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ORIGINAL ARTICLE

Evaluation of impacted maxillary canine position using panoramic radiography and cone beam computed tomography

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Abstract *Introduction:* Localization of impacted maxillary canine (IMC) position is essential in orthodontic treatment for accurate orthodontic treatment as well as prognosis.

Objectives: This study aimed to: 1- investigate the relationship between the locations of IMC in panoramic radiograph (PR) using sectors in relation to their labio-palatal position in cone beam computed tomography (CBCT): 2- report the incisor root resorption in CBCT in relation to its sector location of IMC in PR.

Material and Methods: The study is a retrospective imaging assessment of 60 IMCs in multiple centers in Riyadh, Saudi Arabia. Sector location of IMC was determined on the PR and correlated with each of their labio-palatal positions and resorption of the root of permanent incisors using CBCT.

Results: There is a significant correlation between sector location and impaction location of IMC. No statistical correlation was found between IMC sector location and lateral incisor root resorption, whereas a significant correlation was found between sector location and central incisor root resorption.

Conclusions: **For** Sectors I and II, IMC tended to be in either the mid-alveolus or labial location, whereas Sectors III and IV tended to show palatal impaction. Therefore, sector could be a good tool for localization of IMC and to predict the possibility of incisor root resorption.

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1. Introduction

The tooth is considered impacted if it remains embedded in the bone past its normal eruption period (Andreasen et al., 1997). The prevalence of maxillary canine impaction is reported to be from 1 to 3% in different populations (Ericson and Kurol,

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1987, 1988b; Fox et al., 1995; Elefteriadis and Athanasiou, 1996; Stewart et al., 2001). Impacted teeth present a great concern in the orthodontic field because of their potential to complicate orthodontic treatments. In addition, precise localization of the impacted canine can aid in selecting a less aggressive technique when exposure of impacted canine is required. In addition, correct localization helps to assess the prognosis of orthodontic treatment (Nagpal et al., 2009). Panoramic radiography (PR) is considered one of the most important imaging tools reported in the literature. PR promotes localizing impacted maxillary canine (IMC), where it is considered helpful and imparts a lower radiation dose to the young patient in comparison with cone beam computed tomography (CBCT).

Sector localization serves to locate the tip of IMC in the mesio-distal direction in PR by drawing lines that differ from different systems of sectors introduced by several researchers. The first sector classification introduced by Ericson and Kurol 1988a, consisted of 5 sectors. In 1992, Lindauer *et al.* modified the Ericson and Kurol (1988a) classification by introducing 4 sectors. Later, Kim et al. (2012) modified the classification proposed by Lindauer et al. (1992) and introduced a new sector classification that consisted of only 3 sectors.

The development of CBCT in dentistry offered practitioners assistance in diagnosing pathologies and locating several structures, while saving the patients from excessive radiation exposure from multiple conventional two-dimensional (2D) radiographs or multidetector CT. Several studies have been published indicating and recommending the use of this modality in locating IMC (Agrawal et al., 2013; Alamri et al., 2012; Ali Alqerban et al., 2014; Sesham et al., 2012).

One of the complications that could be associated with IMC is resorption of neighboring incisors root. Alqerban et al. (2009) conducted a review of lateral incisor root resorption induced by IMC and concluded that early diagnosis of root resorption may reduce the complications. Presence or absence of root resorption also play a role in determining the treatment plan (Alqerban et al., 2011; Botticelli et al., 2011; Haney et al., 2010; Serrant et al., 2014).

Sector localization of IMC using PR is simple and inexpensive, but there are inadequate studies supporting the reliability of using sectors in PR to aid in locating IMC or incisor root resorption. Therefore, we aimed to investigate sector reliability to locate IMCs and investigate incisors root resorption, using a superior modality (CBCT) in locating IMC as a reference.

2. Materials and method

This research was approved by the institutional review board of the College of Dentistry, King Saud University (registration number PR 0008).

The study is a retrospective imaging assessment of a total of 47 patients' records with a total of 60 IMCs who were referred for PR then for a CBCT scan for visualization and assessment of IMCs.

Sample inclusion criteria are: (1) subjects of 13 years or older, (2) PR and CBCT of acceptable diagnostic quality, free from positioning errors. The exclusion criteria are: (1) syndromic patients or patients with cleft lip and palate, (2) presence of any pathological condition in the area of interest that could affect the measurements taken, (3) difference of more than 5 mm in mesio-distal width between the right and left maxillary first permanent molars.

Digital and conventional panoramic images were taken by: (1) OP100 (Instrumentarium Corporation Imaging Division, Tuusula, Finland), (2) ORTHOPHOS XG 3 (Sirona Dental Systems GmbH, Wals bei Salzburg, Austria). Conventional PRs were digitized (JPEG format) using an Epson Perfection V700 Photo Scanner (Epson America, Inc. CA, USA). Romex software (PLANMECA USA, Illinois, and USA) was used for determination of sectors in each panoramic image. PR for each patient was analyzed and evaluated regarding cusp tip location in the mesio-distal dimension by drawing 3 lines that divide the area into 4 sectors (I, II, II, IV) as described by Lindauer et al. (1992) (Fig. 1). Crown's cusp tip selected to verify the sector in which the canine is situated. Sector I was distal to a line tangent to the distal highest of contour of the lateral incisors crown and root. Sector II was mesial to Sector I but distal to a line bisecting the mesio-distal dimension of the lateral incisors along the long axis of the tooth. Sector III was mesial to Sector II, but distal to a line tangent to the mesial highest of contour of the lateral incisors crown and root. Sector IV enclosed all areas mesial to Sector III.

The CBCT scans were obtained using: (1) Iluma CBCT (IMTEK Imaging, 3 M Company, OK, and USA), with a large field of view (FOV) and voxel size: 0.29 mm; (2) Carestream CS 9300 CBCT (Carestream Dental LLC, Atlanta, USA) with a voxel size: 0.09 to 0.5 mm, with adjustable FOV; (3) GALILEOS Comfort PLUS 3 (Sirona Dental Systems GmbH, Wals bei Salzburg, Austria), with a large FOV and with voxel size: 0.25 to 0.125 mm. The images were saved as DICOM (digital imaging and communications in medicine) format and transferred to another computer equipped with 3D image reformatting software, the OnDemand3D™ software, (OnDemand Software, version 1.0, Cybermed Inc., Seoul, South Korea).

All PR images were interpreted by the 2nd author, who was blinded about CBCT readings of impaction location of maxillary canine.

For CBCT data, the examiner was trained for reconstruction of the orthogonal plane and supervised by an oral and maxillofacial radiologist who is an expert in CBCT, with more than 15 years of experience in CBCT. The 3D module was used to obtain the cross-sections of the reformatted orthogonal plane to identify the location of IMC (the sagittal and coronal coordinate was aligned parallel to the long axis of the impacted canine). For detection of the root resorption of incisors, reconstruction was performed either parallel to central or lateral incisor.

From the cross-sectional plane of CBCT images, the location of IMC was classified as labial, mid-alveolus, and palatal as demonstrated by Fig. 2A–C. For root resorption, the examiners scrolled up and down along the incisor root for detection of any resorption, and re-formatted orthogonal planes (parallel to the long axis of intended tooth) were used to identify the presence or absence of root resorption. Resorption was considered present if there was any loss of the root surface without assessment of its degree of severity as seen in Fig. 3.

The examiner was allowed to adjust zoom, contrast, and brightness of the CBCT and PR images using the tools available in viewer. All radiographic interpretation was done in a dim light room.

Intra-examiner reliability for determining sector location in PR, canine CBCT impaction location, and incisor root resorp-

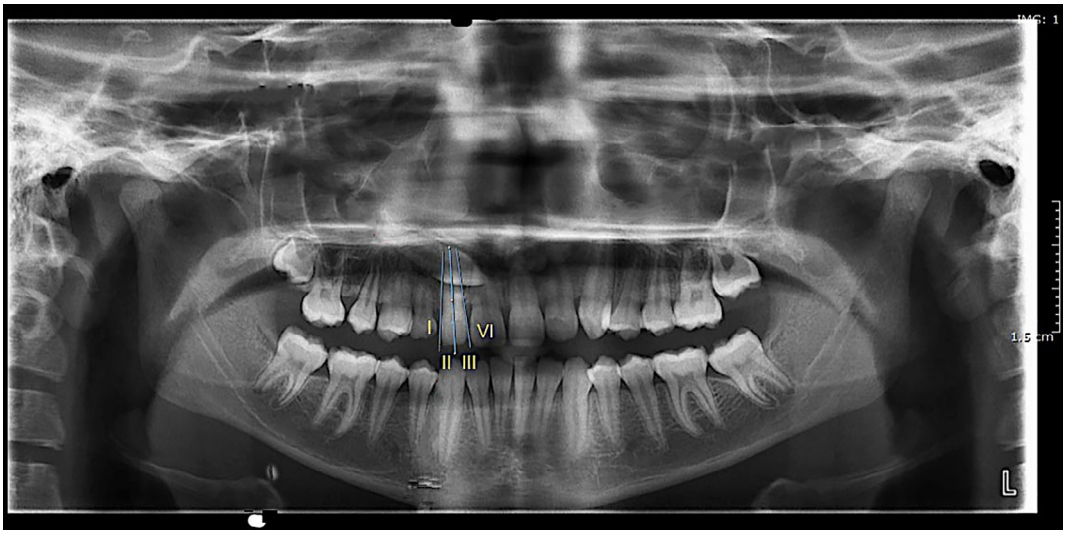

Fig. 1 Digital panoramic radiograph shows sector classification described by Lindauer et al. (1992).

tion in CBCT were re-assessed by interpreting the PR and CBCT at an interval of more than 10 days for 10 IMCs by the same investigator.

2.1. Statistical analysis

Statistical analysis was conducted using SPSS for Windows (22; SPSS Inc., Chicago, IL). The correlation between sector location in the PR and labio-palatal position in CBCT was done using the chi-squared test. In addition, correlation between sector location in the PR and root resorption of each of central and lateral incisor in CBCT was performed using the chi-squared test. The level of significance was set at an alpha level of 0.05. The kappa test was used to assess the intra-examiner reliability for sector location and impaction location of the IMC and incisor root resorption.

3. Results

Forty-seven individuals were included in this study. The mean age was 19.8 years old (SD ± 6.8). The youngest patient was 13 years old, and the oldest was 49 years old. Sex analysis showed 31 female patients (66%) and 16 male patients (34%) of the total sample. There were 13 cases with bilateral impactions and 34 cases with unilateral impactions. A total of 60 canines were analyzed. Of these, 51.7% were located on the right side and 48.3% were located on the left side.

Based on CBCT examination, 55% of impacted canines were located palatally, followed by labial impactions that accounted for 28.3%, whereas mid-alveolus location was found in only 16.7% of cases.

To calculate the intra-examiner reliability of the measurements, the kappa test was used. Kappa coefficient indicates very high intra-examiner reliability for sector location in PR. Regarding IMC localization intra-examiner reliability, kappa coefficient was (0.79). Also, agreement between readings of incisor root resorption showed a kappa coefficient of 0.6 for central incisors and 0.8 for lateral incisors, indicating substantial agreement.

3.1. Sector location and impaction location of maxillary canine

Fifty-eight teeth were included in the analysis. Two cases were not included due to missing lateral incisors. In Sector I, the impacted canine tended to be located in mid-alveolus. In Sector II, 40% of IMCs were located labially, which was similar to that found in mid-alveolus (40%).,whereas palatal impactions accounted for 20%. In Sectors III and IV, the majority of maxillary canines were palatally impacted. Table 1 shows the distributions of IMC location within sectors.

Using the chi-squared test, the results of this study showed that there is a significant statistical correlation between sector identification of IMC cusp tip and its labio-palatal location in CBCT ($P < 0.05$).

3.2. Sector location and root resorption of central and lateral incisors

Fifty-eight teeth were included to investigate the relationship between the impacted canine's sector location and central incisor root resorption. Two cases were non-applicable to determine sector location because of missing lateral incisors.

We found that 64.5% of central incisors with impacted canines located in Sector IV had root resorption, and 9.1% of centrals with canines located in Sector III were found to have root resorption. No resorption of central incisors was found when IMC was located in Sectors I and II, as seen in Table 2. There was significant statistical correlation between central incisor root resorption and position of the IMC within the sector ($P < 0.05$) using the chi-squared test.

For lateral incisor root resorption, 57 teeth were included to investigate the relationship between the IMC's sector location and root resorption. Three cases were excluded because 2 had missing laterals, and 1 case was non- applicable to assess root resorption because of the presence of root canal treatment and a possible beam hardening artifact that may have affected root resorption assessment. Table 2 shows the distribution of lateral incisor root resorption within the sectors.

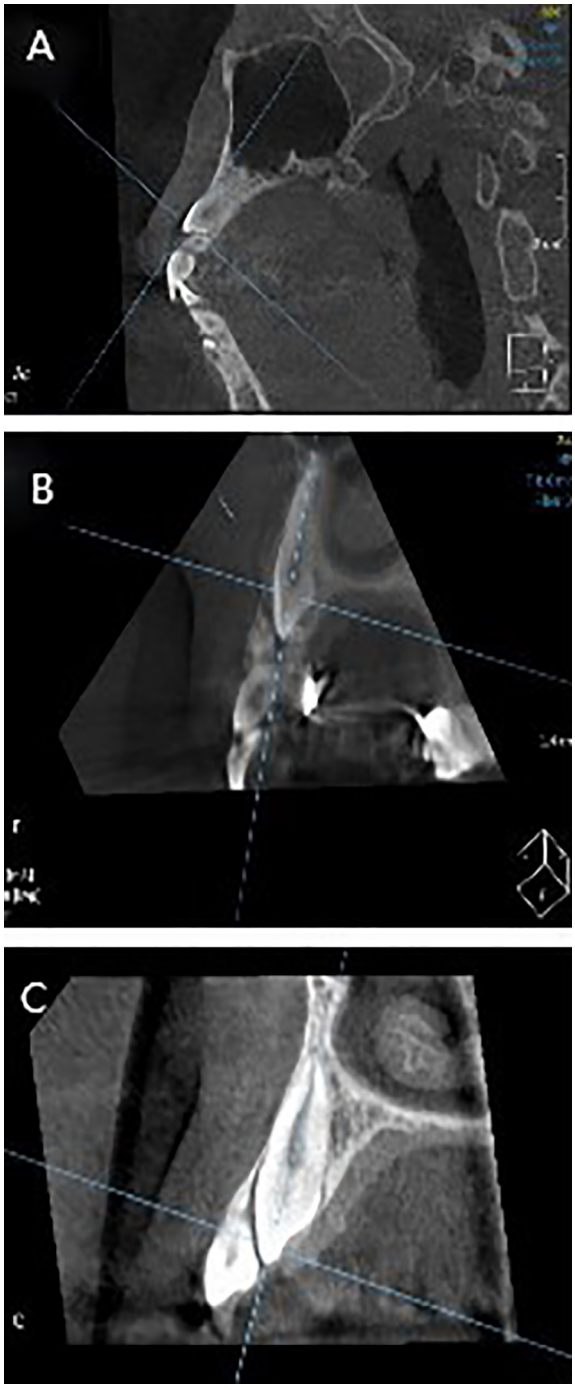

Fig. 2 Reformatted cross-sectional plane demonstrates IMC position. A; labial, B; mid alveolus. C; palatal.

Resorption of lateral incisors was a very common finding. CBCT showed that 91.2% of lateral incisors had root resorption, and 8.7% did not show any root resorption. No significant correlation was found with regard to IMC sector location and lateral incisor root resorption where P value was 0.891. All sectors were found to have a high percentage of lateral incisor root resorption (Table 2).

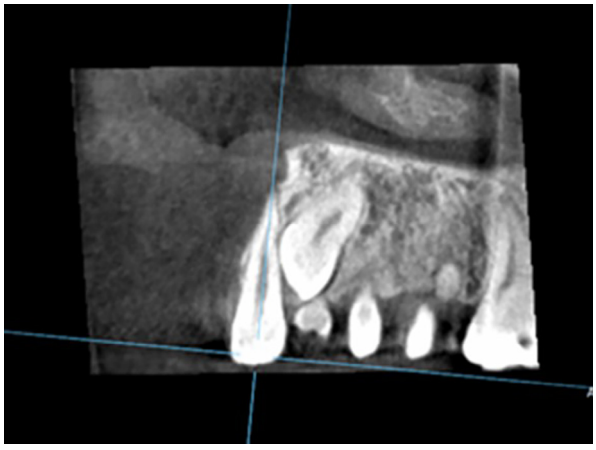

Fig. 3 Reformatted coronal planes show root resorption of central incisor.

4. Discussion

In clinical practice, IMC is considered the cornerstone of the dental arch and has an important role in occlusion during mandibular lateral excursion. Consequently, its position in the jaw has a significant importance for esthetics and function. (Ash and Nelson, 2003; Chandra, 2004).

Retrieval of impacted canines achieved by numerous practices by orthodontists to effectively restore the function and esthetics (Bedoya and Park, 2009).

Park (2012) summarized the management of IMCs in two approaches: either interceptive or corrective. The interceptive approach considered when canine impaction is predicted, at the age of 10–13 years old by extraction of the primary canine (McSheey, 1996). The corrective approach comprises a surgical method for exposing the impacted canines then allowing the canine to erupt spontaneously or surgical exposure with auxiliary attachment for further orthodontic treatment (Bishara, 1992). Surgical and orthodontic management of IMC is difficult and time-consuming. Consequently, when surgical intervention is required, accurate localization of IMCs is essential (Rossini et al., 2012). In addition, exact localization of the impacted tooth determines the feasibility of the surgical approach and the best access to use, as well as the proper direction of orthodontic force application (Nagpal et al., 2009).

In daily practice, PR is considered the first method of detecting any abnormalities in maxillofacial structure that could indicate the presence or absence of impacted teeth (Lindauer et al., 1992), and several researchers have studied its reliability to locate IMC in particular. In this study, we investigated the reliability of sector localization and identification of IMC position using PRs since these radiographs are frequently requested for patients undergoing orthodontic treatment because they affordable to the patient, easy to perform with short duration time, and present no additional radiation exposure to the patient.

To test the clinical validity of PR in locating IMC localization based on the magnification of the crown size, the localization of the impacted canines could be predicted in approximately 80% of cases. However, some limitations were identified (Fox et al., 1995). Several studies were implemented

Table 1 Distribution of maxillary canine impaction locations within sectors.

		Labial	Palatal	Mid-alveolus	Total
Sector I (Frequency, % within sector)		3 (37.5%)	0	5 (62.8%)	8
Sector II		2 (40%)	1 (20%)	2 (40%)	5
Sector III		2 (18.2%)	9 (81.8%)	0	11
Sector VI		9 (29%)	21 (67.7%)	1 (3.2%)	31
Border line cases	Over line between sector I & II	0	0	1 (100%)	1
	Over line between sector II & III	0	1 (100%)	0	1
	Over line between sector III & VI	1 (100%)	0	0	1

Table 2 Frequencies and percentage of central and lateral incisors root resorption within sectors.

		Resorption of central incisors		Resorption of lateral incisors	
		Present	Not present	Present	Not present
Sector I (Frequency, % within Sector)		0	8 (100%)	7 (87.5%)	1 (12.5%)
Sector II		0	5 (100%)	5 (100%)	0
Sector III		1 (9.1%)	10 (90.9%)	9 (81.8%)	2 (18.2%)
Sector VI		20 (64.5%)	11 (35.5%)	28 (93.3%)	2 (6.7%)
Border line cases	Over line between sector I & II	0	1 (100%)	1 (100%)	0
	Over line between sector II & III	0	1 (100%)	1 (100%)	0
	Over line between sector III & VI	1 (100%)	0	1 (100%)	0

and proved the superiority of CBCT imaging modality over the conventional imaging techniques in localizing IMCs (Alqerban et al., 2011; Botticelli et al., 2011; Haney et al., 2010; Serrant et al., 2014).

Consequently, if CBCT is not accessible or the patients belongs to a young age group, to avoid unnecessary radiation exposure, PR is frequently requested by orthodontists for baseline images. With sector identification, orthodontics can predict the location using single exposure with a lower radiation dose imparted to the patients.

Nagpal et al. (2009) showed a different distribution of canine impaction location using the same sector classification used in this study, which was proposed by Lindauer et al. (1992), but no statistical analysis was done in their study to check the correlation significance. Their results showed that 41% of the total sample of IMC located in Sector I were labially located, while 23% were palatally located. Our results showed that none of the palatally impacted canines were found in Sector I, and 62.8% of IMCs were located mid-alveolus, which contradicts their findings. Their study also showed that impacted canines in Sector II in 50% of their sample were either labial and palatal, which is not supported by the results of this study, in which IMC in Sector II tended to be in either the mid-alveolus or labial location. In Sector III, their study showed no significant difference between labial and palatal location, while in this study, the majority of IMCs in Sector III were located palatally. Also, most of their IMCs in Sector IV were located palatally, which is the same finding reported in this study. The result of this study showed that none of the mid-alveolus impacted canines were found in Sector III, which is compatible with their results.

This variation could be attributed to the use of different references or methodology to determine impaction location, as they used the SLOB (same-lingual, opposite-buccal) technique for localization and surgical exposure as a reference to confirm their findings, whereas in this study, CBCT was used as the reference for identification of the location of IMC because it is highly reliable.

In this study, we used the classification proposed by Lindauer et al. (1992) because it is simple, easy to perform, and results are quickly obtained. Few studies have been conducted using the same sector classification proposed by Lindauer et al. (1992); therefore; it was difficult to compare the results of this study with other research since different sector classifications were used, meaning that comparison is not applicable.

The biological mechanism of root resorption is still unclear, and not well understood (Alqerban et al., 2009). Strong correlation was found between central incisor root resorption and sector location of IMC. We found that the majority of centrals with impacted canines located in either Sectors III and IV have resorption, but those in Sectors I and II did not show any resorption. Therefore, if the IMC was located in either Sector III or IV, CBCT is recommended for the early detection of central incisor root resorption,

In this study, lateral incisor root resorption was a common finding in all sectors with no significant correlation found between the sector location and root resorption of lateral incisors. Therefore, CBCT is recommended to detect the severity of root resorption because the presence of lateral incisor root resorption could influence the orthodontic treatment strategy and the choice of its extraction (Alqerban et al., 2016).

Schindel and Sheinis (2013) observed significantly more lateral incisor root resorption in CBCT if the IMC was located in Sectors III and IV in PR when they combined Sectors III and IV and compared them to Sectors I and II. This is not in agreement with the results found by this study, in which where a further statistics were calculated by pooling the data of all 4

sectors together and comparing in regard to lateral incisor root resorption using the chi-squared test, and no significant differences were found ($P > 0.05$). Moreover, in 2012, Kim *et al.* introduced a modified sector classification to the earlier one by Lindauer et al. (1992) that consisted of only 3 sectors. They investigated the relationship between sector location of IMC and found a statistical significance in Sectors II and III that had a greater tendency for root resorption. We could not compare our results with those of Kim et al. (2012) because they used different sector classification than the sector classification used in this study. In addition, Jung et al. (2012) used the sector classification introduced by Ericson and Kurol (1988a) to correlate the presence of root resorption of permanent incisors in CBCT to the mesio-distal position of canines in PRs. They found that root resorption of permanent incisors showed a significant difference according to sector location and was observed in Sectors III, IV, and V. Also, we could not compare our results with those of Jung et al. (2012) because they used a different sector classification than the sector classification used in this study. They did not specify if root resorption is either for lateral or central incisors in particular.

Alqerban et al. (2016) studied several features they considered as a predictors of the presence of root resorption in adjacent teeth using multivariable analysis, and they found that gender, canine apex, vertical canine crown position, and canine magnification were the strongest predictors of root resorption in the prediction model.

To the best of our knowledge, no study has investigated the correlation between root resorption in central incisors and sector location in PR using CBCT as a reference.

5. Conclusions

- There is a correlation between impaction location and sector location. IMCs found in Sectors I and II tended to be in either mid-alveolus or labial, with no tendency to be palatally impacted. In Sectors III and IV, IMC had a high tendency to be located palatally.
- A significant correlation between central incisor root resorption and sector location was found. A tendency for central incisor root resorption was found in sector IV, with none in Sectors I or II. Lateral incisor root resorption could be expected in any sector where IMC cusp tip is located in close proximity to the lateral incisor root.
- In situations when CBCT is not available at the dental practice, PR could aid in the localization of IMC and prediction of incisor root resorption.

Further investigation with larger sample size is recommended.

Declaration of Competing Interest

The authors of this manuscript have no conflict of interest to declare.

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