

Assessment of Maxillary Incisors' Angulation and Position in Different Types of Malocclusions Using Cone-Beam Computed Tomography

Abstract

Background: This study is aimed to assess the maxillary incisors' root position, angulation, and buccal alveolar bone thickness in both genders and different classes of malocclusion using cone-beam computed tomography (CBCT). **Materials and Methods:** Two hundred and six CBCT images were gathered and analyzed by three-dimensional On-Demand software to measure the variables of 803 maxillary central and lateral incisors. Genders and class difference was determined by unpaired *t*-test, one-way ANOVA, and Chi-square tests. **Results:** Buccal root position of the maxillary incisors accounted for in the majority of the cases followed by the middle and palatal positions. The thickness of alveolar bone appears to have nearly the same pattern of decreasing in the mean values above the level of 2 mm from the crest of the bone up to the 6 mm level then increase in the apex of the root. The angle between the long axis of the maxillary incisors and the corresponding alveolar bone is higher significantly in class II followed by class I and III with no significant gender difference. **Conclusions:** most of the maxillary incisors examined were located in a very close position to the buccal cortical plate and covered by a thin buccal bone wall. The apparent association was noted between the incisors' root position and angulation in the alveolar bone with the buccal bone thickness.

Keywords: Cone-beam computed tomography, maxillary incisor root, orthodontics

Introduction

The major goal of managing different malocclusions with fixed orthodontic therapy is to have an ideal positioning of the teeth over the basal bone to preserve the functions, esthetics and structural durability of the dentition and supporting structures. This can be achieved when the total dental material is well-suited with the existing basal bone. Basal bone is considered as the crucial aspect determining the arc circumference the teeth available should accommodate.^[1] The sum of mesiodistal space occupied by the maxillary anterior teeth is determined by the degree of their crown angulations and inclination to attain the optimum occlusion as proposed by Andrews.^[2]

Maxillary central incisors play an imperative role in supporting the upper lip and smiling thus their positions in the dental arch are considered as reference landmark to support the dentition and assess the esthetic values of the cases before and after treatment.^[3]

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Nowadays, many adults seek orthodontic treatment with variable periodontal health status. Orthodontists should guide the patients to maintain a high level of oral hygiene throughout the progress of the treatment to decrease the chance of missing teeth or aggravating the existing problem. On the other side, a comprehensive assessment of the thickness of alveolar bone around the maxillary incisors should be performed to apply the suitable orthodontic force especially torquing the anterior teeth (that achieved better occlusion, facial esthetics, and stability) to ensure safe treatment free of iatrogenic bone loss or destruction of the periodontium.^[4]

Several techniques have been used in the orthodontic evaluation of maxillary anterior teeth position including the cephalometric measurements, tooth inclination protractor on the casts or intra-orally and the three-dimensional (3D) methods utilizing the angular measurements on 3D cast models. Orthodontists usually used normative values of cephalometric readings in trying to position maxillary incisors teeth, yet once the plan is established, the biomechanical

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principles of tooth movement may or may not bring them to the ideal final treatment position.^[5] The tooth inclination protractor is uncomplicated, cheap, and consistent device for assessing of tooth inclination, yet the measurements' validity in the deep curve of Spee, severe curve of Wilson and canted occlusal plane cases is questionable,^[6] hence the three-dimensional analysis of particular area using cone-beam computed tomography (CBCT) is regarded as the best method determining the bone support. In comparison with conventional radiographs, CBCT offers sensitive true scale, high definition, cross-sectional images devoid of distortions and magnification or superimposition of other structures that were highlighted in previous researches.^[7-10] CBCT precisely and carefully describes the proper diagnosis, treatment, and craniofacial anatomy for a good prognosis. Orthodontics shifts from lines, lengths, and angles to spaces, surfaces, and volumes.^[11] Considering these advantages, besides to its lower costs and radiation doses, CBCT is the favorite method for an accurate appraisal of alveolar bone dimensions and inclination of maxillary incisors.^[7-10]

This study was conducted for the first time in (College of Dentistry -University of Baghdad) to measure the buccal bone thickness and angulation of the maxillary incisors in different classes of malocclusion using CBCT.

Materials and Methods

Approval for conducting this study was gained from the scientific and ethical committee at the College of Dentistry-University of (Baghdad/Iraq) (no. 131 on December 26, 2018). In this retrospective study, CBCT images were collected for patients who referred to private clinic to get CBCT for diagnosis of impacted teeth or other dental problem issues between 2015 and 2018, so no informed consent from patients was required and they verbally agreed to share their CBCT for research purposes. Each image was examined by the specialist radiologist to fulfil the inclusion criteria and collect data, then the collected data were examined again in 2-week interval.

Inclusion criteria

- Age range between 18 and 35 years old
- No active orthodontic treatment
- Fully formed, intact, and healthy maxillary incisors.

Class I normal

- Bilateral Class I buccal segments “molars and canines”
- Straight facial profile
- Well-aligned teeth, no irregularity
- Normal overjet and overbite.

Class II

- Bilateral Class II buccal segments “molars and canines” with convex facial profile.(The skeletal classification was not considered)
- Overjet is >4 mm.

Class III

- Bilateral Class III buccal segments “molars and canines”
- Reversed overjet or edge to edge incisal relation.

Exclusion criteria

- Gross facial asymmetry
- History of orthodontic treatment
- The loss of alveolar bone >4 mm from the cemento-enamel junction.

Sample

The data of 206 patients (90 males and 116 females with a mean age of 27.11 ± 5.16 years) who met the inclusion criteria were analyzed. The total number of anterior teeth included in the present study was 803 maxillary central and lateral incisors distributed on the genders and classes as shown in Table 1. Twenty-one congenital missing teeth were detected in the CBCT image.

All images were taken by the same operator using Caranex 3D system (Sordax, Finland) with exposure factors (90Kvp, 6.3 mA, 12.6 s scanning time), 0.2 mm voxel size 6×8 or 6×4 field of view, saved in the Digital Imaging and Communications in Medicine format and analyzed using 3D On-Demand software (Sordax, Finland).

Method protocol

Root position

The root position of the maxillary incisors was classified according to the position of the apex into buccal type, middle type and palatal type. “In the buccal type, the apical point of the incisor was positioned within the buccal third of the alveolar bone and the root was closer to the buccal bone wall; in the middle type, the apical point of the incisor was located within the middle third of the alveolar bone and the buccal and palatal bone walls were approximately equal in thickness, while in the palatal type, the apical point of the incisor was positioned within the palatal third of the alveolar bone and the root was closer to the palatal bone wall,”^[12,13] as shown in Figure 1. The buccal type was classified further into subtypes I, II, and III.^[13] When the buccal bone covered the root apex of incisors and thickened toward the apex, this subtype I, while when the thickness is thinner than that, it

Table 1: Distribution of sample according to the genders and classes of malocclusion

Tooth	Missing*	Genders	Class	Class	Class	Total
			I	II	III	
Central incisor	8	Females	90	114	20	403
	1	Males	52	63	64	
Lateral incisor	8	Females	90	114	20	400
	4	Males	48	64	64	
Total	21	Total	280	355	168	803

*Congenitally missing either due to trauma or extraction

is subtype II, finally when the axis of apex angulated very buccally and there were no bone tissue covering it in the long axis of the tooth, this is subtype III [Figure 2].

Angulation

It represents the angle between the long axes of the tooth (from the incisal edge to the apex) and the corresponding alveolar bone^[13] as shown in Figure 3.

Bone thickness

It represents the perpendicular distance between the buccal alveolar bone and the root surface at the level of 2, 4, and 6 mm apical to the crest in addition to that at the level of root apex^[13] as shown in Figure 4.

Statistical analyses

The statistical analyses were executed with the aid of SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Means, standard deviations, frequency distribution and percentages were obtained for the collected data. Independent sample *t*-test, one way ANOVA and Chi-square tests were used to detect the gender and classes differences. $P < 0.05$ was considered statistically significant.

Results

The frequency distributions of the maxillary central and lateral incisors' root position were presented in

Tables 2 and 3 for both genders and all classes. Generally, the buccal position of the root accounted for the majority of the studied samples followed by middle then the palatal position with variable genders and classes differences.

Classifying buccal root position according to the subtypes revealed that subtype III is the predominant one followed by subtype II and I except in class II and III of male group where subtype I is more than subtype II.

Tables 4 and 5 show the descriptive statistics, genders and classes differences for the alveolar bone thickness buccal to the root of the central and lateral incisors at different levels namely; 2, 4, 6 mm. The thickness of alveolar bone appeared to have nearly the same pattern of decreasing in the mean values after the level of 2 mm from the crest of the bone up to the 6 mm level then increased at the apex of the root. The lateral incisor root showed a few variants from the central incisor root in some classes. Gender difference was not significant in nearly all levels. Comparison among the classes indicates the presence of significant difference at different levels in both genders [Table 6].

Regarding the angle between the long axes of the tooth and alveolar bone in both incisors and both genders, the mean values of this angle were higher significantly in class II followed by class I then class III [Tables 4 and 5] with no significant gender difference. Multiple comparisons

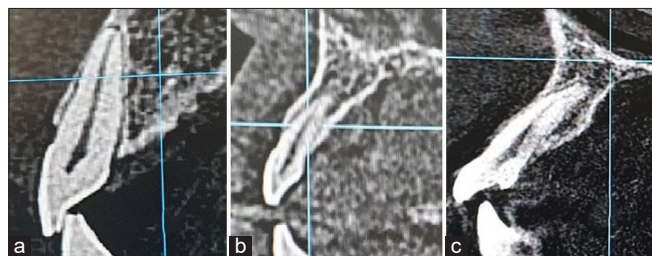


Figure 1: The root position of the incisors in the alveolar bone; (a) Buccal, (b) Middle and (c) Palatal type

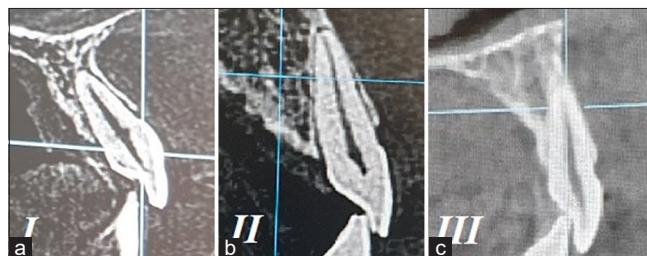


Figure 2: The buccal type is further classified as follows. (a) Subtype I, (b) Subtype II and (c) Subtype III

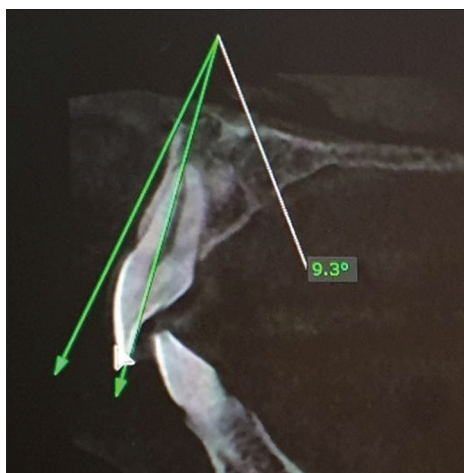


Figure 3: The angle between the long axis of the tooth and the long axis of the corresponding alveolar bone is measured

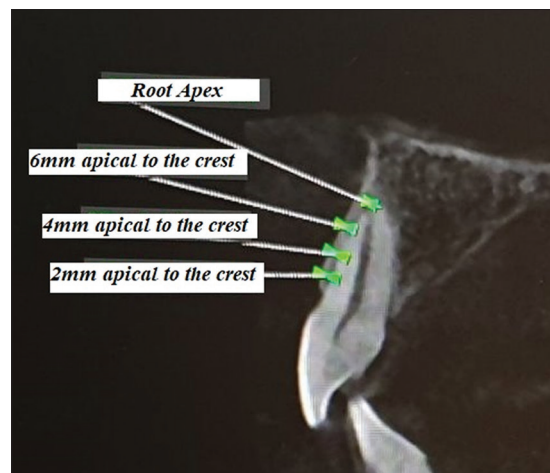


Figure 4: The thickness of the buccal bone is measured 2, 4, and 6 mm apical to the alveolar crest; and at the root apex

Table 2: Frequency distribution and percentage of the maxillary central incisor root position in both genders and different classes

Root position	Central incisors					
	Females			Males		
	Class I, n (%)	Class II, n (%)	Class III, n (%)	Class I, n (%)	Class II, n (%)	Class III, n (%)
Buccal						
Subtype I	12 (13)	13 (11)	2 (10)	4 (8)	13 (21)	10 (16)
Subtype II	31 (34)	33 (29)	5 (25)	11 (21)	14 (22)	7 (11)
Subtype III	33 (37)	52 (46)	6 (30)	17 (33)	19 (30)	34 (53)
Subtotal	76 (84)	98 (86)	13 (65)	32 (62)	46 (73)	51 (80)
Middle	14 (16)	10 (9)	5 (25)	16 (31)	11 (17)	7 (11)
Palatal	0 (0)	6 (5)	2 (10)	4 (8)	6 (10)	6 (9)

Class difference for females: $\chi^2=11.607$, $df=4$, $P=0.021$; Class difference for males: $\chi^2=7.512$, $df=4$, $P=0.111$; Gender difference in class I: $\chi^2=12.807$, $df=2$, $P=0.002$; Gender difference in class II: $\chi^2=4.504$, $df=2$, $P=0.105$, Gender difference in class III: $\chi^2=2.547$, $df=2$, $P=0.279$

Table 3: Frequency distribution and percentage of the maxillary lateral incisor root position in both genders and different classes

Root position	Lateral incisors					
	Female			Male		
	Class I, n (%)	Class II, n (%)	Class III, n (%)	Class I, n (%)	Class II, n (%)	Class III, n (%)
Buccal						
Subtype I	11 (12)	11 (10)	1 (5)	4 (8)	14 (22)	4 (6)
Subtype II	18 (20)	21 (18)	2 (10)	7 (15)	10 (16)	2 (3)
Subtype III	39 (43)	50 (44)	6 (30)	20 (42)	16 (25)	38 (59)
Subtotal	68 (76)	82 (72)	9 (45)	31 (65)	40 (63)	44 (69)
Middle	19 (21)	25 (22)	7 (35)	13 (27)	8 (13)	14 (22)
Palatal	3 (3)	7 (6)	4 (20)	4 (8)	16 (25)	6 (9)

Class difference for females: $\chi^2=10.917$, $df=4$, $P=0.028$; Class difference for males: $\chi^2=10.471$, $df=4$, $P=0.033$; Gender difference in class I: $\chi^2=2.55$, $df=2$, $P=0.279$; Gender difference in class II: $\chi^2=13.781$, $df=2$, $P=0.001$; Gender difference in class III: $\chi^2=3.857$, $df=2$, $P=0.145$

between the classes indicate the presence of significant differences between each two classes in both genders [Table 6].

Discussion

The major goals of successful orthodontic treatment with fixed appliance entail improving the esthetics and function with long-term stability and preserving teeth and periodontium. Management of sagittal relation discrepancies, especially class II and class III malocclusion and bimaxillary proclination involves retraction of maxillary and mandibular anterior teeth to achieve a more pleasant profile when camouflage approach is planned.^[14] Unintended or excessive retraction (excessive lingual crown torque) of these teeth may lead to some iatrogenic effect like the dish-in face or unpleasing smile arch, root resorption, gingival recession, and loss of alveolar bone.^[15,16]

An evaluation of the alveolar bone thickness surrounding the anterior teeth is considered the most essential step before deciding their retraction. CBCT is considered as the most accurate method of assessing the alveolar bone measurements^[17,18] in comparison with other radiographic views such as cephalometric, panoramic, and periapical radiographs.^[18] In a study by Coskun and Kaya^[19] in 2019 of three group of malocclusion buccolingual tooth inclination,

buccal dehiscence/fenestration presence, and lingual dehiscence/fenestration presence were evaluated, they found dehiscence and fenestration prevalence was higher in the anterior buccal region, and these findings make the assessment of the bone thickness before the treatment plan is mandatory; hence, orthodontists must consider the concealed alveolar defects in treatment planning to avoid gingival recession or tooth mobility. Tian *et al.*^[4] and Zhou *et al.*^[20] have proved a relationship between the inclination of the anterior teeth and labial bone thickness surrounding the root. Tian *et al.*^[4] found that the thickness of alveolar bone, especially at the root apex in lingually inclined maxillary incisors is thinner than the normally or labially inclined one, so patients with maxillary protrusion and compensated lingually inclined incisors must be managed with cautions to plan an appropriate approach either by treating them orthodontically or with surgical intervention.

It has been reported that excessive retraction force of anterior teeth with their root apices in approximate position with the cortical plate may result in labial root resorption and perforation,^[21] while dehiscence and fenestrations of the cortical plate have been accounted in case of transverse movement of these teeth is carried out.^[16]

Regarding the root position, the results of the current study revealed that in both genders and all classes, the

Table 4: Descriptive statistics, gender difference and class difference of the alveolar bone thickness at different levels on the central incisor root and angle between the long axis of the bone and tooth

Variables	Level	Genders	Descriptive statistics, mean±SD			Class difference	
			Class I	Class II	Class III	ANOVA	
						<i>F</i> -test	<i>P</i>
Bone thickness (mm)	At two mm	Females	0.279±0.403	0.279±0.425	0.239±0.253	0.061	0.941
		Males	0.25±0.321	0.351±0.416	0.144±0.22	4.912	0.009
		<i>t</i> -test	0.365	-0.952	1.349		
		<i>P</i>	0.715	0.343	0.182		
	At four mm	Females	0.269±0.354	0.246±0.423	0.208±0.233	0.175	0.839
		Males	0.22±0.285	0.329±0.42	0.149±0.23	3.765	0.026
		<i>t</i> -test	0.698	-1.093	0.816		
		<i>P</i>	0.487	0.276	0.418		
	At six mm	Females	0.25±0.352	0.247±0.449	0.162±0.229	0.285	0.753
		Males	0.175±0.235	0.344±0.453	0.157±0.253	4.301	0.016
		<i>t</i> -test	1.105	-1.201	0.066		
		<i>P</i>	0.272	0.232	0.948		
At apex	Females	1.786±2.771	1.247±2.227	1.922±2.328	0.368	0.693	
	Males	1.935±2.331	1.845±2.361	1.255±2.184	1.582	0.208	
	<i>t</i> -test	-0.143	-1.674	1.150			
	<i>P</i>	0.887	0.096	0.253			
Angle°	Females	4.559±3.676	12.668±3.971	3.575±1.704	140.350	0.000	
	Males	4.596±2.765	11.533±4.687	3.176±2.625	99.578	0.000	
	<i>t</i> -test	-0.063	1.705	0.791			
	<i>P</i>	0.950	0.090	0.433			

Significant at $P < 0.05$. SD: Standard deviation**Table 5: Descriptive statistics, gender difference and class difference of the alveolar bone thickness at different levels on the lateral incisor root angle between the long axis of the bone and tooth**

Variables	Level	Genders	Descriptive statistics, mean±SD			Class difference	
			Class I	Class II	Class III	ANOVA	
						<i>F</i> -test	<i>P</i>
Bone thickness (mm)	At two mm	Females	0.173±0.26	0.259±0.47	0.1±0.16	1.286	0.279
		Males	0.247±0.41	0.395±0.48	0.05±0.13	9.480	0.000
		<i>t</i> -test	-1.090	-1.548	1.001		
		<i>P</i>	0.278	0.124	0.321		
	At four mm	Females	0.173±0.29	0.231±0.42	0.089±0.2	0.931	0.396
		Males	0.248±0.42	0.4±0.51	0.051±0.14	8.938	0.000
		<i>t</i> -test	-1.014	-1.967	0.697		
		<i>P</i>	0.313	0.051	0.489		
	At six mm	Females	0.169±0.36	0.228±0.44	0.1±0.23	0.466	0.628
		Males	0.215±0.4	0.383±0.51	0.049±0.14	8.437	0.000
		<i>t</i> -test	-0.238	-1.752	0.887		
		<i>P</i>	0.812	0.082	0.379		
At apex	Females	1.479±2.02	1.555±2.17	3.19±2.91	5.344	0.005	
	Males	1.961±2.59	2.57±3.18	1.486±2.25	2.530	0.083	
	<i>t</i> -test	-1.210	-2.512	2.743			
	<i>P</i>	0.228	0.013	0.007			
Angle°	Females	4.279±3.96	12.42±4.65	2.725±1.55	113.662	0.000	
	Males	4.448±3.19	11.14±4.63	2.976±2.93	85.347	0.000	
	<i>t</i> -test	-0.255	1.749	-0.367			
	<i>P</i>	0.799	0.082	0.715			

Significant at $P < 0.05$. SD: Standard deviation

Table 6: Multiple comparisons between each two groups

Tooth	Variables	Females			Males		
		I-II	I-III	II-III	I-I	I-III	II-III
Central incisor	Two mm						0.002
	Four mm						0.007
	Six mm				0.030		0.007
	Angle	0.000		0.000	0.000	0.033	0.000
Lateral incisor	Two mm					0.023	0.000
	Four mm				0.031		0.000
	Six mm						0.000
	At apex		0.002	0.002			0.026
	Angle	0.000		0.000	0.000	0.039	0.000

Significant at $P < 0.05$

predominant root position is the buccal one followed by the middle then the palatal; this comes in agreement with the findings of other studies.^[12,13,22-25] Reviewing the subtypes of buccal position, the results showed that the highest percentage belong to subtype III, this disagrees with the findings of Jung *et al.*^[13] who found that most of the central incisors lie within subtype I while the majority of lateral incisors lie within subtype II. This indicates that retraction of these teeth must be planned with utmost care and bodily movement is required as the incisors are not covered by enough bone tissue along the long axis of the tooth and this is confirmed by the thickness of alveolar bone at different levels [Tables 2 and 3].

Regarding the angle between the long axes of the tooth and corresponding alveolar bone, the results showed that cases of class II (in both genders) have a significant higher mean values in comparison with class I and III where an obvious decrease in the mean value of this angle is presented in class III cases. This can be attributed to the role of the soft tissue factor and dentoalveolar compensation in aggravating or masking the underlying skeletal defect.^[26,27] Cases with class II malocclusion can be caused by maxillary prognathism, mandibular retrognathism or both. In case of moderate severity of class II, the lower lip will act behind the maxillary incisors resulting in their proclination that increases this angle. Bad oral habits like finger sucking and tongue thrusting play the same role. Conversely, in class III cases, the soft tissue may compensate for (mask) this malocclusion by retroclining the maxillary incisors and proclining the mandibular ones.^[26,27]

In the present study, the thickness of the alveolar bone was assessed along four levels. The results in class I cases indicated that the thickness is decreased from the level of 2 mm to 6 mm and returned to increase at the apex. This comes in accordance with the results of Jung *et al.*^[13] In class II and III, the same pattern may not be applied because of the variations of the angle between the long axis of the tooth and bone and the role of dentoalveolar compensation and difference in the torque between the central and lateral incisors which make such a difference.

Cassetta *et al.*^[28] found that the density and bone thickness may vary at different levels of inter-radicular sites starting from the alveolar crest to the incisor's apex confirming the findings of the current study.

Class II cases characterized by relatively thicker alveolar bone on the labial surface with high mean value of the angle between the long axes of the incisors and corresponding bone in comparison with other classes. This finding comes in agreement with the finding of Tian *et al.*^[4] This means that patients suffering from class II malocclusion due to maxillary dentoalveolar protrusion can be managed with some tipping movement safely during the retraction of the maxillary anterior teeth as adequate amount of bone is available. The retraction in this case results in uprightened incisors on the basal bone with long-term stability.^[14] A general look for the results indicates the presence of an association between the angle between the long axes of the incisors and corresponding bone, alveolar bone thickness and the incisor's root position; moreover, the alveolar bone thickness is relatively thin [Tables 4 and 5], and hence, the vulnerability to loss of marginal alveolar bone and gingival recession will be high;^[16] hence, it is advisable to apply light force with long-term activations and avoid heavy force and/or frequent activations to give time for alveolar bone remodeling to reduce the incidence of bone loss and gingival recession.

Further studies are required to elucidate the effect of variations in the vertical jaw relationships on the alveolar bone thickness and the angle between the long axes of the incisors and corresponding alveolar bone in different sagittal jaw relationships; moreover, large samples must be included to classify the sample according to the etiology of the malocclusion.

Conclusions

As a conclusion; most of the maxillary incisors examined were located in a very close position to the buccal cortical plate and covered by a thin buccal bone wall. The apparent association was noted between the incisors' root position and angulation in the alveolar bone with the buccal bone thickness.

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Conflicts of interest

There are no conflicts of interest.

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