Original Article

An *in vitro* study to evaluate the accuracy of orthopantomograph as an aid to determine condylar guidance

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Abstract

Purpose: The study was conducted to evaluate the accuracy of orthopantomograph (OPG) as an aid to determine condylar guidance.

Methodology: The condylar guidance was measured using the impressions of glenoid fossae and radiographs (OPG) on thirty dried human skulls. Frankfurt horizontal plane (FHP) was used as a reference plane in both the methods and wire markers were adapted to make the contours of glenoid fossae discernible for both the methods. The condylar inclination angle was measured between FHP and a line joining the most concave point on the glenoid fossa with the most inferior point on the articular eminence on both right and left sides.

Results: Pearson correlation was used for statistical analysis, and it showed a strong correlation between anatomic and radiographic methods ($r = 0.864$ for the left side, $r = 0.873$ for the right side) as well as between right and left sides ($r = 0.830$). The data were also subjected to regression analysis (linear and panel estimation approach) which showed that OPG could be effectively used to predict the condylar guidance ($r^2 = 0.6160$).

Conclusion: Although OPG shows a higher value than anatomic method, it can be used as an aid to set condylar guidance on semi-adjustable articulator.

Keywords: Articular eminence, condylar guidance, glenoid fossa, orthopantomograph

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INTRODUCTION

Condylar guidance is described as the mandibular guidance generated by the condyles and articular discs traversing the contour of the glenoid fossae or, synonymously, as the mechanical form located in the upper posterior region of an articulator that controls movement of the mobile member.[1] In prosthodontics, this mechanical form, a primary requisite of an articulator, is adjusted by individual interocclusal registrations.[2] Christensen and Slabbert have mentioned, "perhaps there is no single and well defined condylar guidance *in vivo*."[3] Studies have also shown the unreliability and inconsistency of recording

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the condylar guidance on the semi-adjustable articulators due to various reasons such as guides (e.g., central bearing, occlusal guides, or tooth surfaces), lateral movement of jaw during protrusion, inability to locate the central bearing at central point, etc. The average variation between interocclusal records for the condylar guidance inclination has been reported to be 21°–64°. An alternative to such inaccuracy can be the use of some stable technique such as radiographs, for example, transcranial temporomandibular joint (TMJ) radiographic records, cephalometric roentgenograms, ultrasonic probes etc. Orthopantomograph (OPG) presents a viable option for this purpose as it provides bilateral and composite sagittal imaging of the skeletal structures.[4] Though there are some limitations of this radiographic method, e.g., panoramic distortion, orientation of head and reference plane, and also difficulty in distinguishing the outline of articular eminence from the zygomatic arch, yet OPG is useful for comparison between right and left sides since both the TMJs are recorded with relatively same magnification errors (×1.2). Also, its reproducibility makes it radiograph of choice whereas the other TMJ specific radiographs are subject to projection errors.[5] So if the OPG image represents the outline of the articular eminence accurately, it may be possible to set the condylar guidance inclination of a semi-adjustable articulator on the basis of angle of inclination of articular eminence obtained from this panoramic image.[4]

METHODOLOGY

Thirty dried human skulls were selected. A solder wire of 0.9 mm diameter (inner) was adapted on the middle of the most concave aspect of the glenoid fossa till articular eminence in an anteroposterior direction. Another solder wire of 0.3 mm diameter (outer) was adapted to the inferior aspect of the zygomatic arch running adjacent to the articular eminence of the skull. These two wires were then fixed with cyanoacrylate glue [Figure 1]. Reference metal balls of 2 mm diameter were then fixed to the upper margin of both right and left external auditory meatuses (Porion) as well as to the lowermost point on the lower margin of both the orbits (Orbitale). Hence, these four balls represented Frankfurt horizontal plane (FHP).

With wires in place, impressions of the right and left glenoid fossae and the articular eminences were made for each skull [Figure 2a] using vinyl polysiloxane putty (Aquasil soft putty, Dentsply, Konstanz, Germany). The FHP was incorporated into the impression using Hanau face-bow and an attached bite fork with a platform fixed over it. Sagittal sectioning of articular eminence and

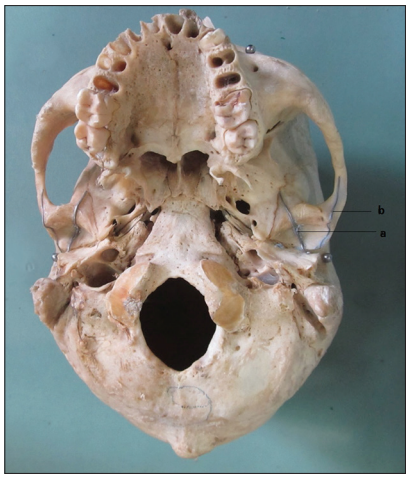

Figure 1: Adapted inner and outer wire markers

fossa impressions was done along each wire groove at right angle to the reference plane using a cutter [Figure 2b]. These sections were inked and impressed on a paper, and the outline of each curvature and the flat reference line was traced on a overhead projector sheet. On the tracing, a line was drawn connecting the most superior and inferior points of curvature line, and the angle between the mean curvature line and the FHP was measured [Figure 2c].

The skull with the wires *in situ* was then placed and stabilized at sufficient height in the focal trough of the panoramic machine (ORTHOPHOS XG 5, Sirona-the dental company, Salzburg, Germany) by using thick floral foam because of its property to support things in place by undergoing selective compression under pressure. With the help of inbuilt laser pointer in the panoramic machine, skull was adjusted three-dimensionally in relation to the midline of the machine and the path of rotation of the recording device. Images were acquired at 70 kV and 10 mA and printed. Three OPGs were made: The first radiograph with both inner and outer wire markers [Figure 3a], second with only the inner wire marker alone [Figure 3b] and the third sans any wire markers [Figure 3c]. All radiographs were made by the same operator, at the same time and with the same OPG machine and printer (DRYPRO SIGMA, Konica Minolta, Inc., Tokyo, Japan).

The tracing of the images with wire marker of each radiograph was made on transparent overhead projector (OHP) sheets. Articular eminence and the inferior border of the zygomatic arch were represented by thick wire and thin wire respectively. Two points were marked on the most superior and the most inferior point of each curve. These two points were joined, and a line was drawn representing a mean curvature line. Horizontal reference line (FHP) was drawn joining the images of two reference

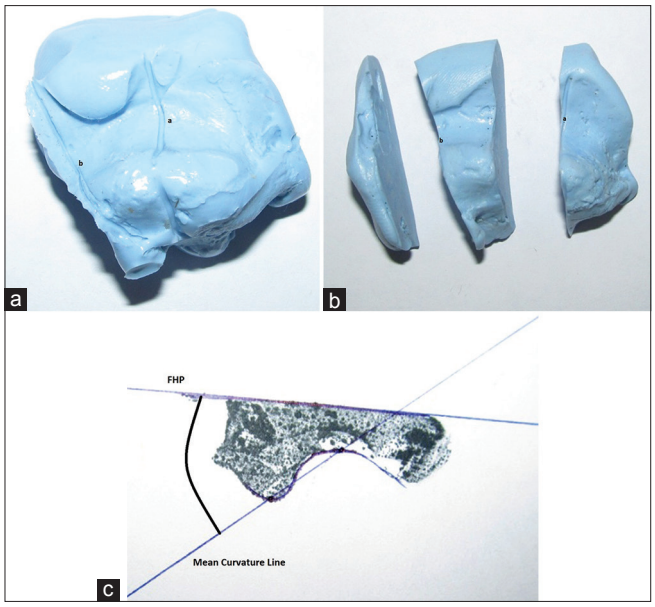

Figure 2: (a) Impression of glenoid fossa. (b) Sectioned impression. (c) Tracing of the sectioned impression

balls. Angles made by the intersection of these two lines were measured.

RESULTS

For thirty dried human skulls, the outlines of right and left articular eminences and glenoid fossae were traced for both vinylpolysiloxane putty impression and radiograph (OPG) separately. The angle was measured (in degrees) between the mean curvature line and the reference line (FHP) and the data obtained for both the sides of skulls were analyzed using Pearson correlation test and Simple Linear Regression Analysis and Panel Regression Analysis.

Table 1 shows that mean difference in angle of inclination of articular eminence from OPG and skull on the left side is 4.52 and on the right side is 4.45. The differences of mean angles of inclination of zygomatic border on the left and right side of OPG and skull are 8.00 and 8.47 respectively.

Table 2 shows the Pearson correlation and *P* value between the angle of inclination as represented by the anatomic contours and panoramic radiographs. Significant correlations are found between the inclination of the articular eminences and their corresponding radiographic images (left articular eminence $r = 0.864$, $P \cong 0.000$, right articular eminence, $r = 0.873$, $P \cong 0.000$). Significant correlations are also found between the actual anatomic contours and the panoramic radiographic images of the zygomatic arches (left zygomatic arch $r = 0.636$, $P \cong 0.000$, right zygomatic arch, $r = 0.761$, $P \cong 0.000$). The correlation between inclination of the right and left articular eminences

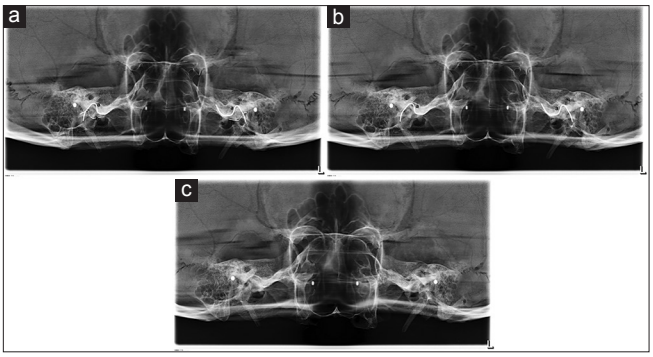

Figure 3: (a) Orthopantomograph showing both inner and outer wire markers. (b) Orthopantomograph showing only inner wire markers. (c) Orthopantomograph without any inner or outer wire markers

on the same skull ($r = 0.830$, $P \cong 0.000$) is also found to be significant.

A perusal of Table 3 indicates that anatomic angles of inclination (i.e., articular eminence and zygomatic border) could be estimated on the basis of OPG values using an estimated equation [Figure 4a and b]. For left articular eminence, the r^2 and its *P* value is 0.747 and ≅ 0.000. For right articular eminence, the values are 0.762 and ≅ 0.000 respectively. Similarly, for left and right zygomatic borders, the r^2 values are 0.404 and 0.579 and their corresponding *P* values is ≅ 0.000 for both. The values of r^2 and their corresponding *P* value are found to be significant at 0.1% probability level.

Table 4 shows that anatomic angles of inclination (i.e., articular eminence and zygomatic border) could be predicted if the OPG values are known [Figure 5]. A panel data estimation approach is adopted for this regression analysis where r^2 is calculated to be 0.6160 for all the combinations. When the equation is carried out with different intercepts for various combinations, corresponding *P* values are found to be highly significant at 0.1% probability level for the left and right articular eminence and significant at 10% probability level for the left and right zygomatic border

DISCUSSION

The inclination of the condylar path plays a significant role in oral rehabilitation as it helps to measure the condylar guidance. Although there is an articular disc interposed between the glenoid fossa and condyle to modify the condylar path, condylar guidance largely depends on the inclination of articular eminence the size and shape of which is not constant throughout life.[6] Since the condylar guidance is specific for each patient, inaccuracy in its registration can result in problems such as posterior teeth disocclusion or multiple occlusal interferences. It has been reported that semi-adjustable

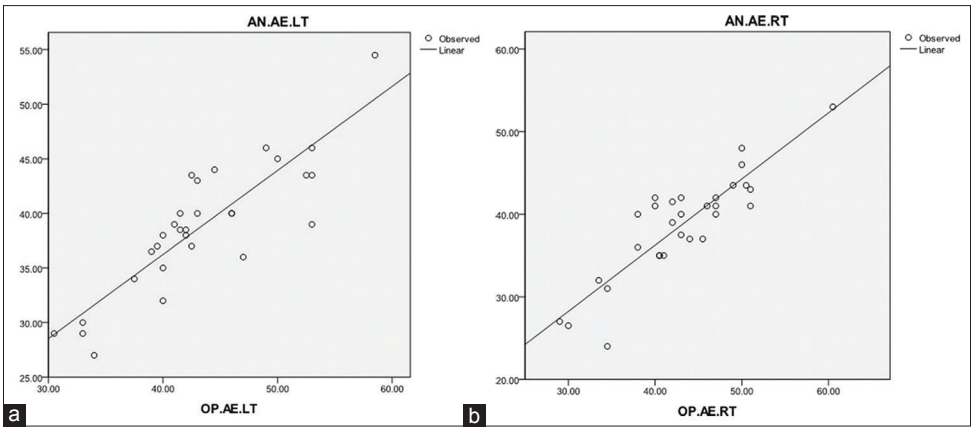

Figure 4: (a) Scatter graphs showing regression equation for predicting anatomic angles of inclination of left side on the basis of orthopantomograph measurements - Simple linear estimation approach. (b) Scatter graphs showing regression equation for predicting anatomic angles of inclination for the right side on the basis of orthopantomograph measurements - Simple linear estimation approach

Table 1: Comparison of mean inclination of articular eminence and zygomatic border on skull and orthopantomographs

Various angle of inclinations	Mean angles on the left side			Mean angles on the right side		
	Skull	OPG	Difference	Skull	OPG	Difference
Angle of inclination of AE	38.75	43.27	4.52	38.68	43.13	4.45
Angle of inclination on ZB	29.95	37.95	8.00	30.13	38.60	8.47

OPG: Orthopantomograph, AE: Articular eminence, ZB: Zygomatic border

Table 2: Pearson correlation between the angle of inclination of anatomic contours and panoramic radiographs

Various angle of inclination of anatomic contours and panoramic radiographs	Correlation coefficient (*r*)	*P* for *r*	Nature of *r*
Left articular inclination and left radiograph	0.864	≅0.000	***
Right articular inclination and right radiograph	0.873	≅0.000	***
Left zygomatic inclination and left radiograph	0.636	≅0.000	***
Right zygomatic inclination and right radiograph	0.761	≅0.000	***
Inclination of the left and right AEs	0.830	≅0.000	***

***Highly significant at 0.1% probability level. ≅: Approximate value, AEs: Articular eminences

articulators using interocclusal records have a low level of reproducibility and are also subject to variables of the instrument, operator, and occlusal records.[7] Clinically, several extraoral (Gysi and McCollum) and intraoral methods (intraoral tracers, interocclusal protrusive records, leaf gauge and Lucia jig) are used to record the condylar guidance inclination.[2,8-11] Radiographs have been in use for this purpose since 1951 as reported by Boos.[12] Radiographically, the various methods documented in the literature include lateral cephalometrics, pantomograph, tomography, digital computed tomography (CT) scans and electronic axiography.[13] Radiographic measurements involve stable bony landmarks as compared to clinical methods, and standardization is also possible. OPG may also prove to be a useful aid for this purpose.

In our study, the angle of inclination of articular eminence recorded on skull using impression of the fossa ranged from 27° to 54.5° on the left side (mean 38.75°) and from 25° to 53° on the right side (mean 38.68°). Using photographic method, Kranjcic *et al.*[14] found that the mean articular eminence inclination for 14 medieval skulls was 49.57 while for 137 contemporary human skulls, mean angle of 62.54° in edentulous, and 61.56° in the dentulous skulls was found. The mean of articular eminence inclination in our study is close to the medieval skull group. Variations in the means might be due to different materials and methodology, and different age groups of the patients whose skulls were studied. Gilboa *et al.*[4] conducted a similar study on 25 human skulls using vinyl polysiloxane impression material and found that mean of inclination on the left side was 37.7 and 35.2 on the right side. These values correspond to those of our study.

The inferior and lateral aspect of the posterior slope of the articular eminence is continuous with the inferior border of the zygomatic arch. The mean angle of inclination of the inferior border of zygomatic arch with the FHP in our study was found to be 29.95° (standard deviation [SD] ± 5.63) on the left side and 30.13° (SD ± 6.23) on the right side. Keesler *et al.*[15] measured the lateral eminence angle on 20 human cadaver heads using the photographic method. They found that the mean angles were 45.7° and 47.5° on the left side and the right side, respectively, which is quite higher than those of our study. These angles when observed by Gilboa *et al.*[4] were 35.2 on the left side and

Table 3: Regression equation for predicting anatomic angles of inclination on the basis of orthopantomograph measurements - simple linear estimation approach

Combination of anatomic contour and corresponding OPG image	Estimated equation (y = a + bx)	r^2	*P* for r^2	Nature of r^2
AE				
Left	Anatomic AE inclination = 5.4243+0.7702 × OPG value	0.747	≅0.000	***
Right	Anatomic AE inclination = 4.6283+0.7895 × OPG value	0.762	≅0.000	***
ZB				
Left	Anatomic ZB inclination = 10.2943+0.5179 × OPG value	0.404	≅0.000	***
Right	Anatomic ZB inclination = 3.5785+0.6879 × OPG value	0.579	≅0.000	***

x and y: Variables, a: The intercept point of the regression line and the y axis, b: The slope of the regression line. ***Highly significant at 0.1% probability level. ≅: Approximate value, AE: Articular eminence, ZB: Zygomatic border, OPG: Orthopantomograph

Table 4: Regression equation for predicting anatomic angles of inclination on the basis of orthopantomograph measurements - panel data estimation approach

Combination	Regression model (y = a + bx)	r^2	*P* for r^2
AE			
Left	Anatomic AE inclination = 8.8945+0.6900 × OPG value	0.6160	≅0.000
Right	Anatomic AE inclination = 8.9198+0.6900 × OPG value		≅0.000
ZB			
Left	Anatomic ZB inclination = 3.7632+0.6900 × OPG value		0.016
Right	Anatomic ZB inclination = 3.4980+0.6900 × OPG value		0.035

x and y: Variables, a: The intercept point of the regression line and the y axis, b: The slope of the regression line. ≅: Approximate value, AE: Articular eminence, ZB: Zygomatic border, OPG: Orthopantomograph

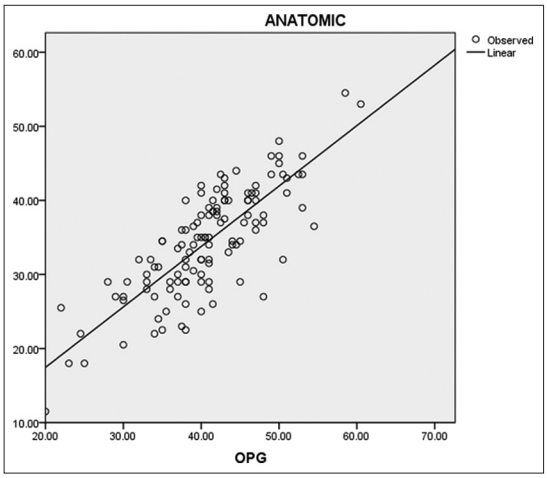

Figure 5: Scatter graph showing regression equation for predicting anatomic angles of inclination on the basis of orthopantomograph measurements (panel data estimation approach)

31.8° on the right side. These findings are close to those in our study.

The mean angle of inclination of articular eminence traced on the OPG image in our study generated the angles as 43.27° on the left side and 43.13° on the right side [Table 1]. These findings were consistent with the findings of Gilboa *et al.*[4] where they recorded these mean angles as 43.6 and 42.8° for the left and right side, respectively. The angles were 42.42° for left and 43.83° for the right side when recorded by Shreshta *et al.*[2] in their study on twelve patients using CT scan as radiographic method. In various clinicoradiographic studies by Prasad *et al.*,[16] Tannamala *et al.*,[17] and Shah *et al.*[18] to compare protrusive interocclusal records with OPGs for determination of sagittal condylar guidance, the radiographic values for the inclination of articular eminence were close to those in our study.

In our study, the mean inclination of zygomatic border and its standard deviation from mean on OPG on the left and right sides was observed to be 37.95 (SD ± 6.91) degrees and 38.60 (SD ± 6.89) degrees, respectively. In a study conducted by Gilboa *et al.*,[4] the mean angle for the left side was 40.9 (SD ± 8.7) and for right side, it was 38.9 (SD ± 6.9) degrees. This study, like our study, showed an increase in angulation when measured by the radiographic method. This increase in angles may be attributed to the magnification factor and curvilinear mode of imaging in the OPG.

A positive correlation existed between the anatomic contours of the left and right articular eminences and their respective OPG images in our study. The correlation coefficient was 0.864 for the left articular eminence and 0.873 for the right articular eminence. Gilboa *et al.*[4] have also found a positive correlation between the anatomic and radiographic angles for inclination of articular eminence, the correlation coefficient being 0.561 and 0.802 for left and right sides respectively. Prasad *et al.*[16] in their study in 75 dentate patients using protrusive interocclusal record and panoramic radiographs found a strong positive correlation between the two methods. Tannamala *et al.*[17] and Shah *et al.*[18] found no statistically significant difference between the mean sagittal condylar guidance angles obtained by protrusive interocclusal records and panoramic

radiographs. However, a statistically highly significant difference was found when the protrusive interocclusal records were transferred to Hanau H2 articulator by Shah *et al*.[18] In contrast to our study, low Pearson correlation values between clinical methods and CT scan were recorded by Shreshta *et al*.[2]

In our study, it was found that the radiographic method showed a higher value for inclination of articular eminence in comparison to anatomic method. The mean difference was 4.52° for the left side and 4.45° for the right side [Table 1]. Gilboa *et al*.[4] reported the mean difference between inclination of articular eminence on OPG and skull to be 7°. Tannamala *et al*.[17] in their clinical study found this difference to be about 4° for both the sides whereas Prasad *et al*.[16] reported it to be 3.18° and 1.97° for the left and right side, respectively.

In our study, the mean difference between the angles of inclination of inferior border of zygomatic arch, when measured by radiographic and anatomic method, was found to be 8 and 8.47 for the left and right side, respectively [Table 1]. This consistently higher value for radiographic method may be attributed to the magnification of the image, coupled with errors in positioning of the skull or patient's head in the focal trough, as reported by Catić *et al*.[19]

The inclination of articular eminence showed a positive Pearson correlation between left and right side in our study, the value of correlation coefficient being 0.830. This finding is in accordance with the findings of Gilboa *et al*.,[4] Prasad *et al*.,[16] Shreshta *et al*.,[2] and Tannamala *et al*.[17] It implies that there is a considerable bilateral symmetry in both the temporomandibular joints in terms of inclination of articular eminence.

A significantly positive correlation was also found between the anatomic contours of zygomatic border on the left and right sides and their respective OPG images in our study. The correlation coefficient was 0.636 for the left side and 0.761 for the right side. Gilboa *et al*.[4] found the correlation coefficient to be 0.724 and 0.522 for the left and right sides, respectively.

For estimating the value of anatomic angles of inclination of articular eminence and inferior border of zygomatic arch using the radiographic measurements, the data were subjected to regression equations using simple linear estimation approach and panel data estimation approach. The anatomic values were considered as "dependent" variables while panoramic radiographic measurements were taken as 'independent' variables. The estimation equation used was: $Y = a + bx$; where x and y are variables, "a" is the intercept point of the regression line and the y-axis while "b" is the slope of the regression line. In our study, the regression coefficients showed a strong degree of association between the two methods by the above-mentioned equation, and it was found that the estimation equation could be effectively used to predict the anatomic angles of inclination of articular eminence and inferior border of zygomatic arch.

CONCLUSION

1. The angles of inclination of articular eminence as by radiographic method were 4.52 and 4.45° higher than anatomic method on the left and right side, respectively
2. When measured, the angle of inclination of inferior border of zygomatic arch was higher in radiographic method as compared to anatomic method by 8 and 8.47 on the left and right side, respectively
3. The Pearson correlation was highly significant between anatomic and radiographic angles for inclination of left and right sides of articular eminence as well as for inferior border of zygomatic arch. It was also observed that a highly significant positive correlation existed between left and right sides for inclination of articular eminence on skulls
4. Using the simple linear regression equation and panel data regression analysis, anatomic angles of inclination for articular eminence could be predicted on the basis of OPG measurements.

On the panoramic radiograph, inferior border of zygomatic arch was located inferior to the curvature of articular eminence. Hence, it should not be mistaken for the inclination of articular eminence which actually helps determine the condylar guidance. However, within the limitations of our study, it is concluded that OPG can be used as an aid to set the horizontal condylar guidance on a semi-adjustable articulator. Further studies are required in this context to take a deep insight into the possibilities of effective use of this radiographic technique for simplification of recording procedure for condylar guidance, keeping in view that soft tissues are also present over the bony landmarks in human beings.

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Conflicts of interest
There are no conflicts of interest.

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