescription advanced by Capelozza Filho et al[5] while confirming the finding that the incisor compensation seen in cephalometric studies of Class III patients described in the literature[1,7,11] appear to be accompanied by changes in canine angulation.

This study found a mean angulation of 10.03° for maxillary canines and -1.75° for mandibular canines in the Class III group. These measures are very close to the measures suggested for use in compensatory brackets recently introduced[5] for Class III brackets (11 degrees for upper and 0 degree for lower canines). The Class I group displayed a mean angulation of 8.02° for maxillary and 3.5° for mandibular canines, whereas Capelozza et al[5] prescribes a mean angulation of 8° for upper and 5° for lower canines. It should be noted, however, that the measurements obtained in this study were taken from individuals with malocclusion, although every effort was made to avoid interference from other confounding factors such as crowding, bimaxillary protrusion and tooth loss, while seeking to deal with incipient Class I malocclusions.

Even individuals with normal occlusion failed to exhibit all mesial angulations, as described in the original study.[2] A recently published study[12] found that only 27.9% of the examined models displayed correct dental crown angulations. This means that tooth positioning changes depending on the type of malocclusion and that this factor is very important when orthodontic treatment is aimed at correcting skeletal errors by way of dental compensation. In these cases, special attention should be paid to canine angulation because if such angulation proves beneficial for treatment it should be maintained or even enhanced.

The mean angulations found in this study support the idea of inserting modifications in the slot angulation of canine brackets. However, analysis of data dispersion revealed a significant standard deviation (Table 2) and wide total range (minimum and maximum values) (Figs 5 and 6), which justified the need for customizing canine angulation even before the orthodontic appliance had been installed. The wide variability found in this study can be ascribed, among other factors, to a heterogeneous canine crown morphology.[8] Clinically, brackets with compensatory prescriptions may be used but orthodontists should customize each clinical case, increasing or reducing these offsets accordingly. For cases where the need arises to measure pre-existing tooth angulations, it is believed that the method described in this article provides sufficient reliability to justify its use.

CONCLUSIONS

Based on the data described above it can be concluded that:

1. The method showed excellent repeatability, with no differences between the two measurements, and relatively small random error (<2°).

2. Statistically significant differences were found in the angulation of permanent canines between individuals with Class I and Class III malocclusions, especially in mandibular canines. Such differences are in line with natural compensations for Class III incisor inclination, widely described in literature.

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