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Avaliação da angulação e inclinação coronárias com modelos digitais em pacientes tratados ortodonticamente

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Tese de Doutorado apresentada ao Programa de Pós-Graduação em Ciências da Saúde da Universidade Federal de Goiás para obtenção do Título Doutor em Ciências da Saúde.

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Ainda não saberia como declarar
O que dedicaria a quem devo cultivar
À família querida, filiados e genitor (a)
Dedicarei a minha vida e o eterno amor

Vida que semeia aspirações
Onde cultivo amigos verdadeiros
Ficam as grandes emoções
E os convívios derradeiros

Ao colaborador, mestre e professor
A grande esperança
De um pequeno sonhador

À ciência e ao criador
A crença
De um filho seguidor

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SUMÁRIO

TABELAS E FIGURAS

SÍMBOLOS, SIGLAS E ABREVIATURAS

2D	Bidimensional
3D	Tridimensional
TCFC	Tomografia computadorizada de feixe cônico
z	Grau de confiança
e	Erro máximo
S	Desvio padrão
n	Tamanho da amostra
%	Porcentagem
º	Graus
STL	Standard Triangle Lines
C	Ponto cervical
D	Ponto distal
I	Ponto incisal
M	Ponto mesial
ENA	Espinha nasal anterior
OE	Orbitário esquerdo
PD	Pório direito
PE	Pório esquerdo
PI	Ponto interincisivo
POD	Ponto oclusal direito
POE	Ponto oclusal esquerdo
®	Marca registrada
IL	Illinois
Inc	Incorporation
$\pm$	Variação estatística de desvio padrão (para mais e para menos)
*	Asterisco
r	Coeficiente de correlação de Pearson
p	Nível de significância
$\bar{x}$	Média
<	Menor
mm	Milímetros

RESUMO

Introdução: A incorporação de novas alternativas e métodos aplicáveis à ortodontia para a análise da angulação e inclinação coronária constitui um verdadeiro desafio. A contribuição de ferramentas que permitem análises tridimensionais tem sido gradativamente incorporada à pesquisa odontológica. **Objetivo**: O presente estudo avaliou a inclinação e a angulação coronária em pacientes tratados ortodonticamente usando modelos digitais e tomografia computadorizada de feixe cônico. **Metodologia**: Com o módulo de cefalometria tridimensional do Software VistaDent 3D foi criado análise cefalométrica para avaliar a inclinação e angulação coronária em modelos digitais de 26 pacientes, exceto segundos e terceiros molares. Para obter os resultados de angulação e inclinação coronária com base nos planos de Camper e Frankfurt, foram necessárias documentações de pacientes com imagens tomográficas finais. Foi utilizado o *teste t-Student* para comparar as médias intra e intergrupo e o coeficiente de correlação de Pearson para avaliar os resultados entre os grupos Camper, Frankfurt e oclusal. **Resultados**: A análise da reprodutibilidade do método não revelou diferença estatisticamente significante. Quanto à avaliação intragrupo, antes e depois do tratamento ortodôntico, os incisivos laterais inferiores, primeiro molar inferior direito, os caninos, primeiros e segundos pré-molares apresentaram diferenças estatisticamente significantes para inclinações. Primeiro molar superior direito e inferior esquerdo, segundos pré-molares inferiores, primeiro premolar inferior direito e incisivos laterais inferiores apresentaram diferenças estatisticamente significantes para angulações. Quanto à avaliação intergrupo, depois do tratamento ortodontico e prescrições, todos os resultados de inclinação e angulação apresentaram diferenças estatisticamente significantes, exceto a angulação dos segundos pré-molares superiores e primeiros molares inferiores. O estudo aponta que entre os planos Camper-oclusal, Camper-Frankfurt e Frankfurt-oclusal as medidas de inclinação coronária para incisivos e caninos não apresentaram correlação, outros correlação fraca ou inversa. Os resultados da angulação coronária apresentaram forte correlação, exceto incisivos centrais inferiores e laterais superiores que demonstraram moderada correlação para Camper-oclusal e Frankfurt-oclusal. **Conclusão**: A angulação e inclinação coronária podem ser mensuradas por meio de modelos digitais e os resultados sugerem a necessidade de dobras adicionais no fio ortodôntico para obtenção de angulação e inclinação coronária com valores próximos aos preconizados em braquetes pré-ajustados. As medidas de angulação e inclinação coronárias apresentaram correlacionadas quando avaliadas pelos planos de Camper, Frankfurt e oclusal, exceto a inclinação dos incisivos e caninos.

Palavras-chave: ortodontia corretiva, modelos digitais, cefalometria, inclinação, angulação, tomografia computadorizada de feixe cônico.

ABSTRACT

Introduction: The incorporation of new alternatives and methods apply to the orthodontics for the analysis of crown angulation and inclination is a challenge. The contribution of tools that enable three-dimensional analysis has been gradually incorporated into dental research. **Objective**: This study evaluated the crown inclination and angulation of patients in orthodontic treatment using digital models and cone beam computed tomography. **Methodology**: With the three-dimensional cephalometric software was created cephalometric analysis to evaluate the crown angulation and inclination in digital models of 26 patients, except second and third molars. For the results of crown angulation and inclination based on Camper and Frankfurt plans were required cone beam computed tomography images. Student's t- test was used to compare the intra and inter-group averages and Pearson's correlation coefficient used to evaluate the results between the groups Camper, Frankfurt and occlusal. **Results**: The analysis of the reproducibility of the method did not reveal a statistically significant difference. In assessing intra-group before and after orthodontic treatment the lower lateral incisors, the lower right first molar, the canine, and the first and second premolars presented statistically significant differences in crown inclinations. The upper right first molar and the lower left molar, the lower second premolar, the lower right first premolar, and the lower lateral incisors presented statistically significant differences in angulation. In the intergroup evaluation, post treatment and prescriptions, all of the results of the crown inclination and angulation presented statistically significant differences except the crown angulation of the second superior premolars and the first inferior molars. The study shows that between the Camper-occlusal, the Camper-Frankfurt and the Frankfurt-occlusal planes, the measures of the crown inclination for incisors and canine teeth did not present a correlation and other correlations were weak or inverse. The results of the crown angulation presented a strong correlation, except for central inferior incisors and upper lateral incisors, which demonstrated a moderate correlation to the Camper-occlusal and Frankfurt-occlusal planes. **Conclusion**: The crown angulation and inclination can be determined by means of digital models and it is evident that there is a need for additional bend to obtain crown angulation and inclination with values close to those recommended in preset brackets. The measures of the crown angulation and inclination presented correlations when evaluated by the Camper, Frankfurt and occlusal planes with the exception of the crown inclination of the incisors and canine teeth.

Key Words: cone beam computed tomography, digital models, cephalometry, orthodontic treatment.

INTRODUÇÃO

A análise de movimentação dentária baseada no encaixe de um fio ortodôntico em peças bandadas ao dente teve início com Edward Hartley Angle em 1925[1], quando desenvolveu o aparelho *Edgewise*[2]. Esse aparelho permitiu o controle das posições coronárias nos três planos do espaço ao inserir os arcos retangulares nas canaletas dos bráquetes. A partir desse princípio várias estratégias mecânicas e modelos de braquetes surgiram.

Andrews[3] estudou o posicionamento coronário ideal em modelos de gesso e mesmo que o grau de inclinação e angulação da coroa dentária não pudesse ser determinado, os estudos permitiram desenvolver o sistema de braquetes pré-programados com uso de arcos retos, denominado *straightwire*[4].

Observa-se carência de estudos como o de Andrews[4] que buscou analisar as inclinações e angulações coronárias individuais em cada grupo dentário. Posterior as prescrições propostas por Andrews[4], estudos indicaram alterações da inclinação e angulação coronária com base em observações clinicas[5,6,7,8,9], telerradiografias[10,11] e radiografias panoramicas[12,13,14].

O posicionamento dentário pode ser determinado em radiografias ou em imagens digitais com uso de programa*s* de cefalometria computadorizada[10,11,12,13,15]. Limitações atribuídas aos métodos radiográficos bidimensionais (2D) têm sido discutidas[11,12,13,14]. As telerradiografias laterais permitem avaliar apenas a inclinação dos incisivos centrais e angulação dos dentes posteriores, e com sobreposição de estruturas anatômicas; a radiografia panorâmica apresenta distorções e ampliação de imagens que limitam determinar a angulação e inclinação dentária[11,12,13,14].

Métodos de diagnóstico mais precisos e com maior detalhamento das estruturas em diferentes planos do espaço têm sido avaliados[11,12,14,15,16,17,18]. A tomografia computadorizada de feixe cônico (TCFC) e os modelos digitais permitem reconstruir virtualmente áreas anatômicas e arcadas dentárias com acurácia, fornecendo informações sobre o tamanho e a forma das estruturas[15,16,17,18]. A TCFC auxilia na determinação da inclinação e angulação coronária com mínimo de sobreposição de estruturas anatômicas[19,20]. No entanto, diretrizes internacionais recomendam o seu uso apenas em situações clínicas de impossível ou difícil diagnóstico com uso de exames 2D[20,21]. Com os modelos digitais e programas específicos para realizar mensurações surgem uma nova possibilidade de avaliação das inclinações e angulações coronárias, menos invasiva e com maior detalhamento das estruturas anatômicas[16,17,18].

A precisão entre modelos digitais e a cefalometria radiográfica foi previamente comparada para mensurar os movimentos dentários[15]. Os modelos digitais mostraram-se acurados e podem substituir a cefalometria radiográfica, incluindo a vantagem de evitar a exposição do paciente aos raios-X. Apesar do alto custo do escâner e programa, a diminuição dos espaços para guarda de arquivos dos pacientes[15], a facilidade de acesso e rapidez nas trocas de informações via internet com outros profissionais supera esta desvantagem[18].

A carência de estudos que avaliam as angulações e inclinações coronárias individuais com uso de cefalometria 3D, a dificuldade em desenvolver métodos que determinam com maior precisão a angulação e inclinação dos dentes e a incorporação de novas tecnologias foram aspectos que encorajaram este estudo.

OBJETIVOS

I. Comparar a inclinação e angulação coronária antes e depois do tratamento ortodôntico com uso de modelos digitais.

II. Com auxílio de TCFC, analisar a correlação das medidas de inclinação e angulação coronária dos grupos dentários com referência aos planos de Camper, Frankfurt e oclusal.

III. Determinar a diferença da angulação e inclinação coronária obtida por meio de modelos digitais após tratamento ortodôntico com prescrições de braquetes descritas na literatura.

MATERIAL E MÉTODOS

Cálculo da amostra

Ao optar pelo grau de confiança de 95%, o valor de z resulta em aproximadamente 1,96. Foram selecionados em estudo piloto seis (n = 6) pacientes para determinar o desvio padrão (S) e erro (e) das medidas de angulações e inclinações coronárias.

O cálculo da amostra indicou a necessidade de pelo menos 22 dentes para estimar as angulações e inclinações coronárias, com nível de significancia de 5%, desvio padrão de 5,9º e um poder do teste de 80%. No presente estudo optou-se por uma amostra de 26 pacientes, consequentemente menor erro e maior confiabilidade dos resultados.

Seleção da amostra

Trata-se de um estudo retrospectivo delineado a partir de arquivos e documentos obtidos em banco de dados de 26 pacientes que submeteram ao tratamento ortodôntico com base na técnica de arco reto (s*traightwire*), com prescrição de Roth[8], canaletas 0,022"x 0,028" e resultados almejados de acordo com as metas propostas pelas seis chaves da oclusão normal de Andrews[3]. Foram realizadas mensurações da angulação e inclinação coronária antes e depois do tratamento ortodôntico nos modelos digitais, exceto segundos e terceiros molares, o que resultou em 1248 medidas.

Os prontuários clínicos dos pacientes registravam um tempo médio de tratamento de 22 meses (S = $\pm$ 4,2) e idade média de 13 anos (S = $\pm$ 2) ao iniciar o tratamento ortodôntico. O fio ortodôntico de maior calibre utilizado foi o 0,019”x 0,025” de aço inoxidável.

Como critérios de inclusão para o estudo foram considerados pacientes com arquivos de modelos de estudos antes e depois do tratamento ortodôntico, com indicação de TCFC depois do tratamento ortodôntico para diagnóstico de possíveis anomalias ou acompanhamento longitudinal de patologias e fraturas maxilofaciais, dentadura permanente, má oclusão de Classe I de Angle e presença de apinhamento leve a moderado. Foram excluídos do estudo terceiros e segundos molares, pacientes com modelos de estudo danificados, com relato de lesão dental traumática, expansão rápida da maxila, extrações de dentes permanentes, periodontites, cáries, desgastes oclusais/incisais e com restaurações metálicas. O estudo foi previamente aprovado pelo Comitê de Ética em Pesquisa local (Universidade Federal de Goiás, Brasil, Parecer nº 392.806).

Método de avaliação da angulação e inclinação coronária

Os modelos de gesso obtidos antes e depois do tratamento ortodôntico foram escaneados em oclusão cêntrica com escâner de bancada (3Shape R700 – 3Shape A/S, Copenhagen, Dinamarca) e armazenados como arquivos formato *Standard Triangle Lines* (STL).

Os arquivos STL foram importados para o programa VistaDent 3D (Dentsply, Nova York, NY, EUA) e uma análise foi desenvolvida com o uso do módulo de cefalometria tridimensional para avaliar a inclinação e angulação coronária.

A partir de uma ferramenta específica do programa VistaDent 3D, três pontos de referência foram marcados na superfície dos modelos digitais para definir o plano oclusal e quatro pontos em cada elemento dentário (Figura 1):

I. Ponto cervical (C): localizado no ponto médio do contorno cervical coronário. Nos molares superiores este ponto está localizado no contorno cervical do sulco vestibular e nos molares inferiores localizado no contorno cervical do sulco mesio-vestibular.
II. Ponto incisal (I): localizado na ponta da cúspide vestibular ou região central da borda incisal. Nos molares este ponto está localizado na parte mais incisal do sulco vestibular.
III. Ponto distal (D): localizado na porção mais distal da incisal dos dentes anteriores e no centro da crista marginal distal de pré-molares e molares;
IV. Ponto mesial (M): localizado na porção mais mesial da incisal dos dentes anteriores e no centro da crista marginal mesial de pré-molares e molares.
V. Ponto oclusal direito (POD): localizado na ponta da cúspide disto vestibular do primeiro molar inferior direito.
VI. Ponto oclusal esquerdo (POE): localizado na ponta da cúspide disto vestibular do primeiro molar inferior esquerdo.
VII. Ponto interincisivo (PI): localizado no ponto médio entre as incisais dos incisivos centrais inferiores.

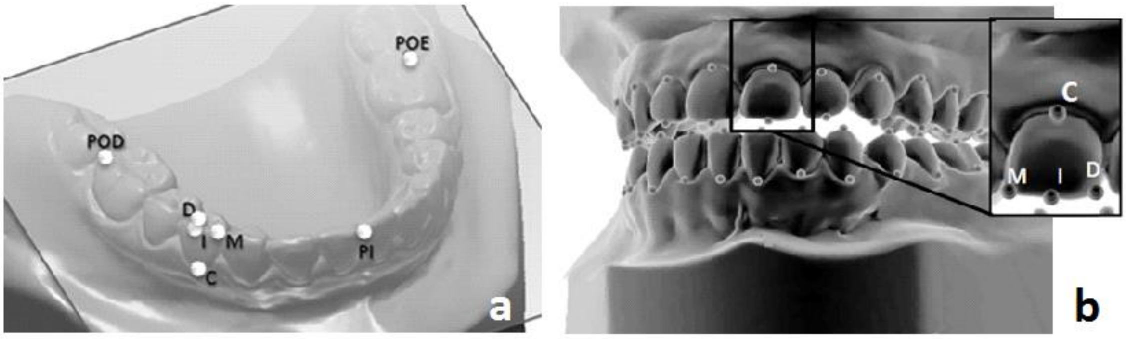

Figura 1. Pontos de referencia POE, POD e PI marcados nos modelos digitais gerados no programa VistaDent 3D (Dentsply, Nova York, NY, EUA) para definir o plano oclusal (a) e C, I, M, D para determinar a inclinação e angulação coronária (a,b).

Outros quatro pontos foram marcados na reconstrução 3D obtida pela TCFC para definir os planos de Camper e Frankfurt, são eles (Figura 2):

- Pório esquerdo (PE): ponto mais superior do meato acústico externo esquerdo na TCFC.
- Pório direito (PD): ponto mais superior do meato acústico externo direito na TCFC.
- Orbitário esquerdo (OE): ponto mais inferior da margem da órbita esquerda na TCFC.
- Espinha nasal anterior (ENA): ponto mais anterior da espinha nasal anterior na TCFC.

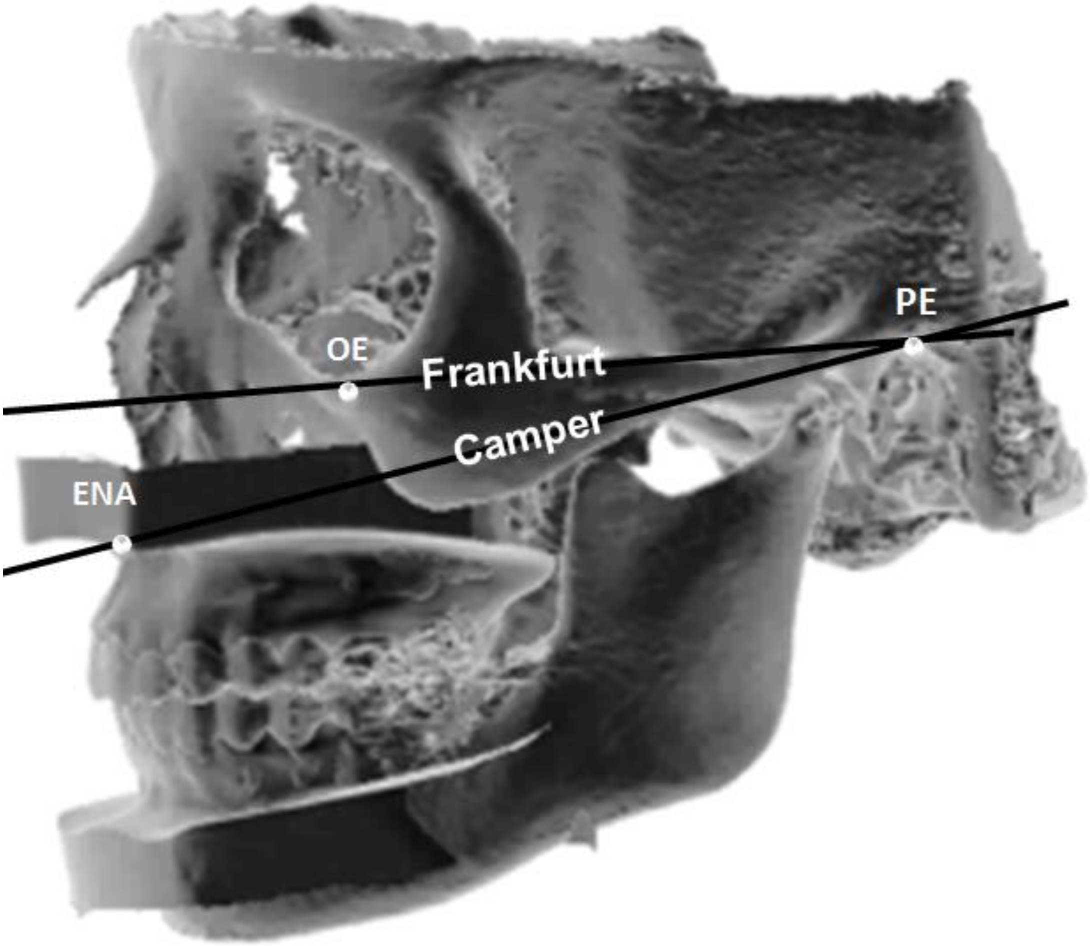

Figura 2. Pontos de referencia PE, OE e ENA marcados na reconstrução 3D (TCFC) com sobreposição do modelo digital para definir os planos de Frankfurt e Camper.

As angulações e inclinações coronárias foram determinadas com base nos modelos digitais e, o uso da reconstrução 3D da TCFC auxiliou na obtenção dos planos de Camper e Frankfurt. Com os pontos de referência definidos foram gerados automaticamente no programa VistaDent 3D (Dentsply, Nova York, NY, EUA) as seguintes linhas e planos para obtenção das medidas de angulação e inclinação coronária (Figura 3):

- Linha MD: linha que une o ponto D e o ponto M.
- Linha CI: linha que une o ponto C com o Ponto I.

- Plano oclusal: plano que passa pelos pontos POD, POE e PI.
- Plano de Camper: plano que passa pelos pontos PE, PD e ENA.
- Plano de Frankfurt: plano que passa pelos pontos PE, PD e OE.
- Plano MD: plano que passa pela linha MD e é perpendicular ao plano oclusal, Camper ou Frankfurt.
- Plano CI: plano que passa pela linha CI e é perpendicular ao Plano MD.

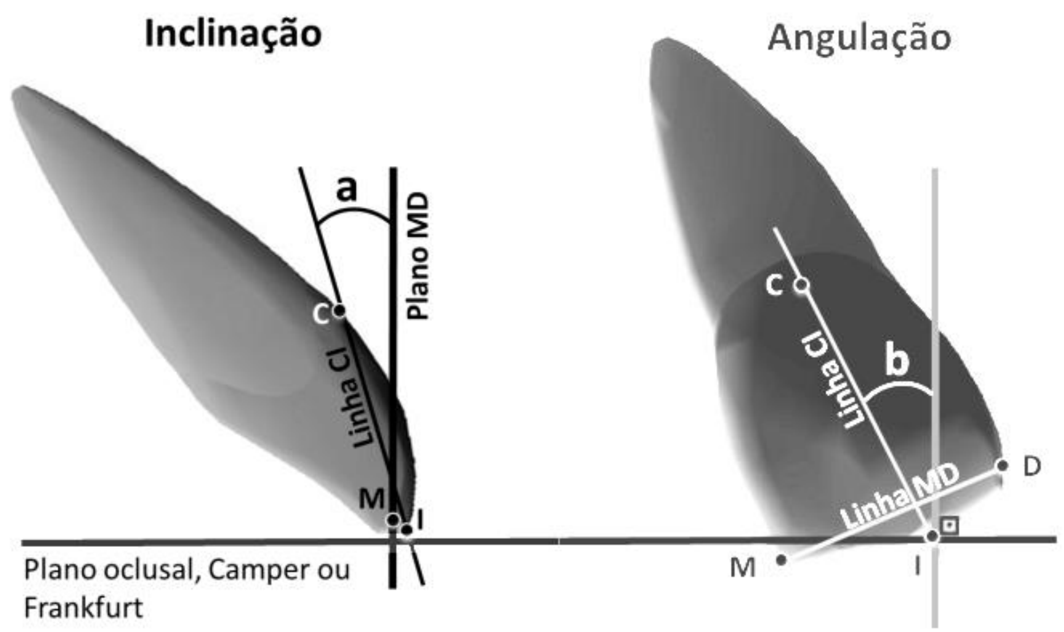

Figura 3. Desenho esquemático dos pontos, linhas e planos para obtenção da inclinação (a) e angulação (b) coronária.

A análise cefalométrica 3D no programa VistaDent 3D (Dentsply, Nova York, NY, EUA) determina a inclinação e a angulação de cada dente com uso de modelo digital e TCFC sobrepostos. Os planos para-axiais determinados pelo plano oclusal, Camper ou Frankfurt, serviram como referência para gerar automaticamente os planos MD e CI.

Em frações de segundos o programa gerou um plano para-sagital para cada dente, determinado pelo plano MD, perpendicular ao plano oclusal, Camper ou Frankfurt e um plano para-coronal determinado pelo plano CI, perpendicular ao plano MD.

Dessa forma, foi obtido um sistema de coordenadas (X,Y,Z) para cada elemento dentário que utilizam os planos oclusal, Camper ou Frankfurt como referencia axial. As medidas foram geradas automaticamente pelo programa da seguinte forma:

- Inclinação Vestíbulo-Lingual (Torque): ângulo formado entre a linha CI e o plano MD. A inclinação da coroa é considerada positiva quando a porção oclusal/incisal da Linha CI estiver vestibular à porção cervical e negativa quando estiver lingual/palatina (Figura 3).
- Angulação Mésio-Distal: ângulo formado entre a linha CI e uma perpendicular ao plano oclusal, Camper ou Frankfurt. A angulação da coroa é considerada positiva quando a porção oclusal/incisal da Linha CI estiver mesial à porção cervical e negativa quando estiver distal (Figura 3).

Análise estatística

A análise estatística descritiva forneceu a média ($\overline{x}$) e o desvio padrão (S) antes e depois do tratamento ortodôntico. A estatística inferencial foi realizada para comparar as médias ($\overline{x}$) intragrupo com *teste t-Student* para amostras pareadas e intergrupo com *teste t-Student* para amostras independentes quando os dados apresentaram normalidade. Para os dados que não apresentaram normalidade, foi utilizado o teste estatístico Wilcoxon para amostras pareadas e *Mann-Whitney* para amostras independentes. A normalidade dos dados foi avaliada pelo teste de *Kolmogorov-Smirnov*. Foi utilizado o coeficiente de correlação de Pearson para correlacionar as medidas entre os grupos dos planos axiais Camper, Frankfurt e oclusal. As médias (x) da inclinação e angulação obtidas para os planos de Camper, Frankfurt e oclusal foram apresentadas por números inteiros e comparadas à prescrição de Roth[8], utilizada no tratamento dos pacientes. Todas as análises estatísticas foram realizadas com auxílio do programa SPSS® (versão 18.0; SPSS Inc, Chicago, IL) e considerado um nível de significância de 5%.

RESULTADOS

A análise da reprodutibilidade do método não revelou diferença estatisticamente significante (*p* = 0,990) entre T1(1,63 ± 1,13) e T2 (1,67 ± 1,20). Nas Tabelas 1 e 2 estão relacionados os dados respectivos à inclinação e angulação antes e depois do tratamento ortodôntico em relação ao plano oclusal.

Tabela 1. Comparação da inclinação em graus antes e depois do tratamento ortodôntico em modelos digitais

DENTE	Antes			Depois			*p**
	x	±	S	x	±	S	
46	- 39,84	±	7,42	- 37,35	±	7,19	0,018
45	- 29,21	±	5,55	- 23,99	±	6,02	<0,001
44	- 22,16	±	5,56	- 16,44	±	5,22	<0,001
43	- 12,77	±	5,87	- 8,66	±	4,6	<0,001
42	- 6,88	±	4,57	- 4,65	±	2,82	0,027
41	- 5,98	±	3,98	- 5,03	±	3,41	0,406
36	- 36,52	±	9,23	- 35,18	±	8,64	0,398
35	- 27,79	±	6,58	- 23,71	±	5,16	<0,001
34	- 19,89	±	6,97	- 14,58	±	5,09	<0,001
33	- 12,62	±	6,68	- 7,83	±	5,72	0,001
32	- 7,28	±	6,39	- 3,91	±	1,96	0,021
31	- 6,36	±	3,96	- 5,5	±	3,92	0,457
26	- 18,94	±	4,89	- 20,38	±	6,58	0,165
25	- 15,59	±	6,61	- 11,83	±	5,52	<0,001
24	- 12,99	±	6,27	- 8,45	±	5,93	0,001
23	- 8,8	±	5,28	- 6,03	±	4,83	0,018
22	- 5,31	±	4,78	- 6,04	±	4,59	0,562
21	- 6,46	±	4,59	- 6,1	±	3,85	0,738
16	- 18,77	±	5,74	- 17,8	±	5,1	0,371
15	- 15,92	±	8,15	- 11,48	±	6,11	0,008
14	- 13,62	±	7,52	- 8,59	±	5,53	0,001
13	- 7,94	±	5,31	- 5,6	±	5,26	0,02
12	- 6,57	±	3,88	- 6,66	±	5,31	0,946
11	- 7,4	±	4,81	- 6,62	±	3,87	0,521

* valor de *p* obtido com *teste t-Student* ou Wilcoxon para amostras pareadas

Tabela 2. Comparação da angulação em graus antes e depois do tratamento ortodôntico em modelos digitais

DENTE	Antes			Depois			*p**
	x	±	S	x	±	S	
46	- 5,38	±	5,76	- 3,95	±	6,26	0,353
45	- 6,49	±	5,14	- 3,25	±	4,72	0,023
44	- 4,6	±	5,49	- 0,77	±	5,15	<0,001
43	- 2,04	±	6,79	- 1,83	±	4	0,88
42	2,93	±	6,74	- 0,24	±	3,03	0,019
41	- 0,19	±	4,53	- 1,06	±	2,15	0,296
36	- 11,4	±	12,21	- 3,02	±	12,87	0,022
35	- 9,39	±	4,88	- 5,99	±	6,51	0,017
34	- 3,06	±	4,72	- 3,36	±	5,74	0,779
33	- 4,75	±	6,79	- 3,69	±	6,31	0,456
32	- 4,47	±	6,41	- 1,47	±	3,95	0,037
31	- 0,19	±	4,53	- 1,06	±	2,15	0,296
26	3,25	±	6,64	5,24	±	5,77	0,304
25	0,46	±	4,79	- 0,15	±	6,33	0,691
24	- 0,49	±	8,58	- 1,84	±	5,11	0,45
23	2,38	±	7,48	1,83	±	6,2	0,748
22	1,95	±	10,63	0,23	±	4,58	0,453
21	- 1,42	±	6,45	- 3,16	±	2,65	0,174
16	1,48	±	6,14	5,57	±	6,36	0,024
15	1,75	±	3,72	0,51	±	4,63	0,263
14	1,52	±	6,64	- 1,29	±	5,1	0,089
13	2,86	±	8,37	3,11	±	5,55	0,88
12	4,02	±	8,73	2,53	±	3,06	0,403
11	1,56	±	5,81	2,17	±	3,24	0,571

* valor de *p* obtido com *teste t-Student* ou Wilcoxon para amostras pareadas

As médias da inclinação e angulação coronárias obtidas nos modelos digitais depois do tratamento ortodôntico foram comparadas aos valores da prescrição dos bráquetes utilizados no presente estudo (Roth)[8]. Apenas o resultado da angulação do segundo premolar superior apresentou valor coincidente com a prescrição de Roth[8] (Tabela 3).

Tabela 3. Comparação dos resultados em graus de inclinação e angulação coronária, obtidos em modelos digitais, depois do tratamento ortodôntico, com a prescrição de Roth

Dente			Roth	Resultados
Inclinação	Superior	Primeiro molar	-14	-20
		Segundo premolar	-7	-12
		Primeiro premolar	-7	-9
		Canino	-2	-6
		Incisivo lateral	8	-6
		Incisivo central	12	-6
	Inferior	Primeiro molar	-30	-36
		Segundo premolar	-22	-24
		Primeiro premolar	-17	-16
		Canino	-11	-8
		Incisivo lateral	-1	-4
		Incisivo central	-1	-5
Angulação	Superior	Primeiro molar	0	5
		Segundo premolar	0	0
		Primeiro premolar	0	-2
		Canino	13	2
		Incisivo lateral	9	1
		Incisivo central	5	0
	Inferior	Primeiro molar	-1	-3
		Segundo premolar	-1	-5
		Primeiro premolar	-1	-2
		Canino	7	-2
		Incisivo lateral	2	-1
		Incisivo central	2	-1

Nas Tabelas 4 e 5 verificam-se os coeficientes de correlação de Pearson entre os resultados das avaliações de inclinação e angulação, respectivamente, com plano oclusal, Camper e Frankfurt para os diferentes dentes. Coeficientes estatisticamente significativos ($p<0,05$) indicam correlação existente entre os valores obtidos nos grupos.

Tabela 4. Correlação dos resultados de inclinação coronária entre os planos axiais obtidos com auxílio de TCFC e modelos digitais

	Dente	Camper-oclusal		Camper-Frankfurt		Frankfurt-oclusal	
		r	P	r	*p*	r	*p*
Superior	Primeiro molar	0,89	<0,001*	0,98	<0,001*	0,89	<0,001*
	Segundo premolar	0,86	<0,001*	0,97	<0,001*	0,87	<0,001*
	Primeiro premolar	0,72	<0,001*	0,91	<0,001*	0,7	<0,001*
	Canino	0,32	0,02*	0,02	0,871	0,42	0,002*
	Incisivo lateral	0,57	<0,001*	0,3	0,03*	0,46	0,001*
	Incisivo central	0,65	<0,001*	-0,04	0,789	0,18	0,191
Inferior	Primeiro molar	0,94	<0,001*	0,99	<0,001*	0,94	<0,001*
	Segundo premolar	0,89	<0,001*	0,94	<0,001*	0,89	<0,001*
	Primeiro premolar	0,68	<0,001*	0,94	<0,001*	0,77	<0,001*
	Canino	0,62	<0,001*	0,92	<0,001*	0,59	<0,001*
	Incisivo lateral	0,27	0,055	-0,44	0,001*	-0,1	0,492
	Incisivo central	-0,46	0,001*	-0,58	<0,001*	0,52	<0,001*

(r) coeficiente de correlação de Pearson

Tabela 5. Correlação dos resultados de angulação coronária entre os planos axiais obtidos com auxílio de TCFC e modelos digitais

	Dente	Camper-oclusal		Camper-Frankfurt		Frankfurt-oclusal	
		r	P	r	p	r	p
Superior	Primeiro molar	0,71	<0,001	0,98	<0,001	0,71	<0,001
	Segundo premolar	0,64	<0,001	0,97	<0,001	0,64	<0,001
	Primeiro premolar	0,57	<0,001	0,97	<0,001	0,58	<0,001
	Canino	0,79	<0,001	0,98	<0,001	0,77	<0,001
	Incisivo lateral	0,44	0,001	0,76	<0,001	0,31	0,024
	Incisivo central	0,76	<0,001	0,92	<0,001	0,63	<0,001
Inferior	Primeiro molar	0,9	<0,001	0,99	<0,001	0,91	<0,001
	Segundo premolar	0,69	<0,001	0,96	<0,001	0,64	<0,001
	Primeiro premolar	0,5	<0,001	0,86	<0,001	0,59	<0,001
	Canino	0,68	<0,001	0,82	<0,001	0,62	<0,001
	Incisivo lateral	0,67	<0,001	0,53	<0,001	0,62	<0,001
	Incisivo central	0,49	<0,001	0,92	<0,001	0,39	0,005

(r) coeficiente de correlação de Pearson

As médias (x) da inclinação e angulação obtidas para os planos de Camper, Frankfurt e oclusal foram comparadas à prescrição de Roth[8], utilizada no tratamento ortodôntico (Tabela 6).

Tabela 6. Comparação dos resultados em graus dos planos de referência axiais com a prescrição de Roth

		Dente	Roth	Média		
				oclusal	Camper	Frankfurt
Inclinação	Superior	Primeiro molar	-14	-20	-18	-20
		Segundo premolar	-7	-12	-10	-13
		Primeiro premolar	-7	-9	-7	-10
		Canino	-2	-6	-5	-7
		Incisivo lateral	8	-6	-10	-6
		Incisivo central	12	-6	-12	-5
	Inferior	Primeiro molar	-30	-36	-38	-35
		Segundo premolar	-22	-24	-27	-23
		Primeiro premolar	-17	-16	-20	-15
		Canino	-11	-8	-14	-6
		Incisivo lateral	-1	-4	-9	-5
		Incisivo central	-1	-5	-7	-7
Angulação	Superior	Primeiro molar	0	5	13	2
		Segundo premolar	0	0	8	-3
		Primeiro premolar	0	-2	6	-5
		Canino	13	2	9	-1
		Incisivo lateral	9	1	4	2
		Incisivo central	5	0	0	0
	Inferior	Primeiro molar	-1	-3	4	-7
		Segundo premolar	-1	-5	2	-9
		Primeiro premolar	-1	-2	4	-6
		Canino	7	-2	3	-5
		Incisivo lateral	2	-1	0	0
		Incisivo central	2	-1	1	-1

Nas Tabelas 7 e 8 estão relacionadas médias das inclinações e angulações obtidas com o plano oclusal e a média de prescrições descritas na literatura[2.]

Tabela 7. Comparação entre os resultados em graus de inclinação coronária obtida depois do tratamento ortodôntico em modelos digitais com a média das prescrições descritas na literatura

	Dente	oclusal			Prescrições			Diferença média	p*
		x	+	S	x	+	S		
Superior	Primeiro molar	-19,09	+	5,97	-8,16	+	5,63	10,93	**<0,001**
	Segundo premolar	-11,66	+	5,77	-5,47	+	3,58	6,18	**<0,001**
	Primeiro premolar	-8,52	+	5,68	-5,26	+	3,48	3,26	**0,005**
	Canino	-5,8	+	4,96	-1,05	+	5,04	4,74	**0,001**
	Incisivo lateral	-6,35	+	4,93	8,84	+	3,79	15,19	**<0,001**
	Incisivo central	-6,36	+	3,83	14,79	+	5,36	21,15	**<0,001**
Inferior	Primeiro molar	-36,27	+	7,94	-22,37	+	7,79	13,9	**<0,001**
	Segundo premolar	-23,85	+	5,55	-17,58	+	5,92	6,27	**<0,001**
	Primeiro premolar	-15,51	+	5,19	-12,58	+	5,5	2,93	**0,042**
	Canino	-8,24	+	5,16	-4,42	+	6,78	3,82	**0,034**
	Incisivo lateral	-4,28	+	2,43	-2,11	+	2,85	2,17	**0,002**
	Incisivo central	-5,26	+	3,65	-2,11	+	2,85	3,16	**0,001**

* Valor *p* obtido pelo teste *t-Student* ou *Mann-Whitney* amostras independentes

Tabela 8. Comparação entre os resultados emgraus de angulação coronária obtida depois do tratamento ortodôntico em modelos digitais com a média das prescrições descritas na literatura

	Dente	oclusal			Prescrições			Diferença média	p*
		x	+	s	x	+	s		
Superior	Primeiro molar	5,4	+	6,02	0,53	+	1,58	4,88	<0,001
	Segundo premolar	0,18	+	5,5	0,74	+	1,37	0,56	0,503
	Primeiro premolar	-1,57	+	5,06	0,32	+	0,75	1,88	0,012
	Canino	2,47	+	5,86	8,79	+	2,3	6,32	<0,001
	Incisivo lateral	1,38	+	4,03	8,89	+	0,74	7,52	<0,001
	Incisivo central	-0,5	+	3,98	4,11	+	1,63	4,6	<0,001
Inferior	Primeiro molar	-3,49	+	10,03	-1,68	+	3,38	1,8	0,447
	Segundo premolar	-4,62	+	5,79	0,58	+	1,77	5,2	<0,001
	Primeiro premolar	-2,06	+	5,55	0,84	+	1,17	2,9	0,001
	Canino	-2,76	+	5,31	4,68	+	1,83	7,45	<0,001
	Incisivo lateral	-0,85	+	3,54	1,58	+	1,87	2,43	<0,001
	Incisivo central	-1,06	+	2,13	0,95	+	1,03	2,01	<0,001

* Valor *p* obtido pelo teste *t-Student* ou *Mann-Whitney* amostras independentes

DISCUSSÃO

O aparecimento de alternativas tecnológicas estimula estudos em busca de protocolos mais precisos para o tratamento ortodôntico. A maioria dos ortodontistas utilizam prescrições únicas, mas é cada vez mais evidente a necessidade de individualizar o posicionamento dos braquetes para obter resultados satisfatórios. Ao conhecer com maiores detalhes os posicionamentos dentários haverá informações importantes para o diagnóstico, prognóstico e análise de finalização dos casos tratados ortodonticamente.

Os modelos digitais e TCFC representam alternativas para se determinar a inclinação e angulação coronária[15,16,17,18]. Os recursos de novos programas e a incorporação de novas tecnologias na terapêutica ortodôntica permitem estudos mais precisos quando comparado aos desenvolvidos em modelos de gesso e radiografias 2D[16,17,18]. A acurácia e reprodutibilidade da largura e comprimento de arco em modelos digitais obtidos no escaner 3Shape (3Shape R700 – 3Shape A/S, Copenhagen, Dinamarca) foram previamente analisadas[18], e confirmaram a reprodutibilidade do método.

A mensuração da inclinação e angulação coronária em modelos digitais antes e depois do tratamento ortodôntico permitiu identificar os dentes que apresentaram alterações mais significativas. As coroas dos incisivos laterais inferiores, primeiro molar inferior direito, caninos, primeiros e segundos pré-molares foram as que apresentaram diferenças estatisticamente significantes para inclinação. Na análise da angulação, o primeiro molar superior direito e inferior esquerdo, segundos pré-molares inferiores, primeiro premolar inferior direito e incisivos laterais inferiores mostraram diferenças estatisticamente significantes. Esses resultados indicam uma disposição mais verticalizada da coroa dentária ao corrigir a má oclusão Classe I de Angle com apinhamento leve a moderado.

Ao comparar os resultados do presente estudo com a prescrição de Roth[8], utilizada no tratamento ortodôntico, verificou que apenas a angulação da coroa do segundo premolar superior foram coincidentes. Essa discrepância pode ser explicada pela subjetividade na definição dos valores da prescrição de Roth[8] e a dificuldade do ortodontista em definir precisamente a posição dos braquetes ao fazer a colagem inicial do aparelho[23,24,25].

É difícil a obtenção de um resultado fiel à prescrição em consequência a influencia da folga existente entre a canaleta do braquete e o fio ortodôntico[26,27,28]. No presente estudo, o fio ortodôntico de maior calibre registrado foi aço inoxidável 0,019"x 0,025" em canaleta de braquetes com dimensões de 0,022"x 0,028". Segundo Viazis (1995)[9], a cada 0,001" de diferença entre o fio ortodôntico e a canaleta do braquete pode resultar em até 4º de diferença angular. Ainda assim, Cash et al. (2004)[26] avaliaram as dimensões das canaletas de 11 braquetes disponíveis comercialmente e verificaram que todos apresentavam suas dimensões maiores que as indicadas pelo fabricante.

Os resultados para inclinação coronária podem ser influenciados pela rigidez do fio ortodôntico, sendo que fios de aço inoxidável expressam melhor às prescrições quando comparado aos de titânio molibidêno e níquel titânio [29].

A individualização do posicionamento do braquete[23,24,25] pode influenciar diretamente o valor das angulações e inclinações obtidas depois do tratamento. O ortodontista pode optar em realizar o posicionamento das canaletas dos braquetes perpendicular a Linha CI, também definida como eixo vertical da coroa clinica por Andrews[3] ou com as arestas incisal/oclusal da base dos braquetes paralelas às incisais/oclusais dos dentes. Como resultado cefalométrico esses valores podem variar e não coincidir com as prescrições adotadas.

Quando avaliado os resultados da amostra do presente estudo com a média das prescrições descritas na literatura[2], as angulações apresentaram diferenças estatisticamente significantes, exceto para coroas dos segundos pré-molares superiores e primeiros molares inferiores. A maioria dos estudos determinam 0º para angulação do segundo pré-molar superior, o que aproxima do resultado médio obtido depois do tratamento ortodôntico nos modelos digitais[2].

A média da angulação coronária do primeiro molar inferior nas prescrições (-1,68º) e nos resultados obtidos em modelos digitais após o tratamento ortodôntico (-3,49º) não apresentaram diferenças estatísticamente significantes, mas não concordam com valores determinados por estudos prévios[2]. Rickets (1976)[7] e Viazis (1995)[9] determinaram -5º para a angulação do primeiro molar inferior e Alexander (1983)[5] -6º. Outras prescrições como Damon (1998)[30], McLaughin (1995)[6] e Andrews (1976)[4] definiram 2º para angulação do primeiro molar inferior, um valor positivo e discrepante quando comparados aos resultados desse estudo.

Todas as médias de inclinação coronária quando comparadas com as prescrições e os resultados obtidos em modelos digitais após o tratamento ortodôntico apresentaram diferenças estatisticamente significantes (p <0,001), sendo acima de 10º para os molares, incisivos centrais e laterais superiores. A dispersão dos resultados da amostra pode ser atribuída também às variações na anatomia da face vestibular da coroa dentária[23,24,25]. Germane *et al.* (1989)[23] avaliaram a superfície vestibular de incisivos a primeiros molares e verificaram que o contorno da oclusal/incisal até a gengiva e o ângulo formado entre o longo eixo coronal variam entre dentes do mesmo tipo. Ressaltaram que a diferença morfológica da coroa dentária entre indivíduos deve ser considerada, pois podem resultar em variações na quantidade de torque, diferentes dos indicados pelas prescrições. van Loenen *et al.* (2005)[25] verificaram diferentes variações na curvatura da superfície vestibular de incisivos centrais superiores. Sugeriram que a colagem dos braquetes deve ser ao menos 4 mm da borda incisal para expressar melhor o torque dos braquetes pré ajustados. Verificaram que ao colar braquetes entre 2 a 4,5mm da borda incisal de incisivos e caninos, a diferença média do torque em um mesmo paciente com o mesmo aparelho é em média 10º pós-tratamento ortodôntico.

O estudo aponta que entre os planos Camper-oclusal, Camper-Frankfurt e Frankfurt-oclusal as medidas de inclinação coronária para incisivos e caninos não apresentaram correlação, outros correlação fraca (incisivo lateral superior) ou inversa (incisivo central e lateral inferior). Esses resultados podem ocorrer em consequência aos diferentes ângulos formados entre os planos, apesar de alguns estudos considerarem o plano oclusal paralelo ao plano de Camper[31,32,33,34,35,36]. O plano oclusal é estabelecido pelo arranjo oclusal dos dentes e os demais planos obtidos com base em pontos craniométricos nas bases ósseas ou tecido mole[31,32,33,34,35,36,37,38].

O aumento na diferença angular entre o plano oclusal e o plano de Camper de aproximadamente 4º para 10º entre 8 a 15 anos de idade, respectivamente foi reportado por Rintala e Wolf (1969)[39]. Após esse período, foi observado não haver mais alterações, mas ao assumir o paralelismo entre o plano oclusal e plano de Camper deve-se considerar um erro de aproximadamente 10º. Olsson e Posselt (1961)[40] avaliaram por meio de radiografias cefalométricas de 27 estudantes com idades entre 20 e 22 a diferença de 7º entre os planos de Camper e oclusal. Venugopalan *et al.* (2012)[31] determinaram o paralelismo entre os planos oclusal e Camper com uso de telerradiografia e verificaram que ambos são relativamente paralelos. Relataram que há correlação entre os planos de Frankfurt e Camper, porém propuseram substituir a referência do plano de Frankfurt em tecido mole pelo plano de Camper, pois sua localização na superfície lateral da face é mais fácil. Os planos de Camper e Frankfurt são constantes e não dependem da idade, diferentemente do plano oclusal.

Os resultados da angulação coronária determinada pelos planos de Camper, Frankfurt e oclusal apresentaram forte correlação, exceto incisivos centrais inferiores e laterais superiores que demonstraram moderada correlação para Camper-oclusal e Frankfurt-oclusal. Os resultados obtidos evidenciaram correlação, mas apenas a angulação do incisivo central superior apresentou numericamente semelhante para os três planos de referencia. Quando comparado os resultados do estudo com a prescrição de Roth[8], utilizada no tratamento ortodôntico, apenas a inclinação do primeiro premolar superior com o plano de Camper e a angulação do segundo premolar superior com o plano oclusal coincidiram.

Os modelos digitais permitem o traçado apenas do plano oclusal para determinar valores de angulação e inclinação dentária. Para avaliar o posicionamento dentário com referência aos planos de Camper e Frankfurt foram necessárias imagens tomográficas. Rangel *et al.* (2013) [41] avaliaram a acurácia e confiabilidade de um método de fusão de modelos digitais com imagens de TCFC. Os autores digitalizaram modelos de gesso de 10 pacientes que foram sobrepostos a suas respectivas imagens de TCFC. Constataram erro menor que 0,1 mm em 81% da amostra e verificaram que o método é confiável.

Apesar da TCFC apresentar maior precisão e ausência de sobreposição de imagens, seu uso deve ser justificado, pois emitem maiores doses de radiação quando comparado aos exames 2D[22]. Há, portanto, controvérsias acerca da quantidade de radiação absorvida pelos métodos radiográficos, pois dependem da finalidade do exame, tempo de exposição, dimensão do escaneamento, corrente e tensão do aparelho[22]. Embora os modelos digitais sejam precisos e possam substituir a radiografia com a vantagem de eliminar a exposição à radiação, estes permitem traçar apenas o plano oclusal.

Mensurações dos dentes posteriores com base nos planos de Camper e Frankfurt poderão ser aproveitadas quando da impossibilidade de uso do plano oclusal. Outros estudos são necessários para melhorar o processo de tratamento digital e aumentar as possibilidades de avaliação em modelos digitais sem expor o paciente à radiação ionizante. O desenvolvimento de programas e ferramentas para obtenção de imagens 3D abrem novas perspectivas cefalométricas.

O avanço tecnológico é essencial para o avanço da ortodontia. A investigação científica é necessária para validar novos equipamentos e programas, entretanto, o alto custo dos recursos tecnológicos e a falta de domínio no manuseio de equipamentos e programas são fatores limitantes. Os resultados de angulação e inclinação coronária obtidos no presente estudo podem não reproduzir os valores atribuídos à prescrição dos braquetes por erros de colagem e uma finalização ortodôntica àquem das metas terapêuticas segundo as seis chaves de oclusão de Andrews. São necessárias investigações que atestam a reprodutibilidade e acurácia dos métodos bem como a qualidade da finalização ortodontica. Observa-se carência de estudos que avaliam essa relação com uso de imagens 3D. Outros estudos são necessários para compreender as variáveis que influenciam os resultados com os sistemas de braquetes preajustados. Esse entendimento amplia as perspectivas para o desenvolvimento de braquetes customizados.

CONCLUSÃO

A angulação e inclinação coronária podem ser determinadas por meio de modelos digitais. Os resultados sugerem a necessidade de dobras adicionais no fio ortodôntico para obtenção de angulação e inclinação coronária com valores próximos aos preconizados em braquetes pré-ajustados.

Os valores de angulação e inclinação coronária determinados com uso de modelos digitais depois do tratamento ortodôntico, com excessão da angulação do segundo premolar superior, não corresponderam aos valores da prescrição utilizada.

As medidas de angulação e inclinação coronárias apresentaram correlacionadas quando avaliadas pelos planos de Camper, Frankfurt e oclusal, exceto a inclinação dos incisivos e caninos.

REFERÊNCIAS

1. Hahn GW. Edward Hartley Angle (1855-1930). Am J Orthod 1965;51:529-35.
2. Brito Júnior VS, Ursi WJS. The pre-adjusted appliance: evolution and prescriptions. Rev Dent Press Ortodon Ortop Facial 2006;11:104-56.
3. Andrews LF. The six keys to normal occlusion. Am J Orthod 1972;62:296-309.
4. Andrews LF. The Straight-Wire appliance: origin, controversy, commentary. J Clin Orthod 1976;10:99-114.
5. Alexander RG. The vari-simplex discipline: Part 1-concept and appliance design. J Clin Orthod 1983;17:380-92.
6. McLaughlin RP, Bennet JC. Bracket placement with the preadjusted appliance. J Clin Orthod 1995;29:302-11.
7. Ricketts RM. Bioprogressive therapy as an answer to orthodontic needs: Part I. Am J Orthod 1976;70:241-68.
8. Roth RH. The straight-wire appliance 17 years later. J Clin Orthod 1987;21:633-42.
9. Viazis AD. Bioefficient therapy. J Clin Orthod 1995;29:552-68.
10. Hans MG, Kishiyama C, Parker SH, Wolf GR, Noachtar R. Cephalometric evaluation of two treatment strategies for deep overbite correction. Angle Orthod 1994;4:255-76.
11. van Vlijmen OJC, Maal TJJ, Berg SJ, Bronkhorst EM, Katsaros C, Kuijpers-Jagtman AM. A comparison between 2-dimensional and three-dimensional cephalometry on frontal radiographs and on cone

beam computed tomography scans of human skulls. Eur J Oral Sci 2009;117: 300-5.

12. Peck JL, Sameshima GT, Miller A, Worth P, Hatcher DC. Mesiodistal Root Angulation Using Panoramic and Cone Beam CT. Angle Orthod 2007;77:206-13

13. Ursi WJS, Almeida RR, Tavano O, Henriques JFC. Assessment of Mesiodistal axial inclination trough panoramic radiography. J Clin Orthod 1990;24:166-73.

14. Bouwens DG, Cevidanes L, Ludlow JB, Phillips C. Comparison of mesiodistal root angulation with posttreatment panoramic radiographs and cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2011;139:126-32.

15. Thiruvenkatachari B, Al-Abdallah M, Akram NC, Sandler J, O'Brien K. Measuring 3-dimensional tooth movement with a 3-dimensional surface laser scanner. Am J Orthod Dentofacial Orthop 2009;135:480-5.

16. Whetten JL, Williamson PC, Heo G, Varnhagen C, Major PW. Variations in orthodontic treatment planning decisions of Class II patients between virtual 3-dimensional models and traditional plaster models. Am J Orthod Dentofac Orthop 2006;130:485-91.

17. Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. Validity, reliability, and reproducibility of plaster vs digital study models: comparison of peer assessment ratiing and Bolton analysis and their constituent measurements. Am J Orthod Dentofac Orthop 2006;129:794-803.

18. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofacial Orthop 2012;142:269-73.
19. American Academy of Oral and Maxillofacial Radiology. Clinical recommendations regarding use of cone beam computed tomography in orthodontics. [corrected]. Position statement by the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013 Aug;116(2):238-57. doi: 10.1016/j.oooo. 2013.06.002.
20. Horner K, Islam M, Flygare L, Tsiklakis K, Whaites E.. Basic principles for use of dental cone beam computed tomography: consensus guidelines of the European Academy of Dental and Maxillofacial Radiology. Dentomaxillofac Radiol. 2009 May;38(4):187-95. doi: 10.1259/dmfr/74941012.
21. McCollough CH, Primak AN, Braunc N, Kofler J, Yu L, Christner J. Strategies for Reducing Radiation Dose in CT. Radiol Clin North Am 2009;47:27–40
22. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirschf E. Cone-beam computed tomography for routine orthodontic treatment planning: A radiation dose evaluation. Am J Orthod Dentofacial Orthop 2008;133:640.e1-640.e5.
23. Germane N, Bentley BE Jr, Isaacson RJ. Three biologic variables modifying faciolingual tooth angulation by straightwire appliances. Am J Orthod Dentofacial Orthop 1989;96:312-9.

24. Smith RN, Karmo M, Russell J, Brook AH. The variability of the curvature of the labial surface of the upper anterior teeth along the facial axis of the clinical crown. Arch Oral Biol 2007;52:1037-42.
25. van Loenen M, Degrieck J, De Pauw G, Dermaut L. Anterior tooth morphology and its effect on torque. Eur J Orthod 2005;27:258–62.
26. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets - are standards as expected? Angle Orthod 2004;74:450-3.
27. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. Am J Orthod Dentofacial Orthop 2004;125:323-8.
28. Joch A, Pichelmayer M, Weiland F. Bracket slot and archwire dimensions: manufacturing precision and third order clearance. J Orthod 2010;37:241-9.
29. Archambault A, Major TW, Carey JP, Heo G, Badawi H, Major PW. A comparison of torque expression between stainless steel, titanium molybdenum alloy, and copper nickel titanium wires in metallic self-ligating brackets. Angle Orthod 2010;80:884-9.
30. Damon DH. The rationale, evolution and clinical application of the selfligating bracket. Clin Orthod Res 1998;1:52-61.
31. Venugopalan SK, SatishBabu CL, Rani MS. Determination of the relative parallelism of occlusal plane to three alatragal lines in various skeletal malocclusions: a cephalometric study. Indian J Dent Res 2012;23:719-25.

32. Kumar S, Garg S, Gupta S. A determination of occlusal plane comparing different levels of the tragus to form alatragal line or Camper's line: A photographic study. J Adv Prosthodont 2013;5:9-15
33. Kazanoglu A, Unger JW. Determining the occlusal plane with the Camper's plane indicator. J Prosthet Dent 1992 Apr;67(4):499-501.
34. Al Quran FA, Hazza'a A, Al Nahass N. The position of the occlusal plane in natural and artificial dentitions as related to other craniofacial planes. J Prosthodont 2010;19:601-5.
35. Oh S, Ahn J, Nam KU, Paeng JY, Hong J. Frankfort horizontal plane is an appropriate three-dimensinal reference in the evaluation of clinical and skeletal cant. J Korean Assoc Oral Maxillofac Surg 2013;39:71-6.
36. Hegde V. Significance of the Frankfort mandibular plane angle in prosthetic management of partially or completely edentulous patients with Class II malocclusions. The Journal of Indian Prosthodontic Society 2005;5:175-9.
37. Koller MM, Merlini L, Spandre G, Palla S. A comparative study of two methods for the orientation of the occlusal plane and the determination of the vertical dimension of occlusion in edentulous patients. J Oral Rehabil 1992;19:413-25.
38. D'Souza NL, Bhargava K. A cephalometric study comparing the occlusal plane in dentulous and edentulous subjects in relation to the maxillomandibular space. J Prosthet Dent 1996;75:177-82.
39. Rintala K, Wolf J. On the relation between the camper plane and the occlusal plane and their relation to the Frankfurt plane between the

ages of 8 and 19 as well as among adults. Suom Hammaslaak Toim 1969;65: 184-190.

40. Olsson A, Posselt U. Relationship of various skull reference lines. J Prosth Dent 1961;11:1045–49.

41. Rangel FA, Maal TJJ, Bronkhorst EM, Breuning KH, Schols JGJH, Bergé SJ, Kuijpers-Jagtman AM. Accuracy and Reliability of a Novel Method for Fusion of Digital Dental Casts and Cone Beam Computed Tomography Scans. PLoS ONE 2013;8: e59130.

ANEXOS E APÊNDICES

APÊNDICE 1

Evaluation of crown inclination and angulation using 3-dimensional digital models

ABSTRACT

Objective: To compare crown inclination and angulation between teeth of the opposing hemi arches as well as the results obtained after treatment with the prescription adopted.

Materials and Methods: Digital models of 26 patients undergoing orthodontic treatment to accomplish the six keys to normal occlusion were studied. We performed 1,248 measurements of crown inclination and angulation of all teeth on digital models, except second and third molars. Quantitative variables are presented as mean and standard deviation and compared using the Student's t-test.

Results: The analysis of the reproducibility of the method did not reveal a statistically significant difference (p = 0.990) between time 1 (1.63 ± 1.13) and time 2 (1.67 ± 1.20) of the pilot study. Maxillary lateral and central incisors presented significant differences in crown angulation ($p < 0.05$). Crown angulation of maxillary second premolars with the occlusal plane was the one that presented a similar value to the adopted prescription.

Conclusion: Crown inclination and angulation, determined using digital models post-treatment, with the exception of crown angulation of maxillary second premolars, did not correspond to Roth prescription values.

Key words: Cone beam computed tomography; digital models; cephalometry; corrective orthodontics; torque; angulation

INTRODUCTION

The orthodontic treatment with an edgewise technique allows the control of crown positions in the three planes of space as well as the insertion of rectangular arch wires into brackets' slots.[1,2] Andrews[3] studied the ideal tooth position in plaster models, and even if the degree of crown inclination and angulation of the dental crown could not be determined, the individual positioning in all the planes of space permitted the development of the preadjusted bracket system named straight-wire.[4–7]

Crown inclination is defined as the angle between a line perpendicular to the occlusal plane and a line that is parallel and tangent to the vertical axis of the clinical crown. Crown angulation corresponds to the angle between the vertical axis of the clinical crown and a line perpendicular to the occlusal plane.[3] After Andrews' proposals,[4] studies indicated alterations of the crown inclination and angulation based on clinical observations,[8–12] teleradiographies,[13,14] and panoramic radiographies.[15,16]

The tooth position can be defined in radiographies or digital images with the use of cephalometric softwares.[1,13–15,17] Limitations attributed to two-dimensional (2D) radiographic techniques have been widely discussed.[1,14–16] Lateral teleradiography only permits the evaluation of crown inclination of central incisors and crown angulation of posterior teeth, with the disadvantage of overlapping anatomical structures. Panoramic radiography presents distortions and magnification of images that limit the determination of crown inclination and angulation.[1,14,16]

More precise diagnostic methods with more details of the structures in different planes of space have been evaluated.[1,14,17] Cone beam computed tomography (CBCT) and digital models allow for virtual reconstruction of anatomical areas and dental arches with accuracy, providing information about the size and shape of the structures.[17–20] CBCT helps to determine crown inclination and angulation with minimal overlapping anatomical structures.[21,22] However, international guidelines recommend the use of

CBCT only in specific clinical situations, not routinely.[23,24] Digital models and specific softwares to perform measurements represent a possibility for evaluation of crown inclination and angulation that is less invasive and more detailed regarding anatomical structures.[18–20]

The precision of digital models and cephalometric radiography to measure teeth movements has been compared.[17] Digital models have been proven to be accurate and may replace cephalometric radiography. Furthermore, they have the advantage of eliminating exposure to X-rays. Despite the cost of the scanner and software, the reduction in file storage space,[17] the ease of access, and the speed of data exchange on the Internet with other professionals overcome this potential disadvantage.[20]

The individual position of teeth in digital models, the difficulty in developing methods that more precisely determine crown inclination and angulation of each tooth group, and the incorporation of new technology were aspects that motivated this research. Therefore, in the present study, we used digital models to compare crown inclination and angulation between teeth of the opposing hemi arches as well as the results obtained after treatment with the prescription adopted.

MATERIAL AND METHODS

Sample calculation

To determine the appropriate sample size for estimating the average value in an infinite population associated with a determined degree of confidence and the margin of error, we used the expression:

$$n = \frac{z^2 . S^2}{e^2}$$

The value of z is associated with the desired degree of confidence for the estimate. By choosing the level of 95% as the degree of confidence, *z* results in approximately 1.96. In order to determine the standard deviation (S) and the error (e), we selected six patients (n = 6) in a pilot study.

The calculation indicated the need for a sample size of approximately 25 patients to estimate crown inclination and angulation. The confidence level was 95%, with a error of 2.3º and a standard deviation of 5.9º. In this study, the sample was composed of 26 patients (n = 26), with less margin of error and greater reliability of results.

Sample selection

The study design was based on files and documents obtained from a database of 26 patients that had undergone orthodontic treatment using the straight-wire technique. This study was conducted in accordance with Roth prescription,[11] using slots measuring 0.022" × 0.028", and reporting results according to Andrews's six keys to normal occlusion.[3] Crown inclination and angulation were measured in all dental crowns on digital models, except impacted second and third molars.

According to the clinical records of patients, the average treatment time was 22 months (*S* = 4.2) and the mean age at the beginning of the orthodontic treatment was 13 years (ranging from 11 to 16 years). The largest dimension stainless steel orthodontic wire used in all patients was 0.019" × 0.025".

The inclusion criteria were: patients presenting with Angle Class I occlusion, mild to moderate dental crowding, who underwent orthodontic treatment without tooth extraction during the stage of permanent dentition, and had study models post-orthodontic treatment to completion based on the six Andrews' occlusion keys. The exclusion criteria were: patients who underwent rapid maxillary expansion, with damaged study models, incisal/occlusal tooth wear, and gingival recession. This study was approved by the Ethics Committee of Local Research.

Evaluation of crown inclination and angulation

All the plaster models obtained post-orthodontic treatment were scanned in centric occlusion using a three-dimensional (3D) desktop scanner (3Shape R700, 3Shape A/S, Copenhagen, Denmark) and saved as standard triangle language (STL) files.

STL files were imported into the 3D software VistaDent (Dentsply, New York, NY, USA) and the analysis was developed using the 3D cephalometric module to evaluate crown inclination and angulation by an examiner, specialist in orthodontics. Using a specific software tool, three reference points were marked on the surface of the digital models to define the occlusal plane and four points on each tooth (Figure 1), as follows:

- Cervical point (C): located in the cervical gingival contour at the center of the clinical crown of the buccal surface. In maxillary molars, this point is located in the cervical gingival contour of the buccal groove, whereas in mandibular molars, it is located in the cervical gingival contour of the mesial buccal groove.

- Incisal point (I): located at the buccal cusp tip or at the midpoint of the incisal edge. In the molars, this point is located in the incisal surface of the buccal groove.

- Distal point (D): located at the most distal point of the incisal surface of the anterior teeth. In the molars, this point is located in the center of the distal marginal crest.

- Mesial point (M): located at the most mesial point of the incisal surface of the anterior teeth. In the molars, this point is located in the center of the mesial marginal crest.

- Right occlusal point (ROP): located at the disto buccal cusp of the mandibular right first molar.

- Left occlusal point (LOP): located at the disto buccal cusp of the mandibular left first molar.

- Interincisal point (IP): located at the midpoint between the incisal edges of the mandibular central incisors.

After defining the reference points, the following lines and planes were automatically generated by the software tool to measure crown inclination and angulation:

- MD line: joins point M to point D.
- CI line: joins point C to point I.
- Occlusal plane: passes through the points ROP, LOP, and IP.
- MD plane: passes through MD line and is perpendicular to the occlusal plane.
- CI plane: passes through CI line and is perpendicular to MD plane.

The 3D analysis determined the crown inclination and angulation of each tooth using digital models. The axial plane, defined by the occlusal plane, served as a reference for generating MD and CI planes. Next, we obtained a plane determined by the MD line for each tooth, perpendicular to the occlusal plane, and a plane determined by the CI line, perpendicular to MD plane. A unique coordinate system (X, Y, Z) was generated for each tooth for which we used the occlusal plane as the axial reference. The following measures were generated automatically by the software:

- Inclination (torque): angle formed between CI line and MD plane. Crown inclination was considered positive when the occlusal portion of CI line was more buccal at the gingival portion, and negative when it was more lingual/palatal (Figure 2a).
- Angulation: angle formed between CI line and a line perpendicular to the occlusal plane. Crown angulation was considered positive when the occlusal portion of CI line was more mesial at the gingival portion, and negative when it was more distal (Figure 2b).

Statistical analysis

Descriptive statistical analysis provided the mean (x) and standard deviation (S) post-orthodontic treatment. Using inferential statistics, we used the Student's t-test for paired samples and Mann-Whitney test to compare crown inclination and angulation of the same teeth of the opposing hemi arches. All the statistical analyses were performed using the software SPSS version 18.0 (PASW Statistics for Windows; SPSS Inc., Chicago, IL, USA) at a 5% significance level. In the present study, we compared the crown inclination and angulation measured on digital models to Roth prescription.[11]

RESULTS

The analysis of the reproducibility of the method did not reveal a statistically significant difference (p = 0.990) between time 1 (1.63 $\pm$ 1.13) and time 2 (1.67 $\pm$ 1.20) of the pilot study. Tables 1 and 2 show the results obtained in this study and the comparison crown inclination and angulation of the same teeth of the opposing hemi arches.

The means of crown inclination and angulation obtained post-orthodontic treatment were compared to the prescription values of the brackets used in the present study (Roth).[11] Only the result of the crown angulation of the maxillary second premolar coincided with Roth prescription[11] (Table 3).

DISCUSSION

The measurement of crown inclination and angulation on digital models post-orthodontic treatment permitted the identification of the teeth that presented the most significant alterations. Maxillary lateral incisors and maxillary central incisors presented statistically significant differences in crown angulation. These results suggest that most of the crown inclination and angulation values are in accordance when compared to the same teeth of the opposing hemi arches.

Digital models represent an alternative to determine crown inclination and angulation.[17–20] The development of new softwares and the incorporation of new technology in orthodontic therapy have favored more precise studies compared to those that use plaster models and 2D radiographies.[18–20] The accuracy and reproducibility of the width and length of the arch in digital models obtained from the scanner have been previously analyzed and they confirmed the reproducibility of the method employed in this study.[20]

The individualization of bracket positioning and anatomy of dental crown[25–27] can be factors that directly influence the values of crown inclination and angulation obtained at the end of the treatment. The orthodontist can choose to perform the positioning of the bracket slots perpendicular to CI line, which is also defined as the vertical axis of the clinical crown by Andrews,[3–5] or with the incisal/occlusal edge of the bracket base parallel to the incisal/occlusal tooth. According to the cephalometric results obtained in the present study, these values can vary and not coincide with the adopted prescription.

The ideal prescription, with unique values of crown inclination and angulation for all patients, seems to be complex to be achieved due to anatomical differences of the buccal surface of teeth, and also to variations in the vertical bracket bonding, which at times can be more incisal or more gingival.[25] van Loenen et al[27] reported that the variation of the vertical positioning of the bracket ranging from 2 mm to 4.5 mm from the incisal edge may result in differences of crown inclination of 10º in the same patient with the same prescription.

Comparing the results of this study to Roth prescription,[11] used in orthodontic treatments, only the crown angulation of the maxillary second premolar coincided. It could have been by chance. The discrepancy can be explained by the subjectivity of Roth prescription[11] values and the difficulty encountered by orthodontists to precisely define the position of the brackets to make the initial bonding of the unit.[25–27] Although we found statistical differences between the results, the literature shows no negative clinical effects between prescriptions when evaluating the final aesthetics.[28] Yet, it is difficult to obtain an accurate result of the prescription due to the influence of the slack between the bracket slot and the orthodontic wire.[29–31] In our study, the largest stainless steel orthodontic wire was used (0.019" × 0.025") in bracket slots measuring 0.022" × 0.028". Every 0.001" difference between the orthodontic wire and the bracket slot can result in up to a 4º difference.[12] The results of crown inclination can be influenced by the rigidity of the orthodontic wire, because stainless steel wires adapt better to the prescriptions compared to titanium molybdenum (TMA) and nickel titanium (NiTi) wires.[32]

In the present study, the angular values of crown inclination and angulation obtained were related to the occlusal plane, analogous to Andrews' plane,[3,4] which was used to define crown inclination and angulation in Roth prescription.[11] In this study, this plane was based on digital models, therefore not requiring radiographic examinations and the consequent exposure of patients to X-rays.

The development of technological alternatives stimulates studies that search for more precise protocols for orthodontic treatment. Most orthodontists use only one prescription,[4,8–12] but it is increasingly evident that it is of fundamental importance to individualize the placement of brackets to achieve satisfactory results. Acquiring deep knowledge of dental positioning in greater detail can provide important information for the diagnosis, prognosis, and analysis of the orthodontically treated cases.

Technological advancements are essential for the improvement of orthodontics. Evidently, scientific research is necessary to validate new equipment and softwares. However, the high cost of technological resources and the lack of knowledge to handle them are limiting factors. Specific training and research are required to attest to the reproducibility and accuracy of methods.

According to our findings, there are no significant differences in crown inclination and angulation between the same teeth of the opposing hemi arches. The discrepancy between the post-treatment results and Roth prescription[11] were probably influenced by anatomic variations, bracket positioning, subjectivity to define the prescription, and the slack between the bracket slot and the orthodontic wire.

CONCLUSIONS

Crown inclination and angulation values are in accordance when compared to the same teeth of the opposing hemi arches, with the exception of crown angulation of the maxillary lateral and central incisors.

Crown inclination and angulation values, determined using digital models post-treatment, with the exception of crown angulation of second maxillary premolars, did not correspond to Roth prescription values.

REFERENCES

1. Peck JL, Sameshima GT, Miller A, Worth P, Hatcher DC. Mesiodistal root angulation using panoramic and cone beam CT. *Angle Orthod*. 2007;77:206-13.
2. Angle EH. Classification of malocclusion. *Dent Cosmos*. 1899;41:248-64,350-7.
3. Andrews LF. The six keys to normal occlusion. *Am J Orthod*. 1972;62:296-309.
4. Andrews LF. The straight-wire appliance: origin, controversy, commentary. *J Clin Orthod*. 1976;10:99-114.
5. Andrews LF. The straight-wire appliance. Explained and compared. *J Clin Orthod*. 1976;10:174-95.
6. Andrews LF. The straight-wire appliance. Case histories: nonextraction. *J Clin Orthod*. 1976;10:282-303.
7. Andrews LF. The straight-wire appliance. Extraction brackets and “classification of treatment”. *J Clin Orthod*. 1976;10:360-79.

8. Alexander RG. The vari-simplex discipline, Part 1: concept and appliance design. *J Clin Orthod*. 1983;17:380-95.

9. McLaughlin RP, Bennet JC. Bracket placement with the preadjusted appliance. *J Clin Orthod*. 1995;29:302-11.

10. Ricketts RM. Bioprogressive therapy as an answer to orthodontic needs. Part I. *Am J Orthod*. 1976;70:241-68.

11. Roth RH. The straight-wire appliance 17 years later. *J Clin Orthod*. 1987;21:632-42.

12. Viazis AD. Bioefficient therapy. *J Clin Orthod*. 1995;29:552-68.

13. Hans MG, Kishiyama C, Parker SH, Wolf GR, Noachtar R. Cephalometric evaluation of two treatment strategies for deep overbite correction. *Angle Orthod*. 1994;64:265-74.

14. van Vlijmen OJC, Maal TJJ, Bergé SJ, Bronkhorst EM, Katsaros C, Kuijpers-Jagtman AM. A comparison between two-dimensional and three-dimensional cephalometry on frontal radiographs and on cone beam computed tomography scans of human skulls. *Eur J Oral Sci*. 2009;117:300-5.

15. Ursi WJS, Almeida RR, Tavano O, Henriques JFC. Assessment of mesiodistal axial inclination through panoramic radiography. *J Clin Orthod*. 1990;24:166-73.

16. Bouwens DG, Cevidanes L, Ludlow JB, Phillips C. Comparison of mesiodistal root angulation with posttreatment panoramic radiographs and cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2011;139:126-32.

17. Thiruvenkatachari B, Al-Abdallah M, Akram NC, Sandler J, O'Brien K. Measuring 3-dimensional tooth movement with a 3-dimensional surface laser scanner. *Am J Orthod Dentofacial Orthop*. 2009;135:480-5.

18. Whetten JL, Williamson PC, Heo G, Varnhagen C, Major PW. Variations in orthodontic treatment planning decisions of Class II patients between virtual 3-dimensional models and traditional plaster study models. *Am J Orthod Dentofac Orthop*. 2006;130:485-91.

19. Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. Validity, reliability, and reproducibility of plaster vs digital study models: Comparison of peer assessment rating and Bolton analysis and their constituent measurements. *Am J Orthod Dentofac Orthop*. 2006;129:794-803.

20. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. *Am J Orthod Dentofacial Orthop*. 2012;142:269-73.

21. Tong H, Enciso R, van Elslande D, Major PW, Sameshima GT. A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. *Am J Orthod Dentofacial Orthop*. 2012;142:133-43.

22. Shewinvanakitkul W, Hans MG, Narendran S, Palomo JM. Measuring buccolingual inclination of mandibular canines and first molars using CBCT. *Orthod Craniofac Res*. 2011;14:168-74.

23. McCollough CH, Primak AN, Braunc N, Kofler J, Yu L, Christner J. Strategies for reducing radiation dose in CT. *Radiol Clin North Am*. 2009;47:27-40.

24. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: A radiation dose evaluation. *Am J Orthod Dentofacial Orthop*. 2008;133:640.e1-5.

25. Germane N, Bentley BE Jr, Isaacson RJ. Three biologic variables modifying faciolingual tooth angulation by straight-wire appliances. *Am J Orthod Dentofacial Orthop*. 1989;96:312-9.

26. Smith RN, Karmo M, Russell J, Brook AH. The variability of the curvature of the labial surface of the maxillary anterior teeth along the facial axis of the clinical crown. *Arch Oral Biol*. 2007;52:1037-42.

27. van Loenen M, Degrieck J, De Pauw G, Dermaut L. Anterior tooth morphology and its effect on torque. *Eur J Orthod*. 2005;27:258-62.

28. Moesi B, Dyer F, Benson PE. Roth versus MBT: does bracket prescription have an effect on the subjective outcome of pre-adjusted edgewise treatment? *Eur J Orthod*. 2013;35:236-43.

29. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets - are standards as expected? *Angle Orthod*. 2004;74:450-3.

30. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. *Am J Orthod Dentofacial Orthop*. 2004;125:323-8.

31. Joch A, Pichelmayer M, Weiland F. Bracket slot and archwire dimensions: manufacturing precision and third order clearance. *J Orthod*. 2010;37:241-9.

32. Archambault A, Major TW, Carey JP, Heo G, Badawi H, Major PW. A comparison of torque expression between stainless steel, titanium molybdenum alloy, and copper nickel titanium wires in metallic self-ligating brackets. *Angle Orthod*. 2010;80:884-9.

FIGURES AND TABLES

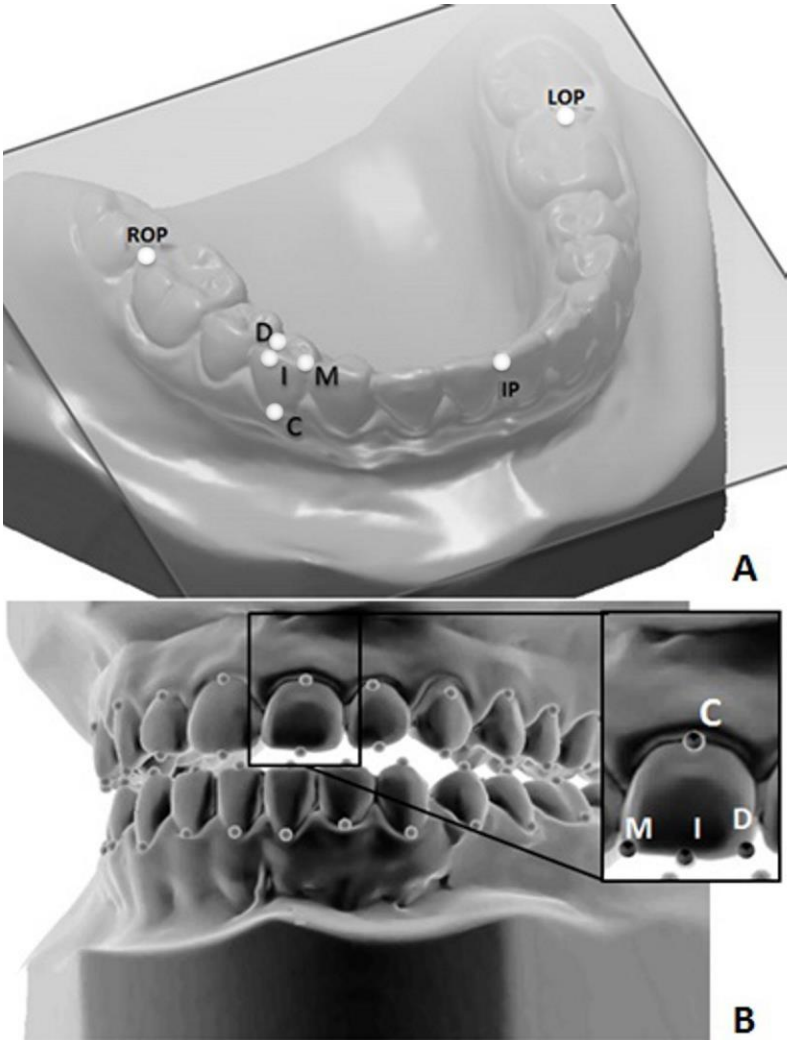

Figure 1. Reference points marked on the digital dental model of clinical crowns to determine A, occlusal plane and B, crown angulation and inclination. C: cervical point; I: incisal point; D: distal point; M: mesial point; ROP: right occlusal point; LOP: left occlusal point; IP: interincisal point.

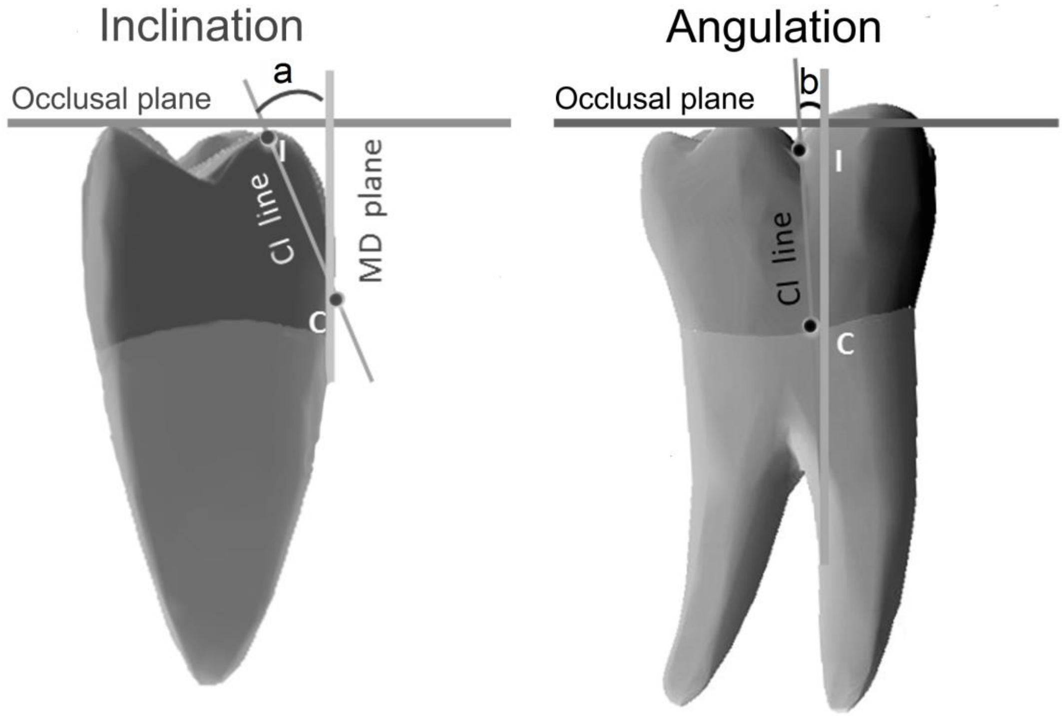

Figure 2. Schematic drawing of points, lines, and planes to obtain (a) crown inclination and (b) crown angulation.

Table 1. Comparison of the crown inclination between left and right teeth.

Tooth	*Crown inclination (º)*						
	Left side			*Right side*			*p**
	x	±	*S*	*x*	±	*S*	
Mandibular first molar	-35.2	±	8.7	-37.4	±	7.2	0.335
Mandibular second premolar	-23.7	±	5.2	-24.0	±	6.0	0.845
Mandibular first premolar	-14.6	±	5.1	-16.5	±	5.2	0.187
Mandibular canine	-7.8	±	5.9	-8.7	±	4.5	0.296
Mandibular lateral incisor	-4.0	±	2.1	-4.6	±	2.9	0.530
Mandibular central incisor	-5.5	±	3.9	-5.0	±	3.5	0.577
Maxillary first molar	-20.4	±	6.7	-17.7	±	5.1	0.216
Maxillary second premolar	-11.8	±	5.4	-11.5	±	6.2	0.667
Maxillary first premolar	-8.5	±	6.0	-8.7	±	5.6	0.905
Maxillary canine	-6.0	±	4.7	-5.5	±	5.4	0.563
Maxillary lateral incisor	-6.1	±	4.5	-6.7	±	5.4	0.861
Maxillary central incisor	-6.1	±	3.9	-6.6	±	3.8	0.642

* Student's t-test for paired samples.

Table 2. Comparison crown angulation of opposing teeth

Tooth	*Crown angulation (º)*						*p**
	Left tooth			*Right tooth*			
	x	+	*S*	*x*	+	*S*	
Mandibular first molar	-3.0	+	12.9	-4.0	+	6.3	0.594
Mandibular second premolar	-6.0	+	6.6	-3.3	+	4.6	0.090
Mandibular first premolar	-3.4	+	5.9	-0.7	+	5.2	0.064
Mandibular canine	-3.7	+	6.3	-1.9	+	4.0	0.222
Mandibular lateral incisor	-1.4	+	4.0	-0.2	+	3.0	0.214
Mandibular central incisor	-1.1	+	2.2	-1.1	+	2.2	1.000
Maxillary first molar	5.3	+	5.8	5.5	+	6.5	0.875
Maxillary second premolar	-0.1	+	6.4	0.5	+	4.6	0.694
Maxillary first premolar	-1.9	+	5.2	-1.2	+	5.1	0.627
Maxillary canine	1.9	+	6.3	3.1	+	5.7	0.448
Maxillary lateral incisor	0.2	+	4.6	2.7	+	3.1	0.030**
Maxillary central incisor	-3.2	+	2.7	2.3	+	3.3	0.000**

* Student's t-test for paired samples.

** $p < 0.05$

Table 3. Comparison of the measures obtained in post-orthodontic treatment to Roth prescription

		Tooth	*Roth prescription (º)*	*Present results (º)*
Angulation	Maxillary	First molar	0	5
		Second premolar	0	0
		First premolar	0	-2
		Canine	13	2
		Lateral incisor	9	1
		Central incisor	5	0
	Mandibular	First molar	-1	-3
		Second premolar	-1	-5
		First premolar	-1	-2
		Canine	7	-2
		Lateral incisor	2	-1
		Central incisor	2	-1
Inclination	Maxillary	First molar	-14	-20
		Second premolar	-7	-12
		First premolar	-7	-9
		Canine	-2	-6
		Lateral incisor	8	-6
		Central incisor	12	-6
	Mandibular	First molar	-30	-36
		Second premolar	-22	-24
		First premolar	-17	-16
		Canine	-11	-8
		Lateral incisor	-1	-4
		Central incisor	-1	-5

APÊNDICE 2

Correlation of crown angulation and inclination based on camper's, frankfurt and occlusal planes using digital models and cone beam computed tomography

ABSTRACT

Objective: To analyze the correlation of crown angulation and inclination measures of teeth orthodontically treated based on Camper's, Frankfurt and occlusal planes.

Materials and Methods: Measurements of crown angulation and inclination were obtained from superimposition of digital models and tomographic images of the teeth from 26 patients, except second and third molars. Pearson's correlation coefficient was used to correlate measures taken based on Camper's, Frankfurt and occlusal planes. Mean crown angulation and inclination were compared to Roth prescription.

Results: The analysis of the reproducibility of the method did not reveal a statistically significant difference. This study showed no correlation between Camper's–occlusal, Camper's–Frankfurt and Frankfurt–occlusal planes regarding crown inclination measures of incisors and canines, and other correlations were weak or inverse. Crown angulation results presented a strong correlation, except for central mandibular incisors and maxillary lateral incisors, which exhibited moderate correlation between Camper's–occlusal and Frankfurt-occlusal planes. Compared to Roth prescription, only the crown inclination of maxillary first premolars based on Camper's plane and the crown angulation of maxillary second premolars based on the occlusal plane coincided.

Conclusion: Crown angulation and inclination measures based on Camper's, Frankfurt and occlusal planes presented correlations, except for crown inclination of incisors and canines.

KEY WORDS: Cone beam computed tomography; digital models; cephalometry; corrective orthodontics; torque; angulation

INTRODUCTION

Orthodontics and dentofacial orthopedics study teeth positioning based on craniofacial references aiming to establish the morpho-functional and aesthetic diagnosis.[1] Camper's and Frankfurt horizontal planes[2] are still frequently used in cephalometric analyses.[3]

Camper's plane passes through the inferior anterior portion of the nose wing to the middle regions of the ear tragus. In the hard tissue, Camper's plane passes from the end of the anterior nasal spine to the porion.[4]

The Frankfurt horizontal plane is a line passing from the superior point of the external auditory meatus to the left infraorbital point. In the soft tissue, this plane passes through the superior edge of the right and left tragus and the lowest point of the left orbit margin. This was determined by palpation and has been accepted as a horizontal reference plane of the skull since 1884.[2] Every observation and description of the skull would be made assuming that this would be conducted horizontally with the Frankfurt plane.[2,5]

Another important plane used in cephalometric analysis is the occlusal plane. In radiographies, this plane is validated by the points that pass through the incisal edge of the incisors and the midpoint tangent to the occlusal surface of the molars. This became the principal reference to determine crown angulation and inclination after Andrews's studies in the early 1970s.[6] Several prescriptions of orthodontic appliances emerged in an effort to adjust crown angulations and inclinations of teeth to produce better aesthetic results based on the occlusal plane.[7,8,9,10,11] Although the occlusal plane is commonly used, studies show Camper's and Frankfurt planes as references for obtaining the occlusal plane because its layout may be limited by dental absence[2,5] and malocclusion.[6,7,8,9,10,11]

Cephalometric studies based on two-dimensional (2D) radiographs, such as teleradiographs and panoramic radiographs, are limited due to overlapping anatomical structures, as well as amplification and distortion of images.[1,12,13] Three points are necessary for the construction of a plane. However, in 2D exams, the radiographic structures are shown on only one surface. In this case, cephalometric planes are transformed into lines traditionally called planes.

In the last few years, lines, angles, planes and craniometric points have been featured in recent studies, particularly after the incorporation of new technologies. Cone beam computed tomography (CBCT) and digital models are accurate diagnostic tools since they permit the observation of more details of the structures at different spatial planes without overlapping anatomical structures.[1,12,14,15,16,17,18]

The lack of studies that evaluate crown angulations and individual inclinations using 3D cephalometry, the relationship between Camper's and occlusal planes, the importance of the Frankfurt plane for orientation of the skull and the latest technology were aspects that encouraged this work. Thus, in the present study, the correlation of crown angulation and inclination measures of patients treated orthodontically and presenting with normal occlusion and a balanced facial profile obtained in reference to Camper's, Frankfurt and occlusal planes was analyzed.

MATERIALS AND METHODS

In a pilot study carried out to determine the standard deviation (SD) and maximum error (e), six patients (n = 6) were selected. Sample calculation indicated the need for a population of approximately 25 patients to estimate crown angulation and inclination. Other requirements necessary for the statistical analysis were a 95% confidence level, a maximum error of 2.3º and an SD of 5.9º. Based on these findings, in this study, a sample of 26 patients was selected.

Files and documents were obtained from a database of patients that had undergone orthodontic treatment based on straight-wire technique (Roth prescription) with the objective of accomplishing Andrews's six keys to normal occlusion. The average treatment time was 22 months and the mean age of the patients at the beginning of the orthodontic treatment was 13 years (11–16 years).

The inclusion criteria in this study were: patients who had study model files, with CBCT taken after the orthodontic treatment, permanent teeth, Angle Class I malocclusion, presence of dental crowding and lack of dental caries and periodontitis. The exclusion criteria were: patients with impacted second and third molars, damaged study models, traumatic dental injury and metal restorations.

Measurements were taken of the crown angulation and inclination superimposing digital models and tomographic images of all teeth, except second and third molars. The post-treatment orthodontic plaster models obtained from patients' database were scanned using a three-dimensional (3D) desktop scanner (3Shape R700, 3Shape A/S, Copenhagen, Denmark) and saved as standard triangle language (STL) files. The digital models were superimposed and adjusted to the tomographic exams to establish dental occlusion (Figure 1a).

STL files were imported into the 3D software VistaDent (Dentsply, New York, NY, USA) and the analysis was developed using the 3D cephalometric module to assess crown angulation and inclination. The study was approved by the Ethics Committee of Local Research.

Using a specific software tool, three reference points were marked on the surface of the digital models to define the occlusal plane and four points for each tooth, except second and third molars (Figure 1b): Cervical point (C): located in the cervical gingival contour at the center of the clinical crown of the buccal surface. In molars, this point is located in the cervical gingival contour of the buccal groove; Incisal point (I): located at the tip of the buccal cuspid or at the midpoint of the incisal edge. In molars, this point is located in the most incisal surface of the buccal groove; Distal point (D): located at the most distal point of the incisal surface of the anterior teeth. In molars, this point is located at the center of the distal marginal crest; Mesial point (M): located at the most mesial point of the incisal surface of the anterior teeth. In molars, this point is located at the center of the mesial marginal crest; Right occlusal point (ROP): located at the tip of the distobuccal cusp of the mandibular right first molar; Left occlusal point (LOP): located at the tip of the distobuccal cusp of the mandibular left first molar; Interincisal point (IP): located at the midpoint between the incisal edges of the mandibular central incisors.

Also, four other points were marked on CBCT images to define Camper's and Frankfurt planes (Figure 2): Left porion (LP): the most superior point of the left external auditory meatus; Right porion (RP): the most superior point of the right external auditory meatus; Left orbital (LO): the lowest point of the margin of the left orbit; Anterior nasal spine (ANS): the most anterior point of the anterior nasal spine.

After defining these reference points, the following lines and planes were automatically obtained using the software tool and used to measure crown angulation and inclination (Figure 3): MD line: joins point M to point D; CI line: joins point C to point I; Occlusal plane: passes through ROP, LOP and IP; Camper's plane: passes through LP, RP and ANS; Frankfurt plane: passes through LP, RP and LO; MD plane: passes through MD line and is perpendicular to the occlusal plane; CI plane: passes through CI line and is perpendicular to MD plane.

The 3D cephalometric analysis determined the angulation and inclination of each tooth using the digital models and CBCT images. A para-axial plane was created based on the occlusal, Camper's and Frankfurt planes. After that, a para-sagittal (CI) plane was obtained perpendicularly to the para-axial plane, and a para-coronal plane was obtained perpendicularly to MD plane.

A coordinate system (X, Y, Z) was then developed for each tooth that used the occlusal, Camper's or Frankfurt planes as an axial reference. The measures were automatically generated by the software as follows:

Angulation: angle formed between CI line and a line perpendicular to the occlusal plane. Crown angulation was considered positive when the occlusal portion of CI line was more mesial at the gingival portion, and negative when it was more distal (Figure 3);

Inclination (torque): angle formed between CI line and MD plane. Crown inclination was considered positive when the occlusal portion of CI line was more buccal at the gingival portion, and negative when it was more lingual/palatal (Figure 3).

Statistical analysis

Pearson's correlation coefficient was used to correlate the measures of the occlusal, Camper's and Frankfurt planes. The statistical analysis was performed using the software SPSS version 18.0 (PASW Statistics for Windows; SPSS Inc, Chicago, IL, USA) at a 5% significance level.

RESULTS

The analysis of the reproducibility of the method did not reveal a statistically significant difference (p = 0.990) between time 1 (1.63 $\pm$ 1.13) and time 2 (1.67 $\pm$ 1.20) of the pilot study. Tables 1 and 2 show Pearson's correlation coefficients obtained for crown angulation and inclination in relation to the occlusal, Camper's and Frankfurt planes for different teeth. A statistically significant correlation (p < 0.05) was found between the values obtained for the groups.

The means (x) of crown angulation and inclination obtained for the occlusal, Camper's and Frankfurt planes are presented as integers in Table 3 and compared to Roth prescription[10,19], which was used in the treatment of the patients selected for the present study.

DISCUSSION

Cephalometric analyses are important as diagnostic tools and for orthodontic planning. The obtention of facial planes using computed tomography and scanners increases the possibility of determining crown angulation and inclination. Based on Camper's–occlusal, Camper's–Frankfurt and Frankfurt–occlusal planes, crown inclination measures of incisors and canines were not correlated, whereas a weak correlation was observed for maxillary lateral incisors and a reverse correlation was found for central and lateral mandibular incisors (Table 1).

These results can be explained by the different angles formed between the planes; however, some studies consider the occlusal plane to be parallel to Camper's plane.[3,5] The occlusal plane is established by occlusal arrangement of the teeth, while the other planes are based on craniometric points on the basal bones or soft tissue.[2,3,5]

An increase in the angular difference between the occlusal and Camper's planes of approximately 4º to 10º between the ages of 8 to 15 years was reported by Rintala and Wolf.[20] After this period, no more alterations occur, but assuming the parallelism between the occlusal and Camper's plane, an error of about 10º should be considered. Altube[21] noted that the occlusal plane joins the Camper's plane to form an angle typically not beyond 3º. Olsson and Posselt[22] evaluated 27 students between the ages of 20 and 22 years using cephalometric radiographs. They discovered a difference of 7º between Camper's and occlusal planes. This difference appeared to be due to the posterior reference point proposed by Gysi.[23] The authors reported that the porion should be determined radiographically because of the high resilience of the soft tissue in the region of the external auditory meatus. Using teleradiography Venugopalan et al.[3] found that the occlusal and Camper's planes are relatively parallel. Ferrario et al.[24] suggested that Camper's plane is nearly parallel to the occlusal plane. They also stated that Camper's and Frankfurt planes are constant and do not depend on age, unlike the occlusal plane. The authors reported a correlation between Frankfurt and Camper's planes, but proposed replacing the reference of the former (soft tissue) with the latter since it is easier to locate it on the lateral surface of the face.

The results of crown angulation determined by the occlusal, Camper's and Frankfurt planes presented a strong correlation in the present study. The exceptions were the mandibular central incisors and maxillary lateral incisors, which had moderate correlation between Camper's–occlusal and Frankfurt–occlusal planes (Table 2). The results showed correlation, but only the crown angulation of maxillary central incisors was numerically similar to the three reference planes (Table 3).

Comparing the present results with Roth prescription, used in the orthodontic treatments of the patients selected for this study, only the crown inclination of maxillary first premolars coincided with Camper's plane and the crown angulation of maxillary second premolars coincided with the occlusal plane. The discrepancy of the results for the occlusal plane can be explained by the gap between the bracket slot and the orthodontic wire, the difficulty to precisely define bracket placement and the subjectivity to define prescription values.[25,26,27,28]

Although 3D images have a higher precision and absence of overlap, their use must be well justified because of higher radiation dose compared to 2D exams.[29] The amount of radiation emitted by radiographic methods is still controversial, since it depends on the purpose of the examination, the time of exposure, the scanned field as well as the voltage and current of the equipment.[29]

In the present study, digital models were used as references to the plaster models used in studies that established orthodontic appliance prescriptions.[7,8,9,10,11] Digital models allow the determination only of the occlusal plane to measure crown angulation and inclination. To evaluate tooth positioning regarding Camper's and Frankfurt planes, it was necessary to use tomographic images. Measurements of the posterior teeth based on Camper's and Frankfurt planes can be taken when the use of the occlusal plane is impossible.

Rangel et al.[30] evaluated the accuracy and reliability of a method for fusion of digital models and CBCT images. The authors superimposed digitized plaster models of 10 patients and their respective CBCT images and found errors smaller than 0.1 mm in 81% of the samples, concluding that the method is reliable.

Nevertheless, further studies are needed to improve the process of digital treatment and increase the possibilities for evaluations using digital models in order to avoid exposure of patients to ionizing radiation. The development of softwares and tools to obtain 3D cephalometric images opens new perspectives. Although digital models are accurate and can replace radiographies, with the advantage of eliminating radiation exposure,[15] they only allow to define the occlusal plane.

The lack of studies that evaluate crown angulation and inclination using 3D images is a fact. Deeper knowledge of teeth positioning based on different facial planes opens new possibilities of better cephalometric diagnosis.

CONCLUSION

Crown angulation and inclination measures presented correlations when assessed using Camper's, Frankfurt and occlusal planes. The exceptions were crown inclinations of incisors and canines.

REFERENCES

1. Peck JL, Sameshima GT, Miller A, Worth P, Hatcher DC. Mesiodistal root angulation using panoramic and cone beam CT. *Angle Orthod.* 2007;77: 206–13.
2. Allen WI. Historical aspects of roentgenographic cephalometry. *Am J Orthod Dentofacial Orthop.* 1963;49:451–9.
3. Venugopalan SK, SatishBabu CL, Rani MS. Determination of the relative parallelism of occlusal plane to three ala-tragal lines in various skeletal malocclusions: a cephalometric study. *Indian J Dent Res.* 2012;23:719–25.
4. Gallão S, Ortolani CF, Faltin Jr K. Plano de Camper. *Rev Clin Ortodon Dental Press.* 2004;3:20–8.
5. Hegde V. Significance of the Frankfort mandibular plane angle in prosthetic management of partially or completely edentulous patients with Class II malocclusions. *J Indian Prosthodont Soc.* 2005;5:175–9.
6. Andrews LF. *Straight-wire: the concept and appliance*. San Diego, CA: LA Well; 1989.
7. Alexander RG. The vari-simplex discipline, Part 1: concept and appliance design. *J Clin Orthod.* 1983;17:380–92.
8. McLaughlin RP, Bennet JC. Bracket placement with the preadjusted appliance. *J Clin Orthod.* 1995;29:302–11.
9. Ricketts RM. Bioprogressive therapy as an answer to orthodontic needs: Part I. *Am J Orthod.* 1976;70:241–68.
10. Roth RH. The straight-wire appliance 17 years later. *J Clin Orthod.* 1987;21:633–42.
11. Viazis AD. Bioefficient therapy. *J Clin Orthod.* 1995;29:552–68.

12. van Vlijmen OJC, Maal TJJ, Bergé SJ, Bronkhorst EM, Katsaros C, Kuijpers-Jagtman AM. A comparison between two-dimensional and three-dimensional cephalometry on frontal radiographs and on cone beam computed tomography scans of human skulls. *Eur J Oral Sci.* 2009;117:300–5.
13. Bouwens DG, Cevidanes L, Ludlow JB, Phillips C. Comparison of mesiodistal root angulation with posttreatment panoramic radiographs and cone-beam computed tomography. *Am J Orthod Dentofacial Orthop.* 2011;139:126–32.
14. Thiruvenkatachari B, Al-Abdallah M, Akram NC, Sandler J, O'Brien K. Measuring 3-dimensional tooth movement with a 3-dimensional surface laser scanner. *Am J Orthod Dentofacial Orthop.* 2009;135:480–5.
15. Whetten JL, Williamson PC, Heo G, Varnhagen C, Major PW. Variations in orthodontic treatment planning decisions of Class II patients between virtual 3-dimensional models and traditional plaster study models. *Am J Orthod Dentofac Orthop.* 2006;130:485–91.
16. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. *Am J Orthod Dentofacial Orthop.* 2012;142:269–73.
17. Tong H, Enciso R, van Elslande D, Major PW, Sameshima GT. A new method to measure mesiodistal angulation and faciolingual inclination of each whole tooth with volumetric cone-beam computed tomography images. *Am J Orthod Dentofacial Orthop.* 2012;142:133–43.
18. Shewinvanakitkul W, Hans MG, Narendran S, Palomo JM. Measuring buccolingual inclination of mandibular canines and first molars using CBCT. *Orthod Craniofac Res.* 2011;14:168–74.
19. Roth RH. Treatment mechanics for the straight wire appliance. In: Graber TM, Swain BF (ed). *Orthodontics: current principles and techniques*. St. Louis, MO: C.V. Mosby; 1985. pp 665–716.
20. Rintala K, Wolf J. On the relation between the Camper plane and the occlusal plane and their relation to the Frankfort plane between the ages of 8 and 19 as well as among adults. *Suom Hammaslaak Toim.* 1969;65:184–90.

21. Altube LAC. *Estudio mecanico del aparato dentário*. Buenos Aires: Ediar; 1952.
22. Olsson A, Posselt U. Relationship of various skull reference lines. *J Prosth Dent.* 1961;11:1045–9.
23. Gysi A. The problem of articulation. *Dent Cosmos.* 1910;52:1–19.
24. Ferrario VF, Sforza C, Tartaglia G, Barbini E, Michielon G. New television technique for natural head and body posture analysis. *Cranio.* 1995;13:247–55.
25. Germane N, Bentley BE Jr, Isaacson RJ. Three biologic variables modifying faciolingual tooth angulation by straight-wire appliances. *Am J Orthod Dentofacial Orthop.* 1989;96:312–9.
26. van Loenen M, Degrieck J, De Pauw G, Dermaut L. Anterior tooth morphology and its effect on torque. *Eur J Orthod.* 2005;27:258–62.
27. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets - are standards as expected? *Angle Orthod.* 2004;74:450–3.
28. Joch A, Pichelmayer M, Weiland F. Bracket slot and archwire dimensions: manufacturing precision and third order clearance. *J Orthod.* 2010;37:241–9.
29. Silva MAG, Wolf U, Heinicke F, Bumann A, Visser H, Hirsch E. Cone-beam computed tomography for routine orthodontic treatment planning: a radiation dose evaluation. *Am J Orthod Dentofacial Orthop.* 2008;133:640.e1–5.
30. Rangel FA, Maal TJJ, Bronkhorst EM, Breuning KH, Schols JGJH, Bergé SJ et al. Accuracy and reliability of a novel method for fusion of digital dental casts and cone beam computed tomography scans. *PLoS One.* 2013;8: e59130.

FIGURES AND TABLES

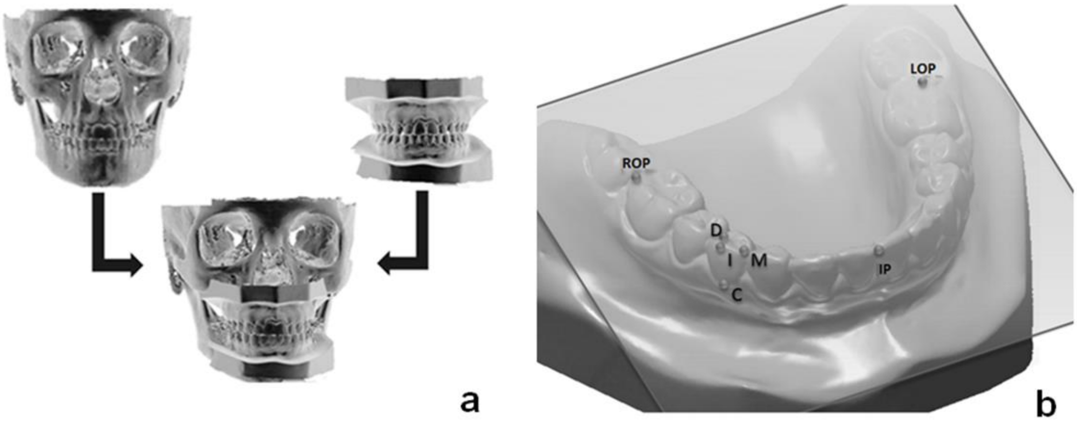

Figure 1. (a) Superimposition of digital models and images acquired using cone beam computed tomography (CBCT). (b) Reference points marked on the surface of digital models. C: cervical point; I: incisal point; D: distal point; M: mesial point; ROP: right occlusal point; LOP: left occlusal point; IP: interincisal point.

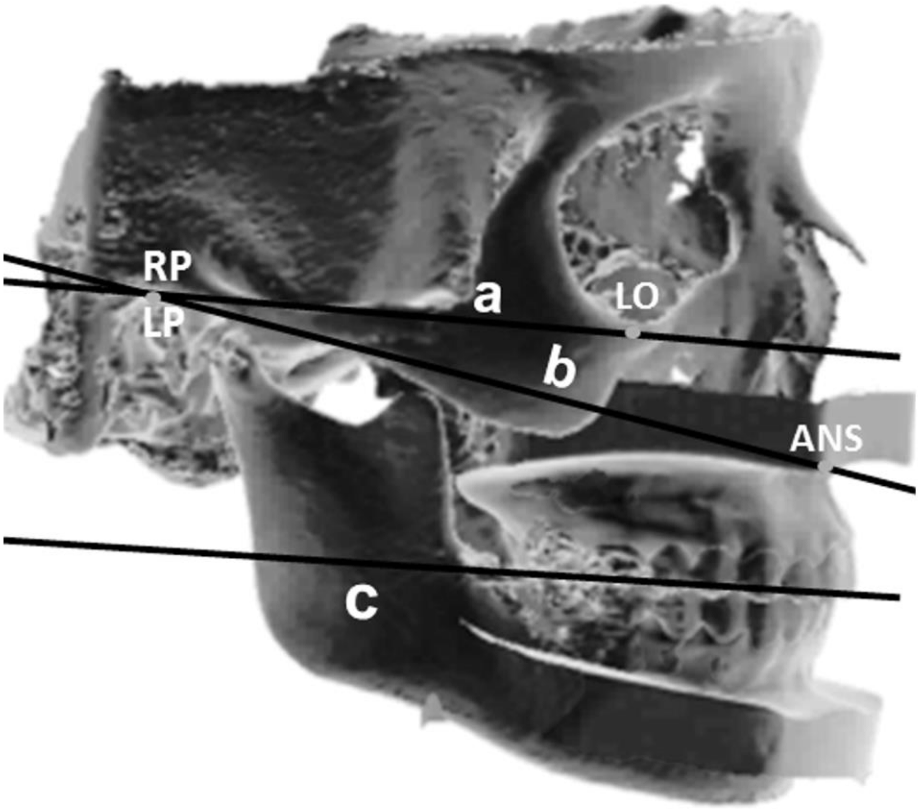

Figure 2. (a) Frankfurt and (b) Camper's and (c) occlusal planes. LP: left porion; RP: right porion; LO: left orbital; ANS: anterior nasal spine.

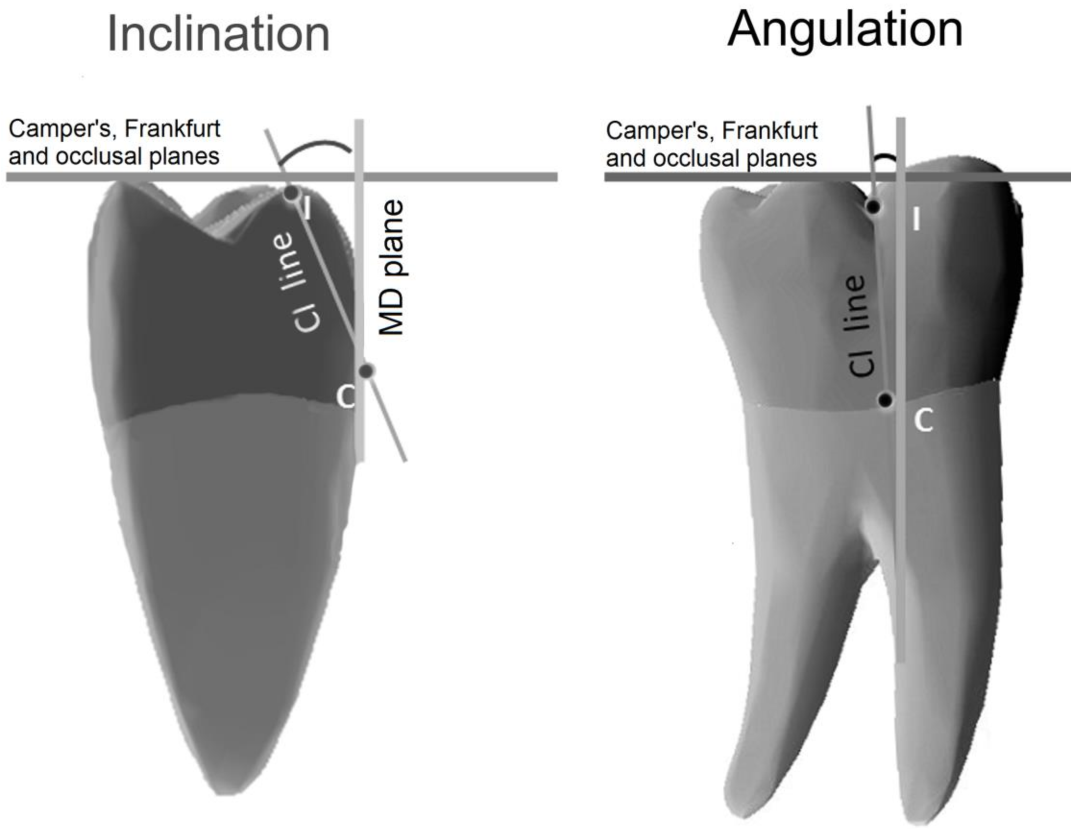

Figure 3. Schematic drawing of points, lines and planes to measure crown inclination and angulation based on Camper’s, Frankfurt and occlusal planes.

Table 1 Correlation of crown inclination between groups

	Tooth	*Camper's–occlusal*		*Camper's–Frankfurt*		*Frankfurt–occlusal*	
		r[1]	*p*	*r*	*p*	*r*	*p*
Maxillary	First molar	0.89	< 0.001	0.98	< 0.001	0.89	< 0.001
	Second premolar	0.86	< 0.001	0.97	< 0.001	0.87	< 0.001
	First premolar	0.72	< 0.001	0.91	< 0.001	0.7	< 0.001
	Canine	0.32	0.02	0.02	0.871	0.42	0.002
	Lateral incisor	0.57	< 0.001	0.3	0.03	0.46	0.001
	Central incisor	0.65	< 0.001	-0.04	0.789	0.18	0.191
Mandibular	First molar	0.94	< 0.001	0.99	< 0.001	0.94	< 0.001
	Second premolar	0.89	< 0.001	0.94	< 0.001	0.89	< 0.001
	First premolar	0.68	< 0.001	0.94	< 0.001	0.77	< 0.001
	Canine	0.62	< 0.001	0.92	< 0.001	0.59	< 0.001
	Lateral incisor	0.27	0.055	-0.44	0.001	-0.1	0.492
	Central incisor	-0.46	0.001	-0.58	< 0.001	0.52	< 0.001

[1] r: Pearson's correlation coefficient.

Table 2 Correlation of crown angulation between groups

	Tooth	*Camper's–occlusal*		*Camper's–Frankfurt*		*Frankfurt–occlusal*	
		r[1]	*p*	*r*	*p*	*r*	*p*
Maxillary	First molar	0.71	< 0.001	0.98	< 0.001	0.71	< 0.001
	Second premolar	0.64	< 0.001	0.97	< 0.001	0.64	< 0.001
	First premolar	0.57	< 0.001	0.97	< 0.001	0.58	< 0.001
	Canine	0.79	<0.001	0.98	< 0.001	0.77	< 0.001
	Lateral incisor	0.44	0.001	0.76	< 0.001	0.31	0.024
	Central incisor	0.76	< 0.001	0.92	< 0.001	0.63	< 0.001
Mandibular	First molar	0.9	< 0.001	0.99	< 0.001	0.91	< 0.001
	Second premolar	0.69	< 0.001	0.96	< 0.001	0.64	< 0.001
	First premolar	0.5	< 0.001	0.86	< 0.001	0.59	< 0.001
	Canine	0.68	< 0.001	0.82	< 0.001	0.62	< 0.001
	Lateral incisor	0.67	< 0.001	0.53	< 0.001	0.62	< 0.001
	Central incisor	0.49	< 0.001	0.92	< 0.001	0.39	0.005

[1] r: Pearson's correlation coefficient.

Tabela 3 Comparison of the present results to Roth prescription

		Tooth	*Roth*	*Means*		
				Occlusal	*Camper's*	*Frankfurt*
Inclination	Maxillary	First molar	-14	-20	-18	-20
		Second premolar	-7	-12	-10	-13
		First premolar	-7	-9	-7	-10
		Canine	-2	-6	-5	-7
		Lateral incisor	8	-6	-10	-6
		Central incisor	12	-6	-12	-5
	Mandibular	First molar	-30	-36	-38	-35
		Second premolar	-22	-24	-27	-23
		First premolar	-17	-16	-20	-15
		Canine	-11	-8	-14	-6
		Lateral incisor	-1	-4	-9	-5
		Central incisor	-1	-5	-7	-7
Angulation	Maxillary	First molar	0	5	13	2
		Second premolar	0	0	8	-3
		First premolar	0	-2	6	-5
		Canine	13	2	9	-1
		Lateral incisor	9	1	4	2
		Central incisor	5	0	0	0
	Mandibular	First molar	-1	-3	4	-7
		Second premolar	-1	-5	2	-9
		First premolar	-1	-2	4	-6
		Canine	7	-2	3	-5
		Lateral incisor	2	-1	0	0
		Central incisor	2	-1	1	-1

APÊNDICE 3

Crown angulation and inclination post-orthodontic treatment in digital models

Abstract

Background: The precision to obtain crown angulation and inclination, the subjectivity to determine orthodontic bracket prescriptions and the incorporation of the latest technologies were important factors for the development of this study, which aims to determine the difference between crown angulation and inclination obtained using digital models and the bracket prescriptions found in the literature.

Methods: The patients selected (n = 26) presented with permanent dentition and Angle Class I malocclusion. The models obtained post-orthodontic treatment was scanned and the files were imported into the 3D software VistaDent to determine crown angulation and inclination.

Results: Crown angulation and inclination presented statistically significant differences ($p < 0.001$), except crown angulation of the second maxillary premolars and the first mandibular molars.

Conclusion: Crown angulation and inclination can be determined by means of digital models. The need for additional bend to obtain crown angulation and inclination with values close to those recommended for preset brackets is evident.

Keywords: Cephalometry; Dental models; Orthodontic Brackets; Torque

Background

Tooth movement analysis based on fitting arch wires attached to brackets bonded to the teeth began with Edward Hartley Angle in 1925. From that time on, various mechanical strategies and bracket models emerged [1].

However, the first devices developed by Angle in the late nineteenth and early twentieth centuries did not allow mass movement of the teeth, permitted only limited dental crown movement or were difficult to install [1]. Another bracket format was proposed that used horizontally open slots, which allowed the placement of rectangular cross-section wires. The edgewise appliance appeared on the market [1,2] and with it came the introduction of torque. The development of edgewise brackets allowed the movement of teeth in the three planes of space, but required manual skills for making first, second and third order bends (handles, in/off set and torques) [1,2]. In the early 1970s, Andrews [3,4] determined the crown inclinations and angulations of the maxillary and mandibular teeth to study the ideal tooth position in plaster models. Bracket positioning was based on a line that vertically crosses the clinical crown. This line is parallel to the proximal surfaces and is called the clinical crown vertical axis [3,4]. Even if the degree of crown angulation and inclination could not be assessed, it defined the individual tooth position in all planes of space. This led to the development of a pre-adjusted bracket system named straight-wire [3]. After the prescriptions proposed by Andrews [3], several studies [5–8] indicated changes in crown angulation and inclination based on clinical observations using teleradiographs and panoramic radiographs [9–12].

Nonetheless, teleradiographs and panoramic radiographs are not accurate X-ray exams for determining crown angulation and inclination of all the teeth [9–12]. Due to technological advances in dentistry, new possibilities of dental evaluation have been developed that allow the visualization of more detailed structures in the three planes of space [13–16]. Digital models, with the help of specific softwares, created the possibility of virtually reconstructing anatomical areas and dental arches more accurately and with a higher degree of reliability [14–16].

The precision to obtain crown angulation and inclination, the subjectivity to determine orthodontic bracket prescriptions and the incorporation of the latest technologies have encouraged the development of this study. Therefore, the differences between crown angulation and inclination obtained using digital models and bracket prescriptions described in the literature were determined.

Method

Sample calculation

Sample size calculation was based on the formula $n = \frac{z^2 . S^2}{e^2}$, in which the value *z* is approximately 1.96 and associated with the desired confidence interval for the estimate (95%). In a previous study, six patients (n = 6) were selected to determine the standard deviation (*S*) and the maximum error (*e*).

The calculation of the sample indicated the need for approximately 26 patients to estimate crown angulation and inclination with a maximum error of 2.3º and a standard deviation of 5.9º.

Sample selection

Documents were obtained from a database of patients that had undergone orthodontic treatment using the straight-wire technique. Additionally, this study was carried out in consonance with Roth prescription [17] using 0.022 × 0.028-inch slots aiming to accomplish Andrews's six keys to normal occlusion [4]. Crown angulation and inclination measurements of all teeth were taken on digital models, except second and third molars, which resulted in 1,248 measures.

Patients' documents registered that the average treatment time was approximately 22 months and the mean age at the beginning of the treatment was 13 years (11–16 years). The largest dimension stainless steel orthodontic wire (0.019 × 0.025 inch) was employed in all patients.

The inclusion criteria were as follows: patients with properly stored post-treatment orthodontic study models, permanent teeth and Angle Class I malocclusion [18]. The exclusion criteria were: patients who underwent rapid maxillary expansion, with dental extractions, damaged study models, second and third molars, bruxism and gingival recession. The present study was approved by the Ethics Committee of Local Research (Universidade Federal de Goiás, Brazil, proc. no. 392.806).

Evaluation of crown angulation and inclination

The plaster models obtained post-orthodontic treatment were scanned in centric occlusion using a three-dimensional (3D) desktop scanner (3Shape R700, 3Shape A/S, Copenhagen, Denmark) and saved as standard triangle language (STL) files. After that, STL files were imported into the 3D software VistaDent (Dentsply, New York, NY, USA) and the analysis was developed using the 3D cephalometric module to evaluate the crown angulation and inclination.

With the aid of a specific software tool, reference points were marked on the surface of the digital models. Three points defined the occlusal plane: 1) right occlusal point (ROP), located at the tip of the distobuccal cusp of the mandibular right first molar; 2) left occlusal point (LOP), located at the tip of the distobuccal cusp of the mandibular left first molar; 3) interincisal point (IP), located at the midpoint between the incisal edges of the mandibular central incisors. Four points were marked on each dental element: 1) cervical point (C), located in the cervical gingival contour at the center of the clinical crown of the buccal surface. In molars, this point is located in the cervical gingival contour of the buccal groove; 2) incisal point (I), located at the tip of the buccal cusp or at the midpoint of the incisal edge. In molars, this point is located in the most incisal surface of the buccal groove; 3) distal point (D), located at the most distal point of the incisal surface of the anterior teeth. In molars, this point is located at the center of the distal marginal crest; 4) mesial point (M), located at the most mesial point of the incisal surface of the anterior teeth. In molars, this point is located at the center of the mesial marginal crest (Figure 1).

After defining the aforementioned reference points, the following lines and planes to achieve crown angulation and inclination measures were automatically generated: MD line, joining point M to point D; CI line, joining point C to point I; occlusal plane, passing through ROP, LOP and IP; MD plane, passing through MD line and perpendicular to the occlusal plane; CI plane, passing through CI line and perpendicular to MD plane.

Crown angulation and inclination of each tooth were determined using digital models. The axial plane, defined by the occlusal plane, served as a reference for generating MD and CI planes. A para-axial plane was created based on the occlusal plane. Then, a para-sagittal (CI) plane was obtained perpendicularly to the para-axial plane, and a para-coronal plane was obtained perpendicularly to MD plane.

A coordinate system (X, Y, Z) was developed for each tooth that used the occlusal plane as an axial reference. The measures were automatically generated by the 3D software VistaDent. Inclination (torque) was obtained by the angle formed between CI line and MD plane. Crown inclination was considered positive when the occlusal portion of CI line was more buccal at the gingival portion, and negative when it was more lingual/palatal. Mesiodistal angulation was obtained by the angle formed between CI line and a line perpendicular to the occlusal plane. Crown angulation was considered positive when the occlusal portion of CI line was more mesial at the gingival portion, and negative when it was more distal (Figure 2).

Statistical analysis

Descriptive statistical analysis provided the mean and standard deviation (*S*) of post-orthodontic treatment. Using inferential statistics, the groups means were compared with the Student's t-test for independent samples. The statistical analyses were carried out using the software SPSS version 18.0 (PASW Statistics for Windows; SPSS Inc, Chicago, IL, USA) at a 5% significance level.

Results

Tables 1 and 2 show the related means of crown angulation and inclination derived from the occlusal plane and the mean found in the prescriptions described in the literature [19] (Andrews [3], Roth [8,17], Bioprogressive [7], Rickets [7], brachyfacial, mesofacial and dolichofacial standards [7], Hilgers [20], Bennett and McLaughin and MBT [6], Alexander and Alexander modified [5], Viazis [21], Burstone and Capelozza [22], Damon [23] and Orthos-Ormco [24]).

Discussion

Different studies have evaluated crown inclinations and angulations with the use of plaster models or clinical observations [3,5–9,17]. In this study, the means of post-orthodontic treatment crown angulation and inclination were obtained from digital models and compared with prescription means described in the literature [19].

The angulations presented statistically significant differences, except for maxillary second premolars and mandibular first molars. Andrews [3] and Damon [23] recorded crown angulation of maxillary second premolar at 2º, while the prescriptions of Alexander [5] and Orthos-Ormco [24] registered it at 4º. On the other hand, the majority of the studies [19] determined crown angulation of maxillary second premolar at 0^o, similar to the average result of the present sample.

The mean crown angulation of mandibular first molar in the prescriptions (-1.68º) and the sample of this study (-3.49º) did not present statistically significant differences, but it did not agree with the values determined in previous studies [19]. Rickets [7], Hilgers [20] and Viazis [21] reported that the crown angulation of the mandibular first molar would be -5º and Alexander [5] determined that it would be -6º. Other prescriptions, such as those recommended by Damon [23], McLaughin [6] and Andrews [3] defined 2º as the crown angulation of the first mandibular molar, a positive and discrepant value compared with the results of this study.

All the results of crown inclination presented statistically significant differences ($p < 0.001$), and were above 10º for molars, maxillary lateral and maxillary central incisors. The dispersion of the sample results can be attributed to variations in brackets positioning [25], anatomy of the buccal crown surface [25–27] and the influence of the gap between the bracket slot and the orthodontic wire [25,28–30] Germane *et al.* [25] evaluated the buccal surface of incisors and first molars and found that the occlusal/gingival contour of the gingiva and the angle formed between the crown long axis and the root vary between the same types of teeth. Crown morphological differences should be considered, because they can lead to variations in torque. van Loenen *et al.* [26] found different variations in the curvature of the buccal surface of maxillary central incisors. This suggests that the bracket should be bonded at least 4 mm from the incisal edge to better reproduce the torque of the prescriptions. The mean difference of the torque in the same patient with the same device is generally within 10º of the mean of post-orthodontic treatment when the brackets are bonded between 2 mm and 4.5 mm from the incisal edge of incisors and canines. Achieving reliable results for bracket prescription is difficult due to the gap between the slot and the orthodontic wire. Every 0.001-inch difference between the orthodontic wire and the bracket slot can result in up to 4º of angular difference [21]. Even so, Cash *et al.* [28] evaluated the dimensions of the slots of 11 commercially available brackets and found that all of them presented their largest dimensions, as indicated by the manufacturers.

In spite of the cost of the scanner and software, the reduction in file storage space [31], ease of access and speed of information exchange on the Internet with other professionals has encouraged the research on digital models [14–16,31].

The results of crown angulation and inclination in orthodontic treatments cannot reproduce the values assigned to bracket prescription. Further studies are needed to understand the variables that influence the results obtained with pre-adjusted bracket systems. This knowledge may give the necessary impulse for the development of customized brackets.

Conclusion

Crown angulation and inclination can be determined using digital models. The need for additional bend to obtain crown angulation and inclination with values close to those recommended for preset brackets is evident.

References

1. Hahn GW. Edward Hartley Angle (1855-1930). Am J Orthod. 1965;51:529–535.
2. McLaughlin RP, Bennett JC. The transition from standard edgewise to preadjusted appliance systems. J Clin Orthod. 1989;23:142–153.
3. Andrews LF. Straight wire: the concept and appliance. San Diego: L. A. Wells; 1989.
4. Andrews LF. The six keys to normal occlusion. Am J Orthod. 1972;62:269–309.
5. Alexander RG. The vari-simplex discipline, Part 1: concept and appliance design. J Clin Orthod. 1983;17:380–395.
6. McLaughlin RP, Bennet, JC. Bracket placement with the preadjusted appliance. J Clin Orthod. 1995;29:302–311.
7. Ricketts RM. Bioprogressive therapy as an answer to orthodontic needs. Part I. Am J Orthod. 1976;70:241–268.
8. Roth RH. The straight-wire appliance 17 years later. J Clin Orthod. 1987;21:632–642.
9. Hans MG, Kishiyama C, Parker SH, Wolf GR, Noachtar R. Cephalometric evaluation of two treatment strategies for deep overbite correction. Angle Orthod. 1994;64:265–276.
10. Ursi WJS, Almeida RR, Tavano O, Henriques JFC. Assessment of mesiodistal axial inclination through panoramic radiography. J Clin Orthod. 1990;24:166–173.
11. Peck JL, Sameshima GT, Miller A, Worth P, Hatcher DC. Mesiodistal root angulation using panoramic and cone beam CT. Angle Orthod. 2007;77:206–213.
12. van Vlijmen OJC, Maal TJJ, Bergé SJ, Bronkhorst EM, Katsaros C, Kuijpers-Jagtman AM. A comparison between two-dimensional and three-dimensional cephalometry on frontal radiographs and on cone

beam computed tomography scans of human skulls. Eur J Oral Sci. 2009;117:300–305.

13. Hechler SL. Cone-beam CT: applications in orthodontics. Dent Clin North Am. 2008;52:809–823.
14. Whetten JL, Williamson PC, Heo G, Varnhagen C, Major PW. Variations in orthodontic treatment planning decisions of Class II patients between virtual 3-dimensional models and traditional plaster study models. Am J Orthod Dentofac Orthop. 2006;130:485–491.
15. Stevens DR, Flores-Mir C, Nebbe B, Raboud DW, Heo G, Major PW. Validity, reliability, and reproducibility of plaster vs digital study models: Comparison of peer assessment rating and Bolton analysis and their constituent measurements. Am J Orthod Dentofac Orthop. 2006;129:794–803.
16. Sousa MVS, Vasconcelos EC, Janson G, Garib D, Pinzan A. Accuracy and reproducibility of 3-dimensional digital model measurements. Am J Orthod Dentofacial Orthop. 2012;142:269–273.
17. Roth RH. Treatment mechanics for the straight wire appliance. In: Graber TM, Swain BF, eds. Orthodontics: current principles and techniques. St. Louis: CV Mosby; 1985:665–716.
18. Angle EH. Classification of malocclusion. Dent Cosmos. 1899;41:248–264,350–357.
19. Brito Júnior VS, Ursi WJS. O aparelho pré-ajustado: sua evolução e suas prescrições. Rev Dent Press Ortodon Ortop Facial. 2006;11:104–156.
20. Hilgers JJ. Bioprogressive simplified, Part 1. Diagnosis and treatment planning. J Clin Orthod. 1987;21:618–627.
21. Viazis AD. Bioefficient therapy. J Clin Orthod. 1995;29:552–568.
22. Capistrano A, Cordeiro A, Siqueira DF, Capelozza Filho L, Cardoso MA, Almeida-Pedrin RR. From conventional to self-ligating bracket systems: is it possible to aggregate the experience with the former to the use of the latter? Dental Press J Orthod. 2014;19:139–157

23. Damon DH. The rationale, evolution and clinical application of the self-ligating bracket. Clin Orthod Res. 1998;1:52–61.

24. Melenka GW, Lacoursiere RA, Carey JP, Nobes DS, Heo G, Major PW. Comparison of deformation and torque expression of the orthos and orthos Ti bracket systems. Eur J Orthod. 2014;36:381–388.

25. Germane N, Bentley BE Jr, Isaacson RJ. Three biologic variables modifying faciolingual tooth angulation by straight-wire appliances. Am J Orthod Dentofacial Orthop. 1989;96:312–319.

26. van Loenen M, Degrieck J, De Pauw G, Dermaut L. Anterior tooth morphology and its effect on torque. Eur J Orthod. 2005;27:258–262.

27. Smith RN, Karmo M, Russell J, Brook AH. The variability of the curvature of the labial surface of the upper anterior teeth along the facial axis of the clinical crown. Arch Oral Biol. 2007;52:1037–1042.

28. Cash AC, Good SA, Curtis RV, McDonald F. An evaluation of slot size in orthodontic brackets - are standards as expected? Angle Orthod. 2004;74:450–453.

29. Gioka C, Eliades T. Materials-induced variation in the torque expression of preadjusted appliances. Am J Orthod Dentofacial Orthop. 2004;125:323–328.

30. Joch A, Pichelmayer M, Weiland F. Bracket slot and archwire dimensions: manufacturing precision and third order clearance. J Orthod. 2010;37:241–249.

31. Thiruvenkatachari B, Al-Abdallah M, Akram NC, Sandler J, O'Brien K. Measuring 3-dimensional tooth movement with a 3-dimensional surface laser scanner. Am J Orthod Dentofacial Orthop 2009;135:480–485.

FIGURES AND TABLES

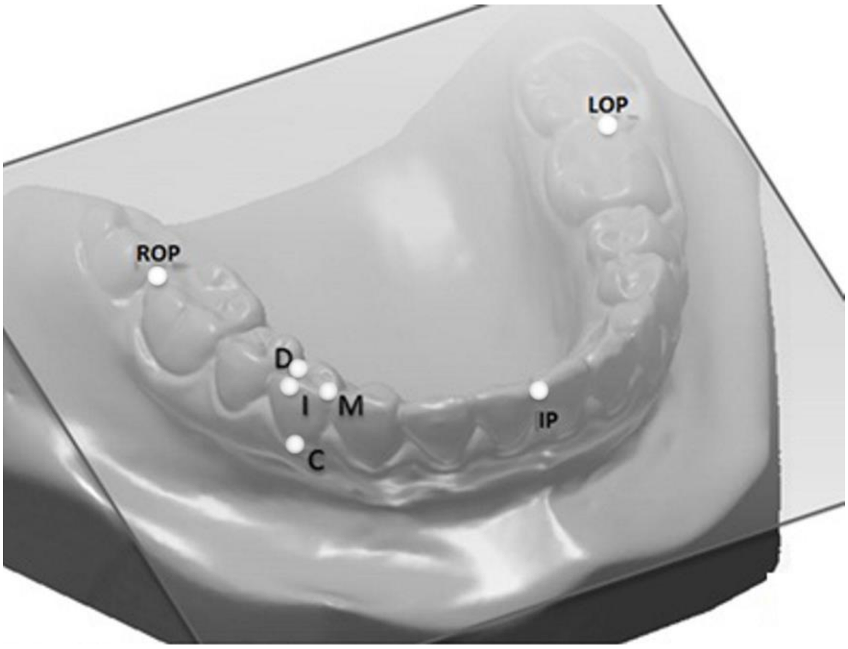

Figure 1. Reference points marked on the surface of digital models.

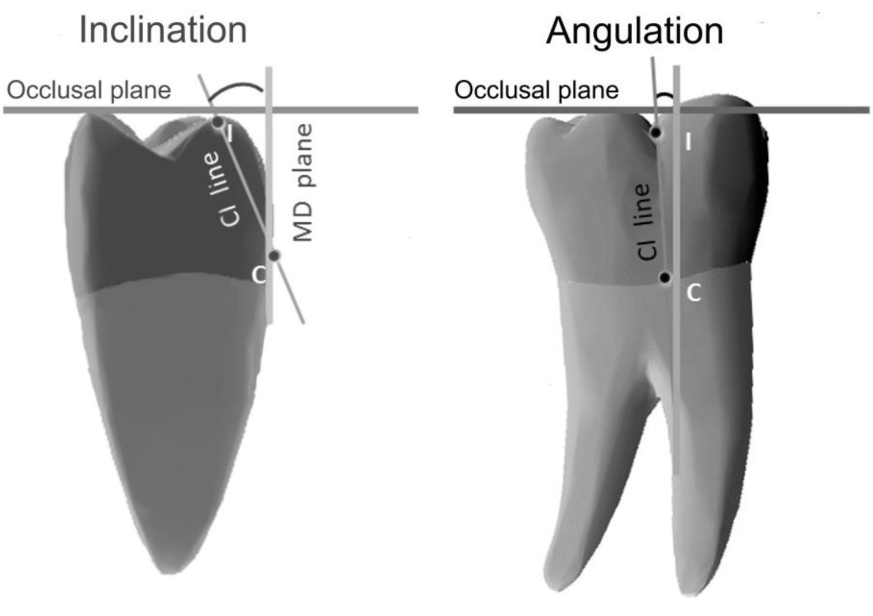

Figure 2. Schematic drawing of points, lines, and planes to obtain crown angulation and inclination.

Table 1. Comparison of coronal inclination between the occlusal group and the prescriptions.

	Tooth	Coronal inclination (º)		Average difference	p*
		Occlusal group (mean ± S^1)	Prescription (mean ± S)		
Maxillary	First molar	-19.09 ± 5.97	-8.16 ± 5.63	10.93	< 0.001
	Second premolar	-11.66 ± 5.77	-5.47 ± 3.58	6.18	< 0.001
	First premolar	-8.52 ± 5.68	-5.26 ± 3.48	3.26	0.005
	Canine	-5.8 ± 4.96	-1.05 ± 5.04	4.74	0.001
	Lateral incisor	-6.35 ± 4.93	8.84 ± 3.79	15.19	< 0.001
	Central incisor	-6.36 ± 3.83	14.79 ± 5.36	21.15	< 0.001
Mandibular	First molar	-36.27 ± 7.94	-22.37 ± 7.79	13.9	< 0.001
	Second premolar	-23.85 ± 5.55	-17.58 ± 5.92	6.27	< 0.001
	First premolar	-15.51 ± 5.19	-12.58 ± 5.50	2.93	0.042
	Canine	-8.24 ± 5.16	-4.42 ± 6.78	3.82	0.034
	Lateral incisor	-4.28 ± 2.43	-2.11 ± 2.85	2.17	0.002
	Central incisor	-5.26 ± 3.65	-2.11 ± 2.85	3.16	0.001

[1] *S*: standard deviation.

* Student's t-test for independent samples ($p < 0.05$).

Table 2. Comparison of coronal angulation between the occlusal group and the prescriptions.

	Tooth	Coronal angulation (º) Occlusal group (mean ± S[1])	Coronal angulation (º) Prescription (mean ± S)	Average difference	p*
Maxillary	First molar	5.40 ± 6.02	0.53 ± 1.58	4.88	< 0.001
	Second premolar	0.18 ± 5.50	0.74 ± 1.37	0.56	0.503
	First premolar	-1.57 ± 5.06	0.32 ± 0.75	1.88	0.012
	Canine	2.47 ± 5.86	8.79 ± 2.30	6.32	< 0.001
	Lateral incisor	1.38 ± 4.03	8.89 ± 0.74	7.52	< 0.001
	Central incisor	-0.50 ± 3.98	4.11 ± 1.63	4.60	< 0.001
Mandibular	First molar	-3.49 ± 10.03	-1.68 ± 3.38	1.80	0.447
	Second premolar	-4.62 ± 5.79	0.58 ± 1.77	5.20	< 0.001
	First premolar	-2.06 ± 5.55	0.84 ± 1.17	2.90	0.001
	Canine	-2.76 ± 5.31	4.68 ± 1.83	7.45	< 0.001
	Lateral incisor	-0.85 ± 3.54	1.58 ± 1.87	2.43	< 0.001
	Central incisor	-1.06 ± 2.13	0.95 ± 1.03	2.01	< 0.001

[1] *S*: standard deviation.

* Student's t-test for independent samples ($p < 0.05$).

Anexo 1 - Normas revista The Angle Orthodontist (Artigos 1 e 2)

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Anexo 3 - Parecer do Comitê de Ética

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DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: DETERMINAÇÃO DA ANGULAÇÃO E INCLINAÇÃO DENTÁRIA POR MEIO DE TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO EM PACIENTES TRATADOS ORTODONTICAMENTE

Pesquisador: IURY OLIVEIRA CASTRO

Área Temática:

Versão: 1

CAAE: 19677713.0.0000.5083

Instituição Proponente: Faculdade de Odontologia

Patrocinador Principal: FUND COORD DE APERFEICOAMENTO DE PESSOAL DE NIVEL SUP

DADOS DO PARECER

Número do Parecer: 392.806

Data da Relatoria: 02/09/2013

Publicações no triênio 2013/2015

1. CASTRO, IO; ALENCAR, AHG; VALLADARES-NETO, J; ESTRELA, C. Apical root resorption due to orthodontic treatment detected by cone beam computed tomography. Angle Orthod. 2013 Mar;83(2): 196-203. doi: 10.2319/032112-240.1. Epub 2012 Jul 19.

2. CASTRO, IO; ESTRELA, C; SOUZA, VR; LOPES, LG; DE SOUZA, JB. Unilateral Fusion of Maxillary Lateral Incisor: Diagnosis Using Cone Beam Computed Tomography. Case Rep Dent. 2014;2014: 934218. doi: 10.1155/2014/934218. Epub 2014 Dec 18.

3. CASTRO, IO ; VALLADARES-NETO, J; ESTRELA, C. Contribution of cone beam computed tomography to the detection of apical root resorption after orthodontic treatment in root-filled and vital teeth. Angle Orthod. 2015 Sep;85(5):771-6. doi: 10.2319/042814-308.1. Epub 2014 Nov 13.

4. CASTRO, LO; CASTRO, IO; DE ALENCAR, AHG; VALLADARES-NETO, J; ESTRELA, C. Cone beam computed tomography evaluation of distance from cementoenamel junction to alveolar crest before and after nonextraction orthodontic treatment. Angle Orthod. 2015 Sep 17. [Epub ahead of print]. DOI: 10.2319/040815-235.1