Original Article

Age Estimation of an Individual by Pulp/Tooth Ratio by Maxillary Lateral Incisor Using Periapical Radiographs (RVG)

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Abstract

Aim: To estimate the age of an individual by pulp/tooth ratio by maxillary lateral incisor using periapical radiographs (RVG).

Material and Methodology: The present study consists of randomly selected sample of 120 (60 males and 60 females) individuals [Graph 1], within the age group of 15–54 years grouped as: 15–24 years, 25–34 years, 35–44 years, and 45–54 years. After taking the informed consent from the patients, intraoral periapical radiographs were obtained from the patients. After exposure, the image was saved as a high-resolution JPEG file on a desktop computer and imported to the Adobe Photoshop CS6 image-editing software program for further measurements.

Results: The results of the present study show that the pulp/tooth ratio of maxillary lateral incisor decreases as the age increases because of deposition of secondary dentin on the walls of pulp chamber with increase in age resulting in narrowing of the pulp chamber. The results shows that the correlation between age and pulp/tooth ratio was statistically significant (r = 0.807), (r^2 = 0.652), and (P = 0.000).

Conclusion: The maxillary lateral incisors and the application of the new regression formulae on data obtained from radiovisiography lead to accurate age estimation, if at least the selection criteria are respected and good quality radiovisiographs with clear radiological images are used.

Key Words: *Age estimation, forensic odontology, maxillary lateral incisor, radiovisiography*

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Introduction

"Forensic science is used to predict not the future but the past."

-Ken Goddard.

Forensic science is the scientific method of gathering and examining information about the past which is then used in a court of law. Determining the identity of a decedent is of considerable significance from the ethical, legal, and criminal perspectives; not only it is the prerequisite for officially declaring an individual dead but also it is the basis for dealing with mass disasters, crimes, and war crimes.[1] Forensic odontology has established itself as an important and often indispensable science in medicolegal matters and in particular in the identification of the dead. Much of its expertise is drawn from clinical experience based on basic research and advances in knowledge in dentistry in general.[2]

One of the interesting applications of forensic odontology is age estimation by means of teeth.

Age of the person is an important cultural, religious, and social phenomenon. Various stages of life are considered important milestones such as a child's first birthday, the time to start school, and the right to vote.[3]

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Forensic age assessment in living individuals has become increasingly important over the last few years.[4] In a developing country like India, a large number of people are illiterate and have no knowledge or records of their date of birth which is required by law enforcing agencies in matters such as criminal responsibilities, identification, judicial punishment, consent, rape, criminal abortion, employment, attainment of majority, kidnapping, and prostitution.[5] Age estimation is also required for admission purposes at the time of schooling, joining services, and during retirement. Estimation of age is also required during the enhancement of pensions in the old age. Hence, scientific determination of age is very important.[6] Age can be determined from a variety of factors such as the appearance of ossification centers and their fusions during skeletal development, from height and weight which is applicable in early periods of life, dental development, and changes occurring at puberty such as appearance of hair and their growth and color changes, development of breast in females, starting of menarche and menopause.[7] It is a well-known fact that the assessment of the dental development can be related to an individual's age, but

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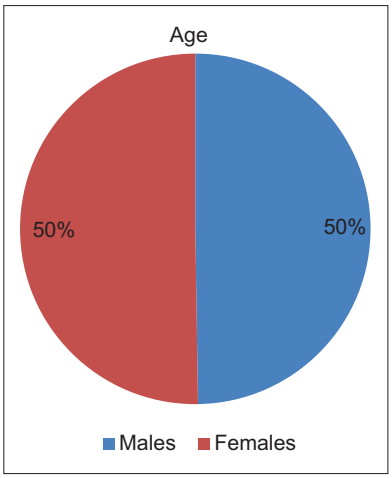
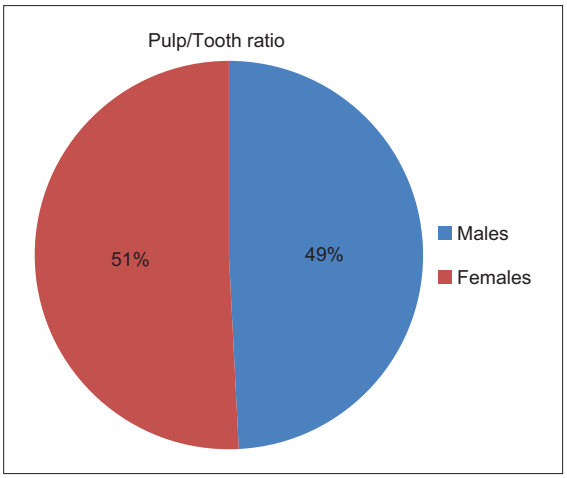
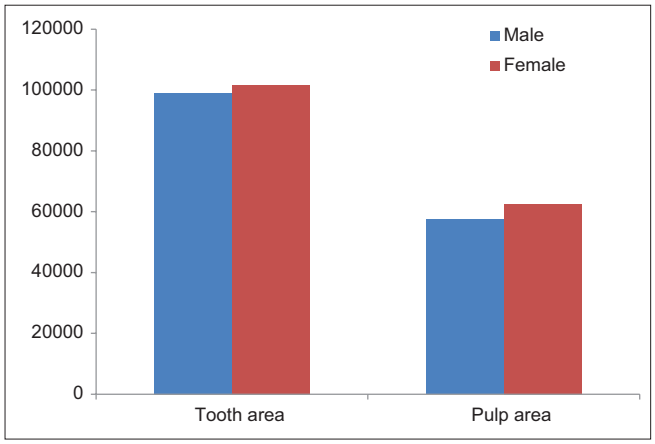


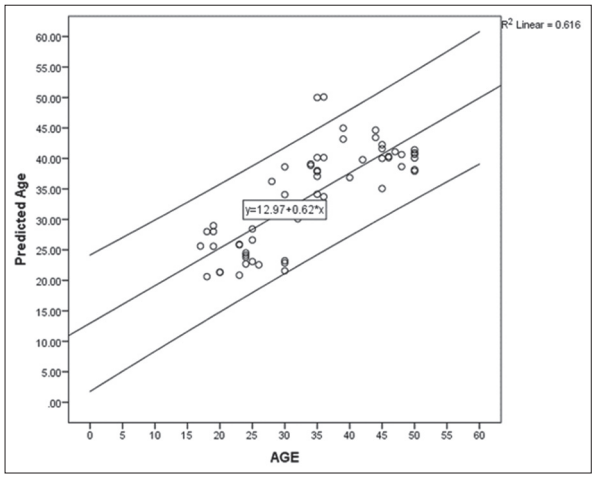
Graph 1: Male-female ratio



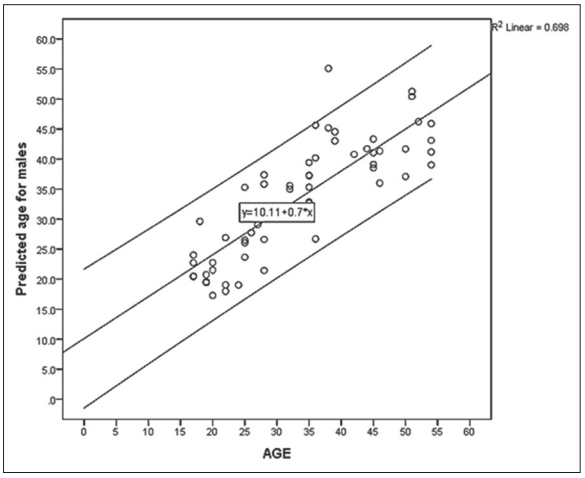
Graph 2: Disribution of male and female according to pulp tooth ratio



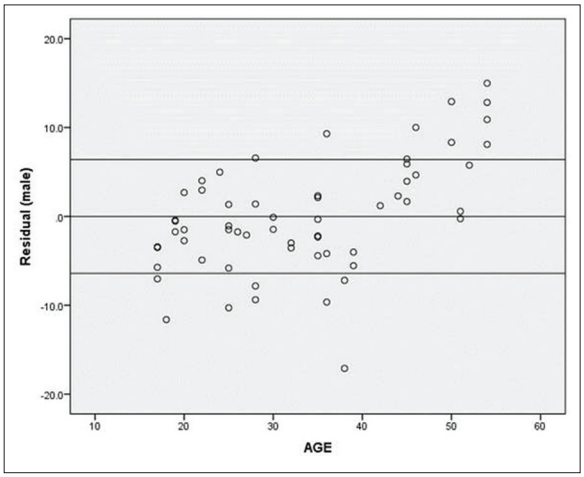
Graph 3: Distribution of tooth area and pulp area



Graph 4: The chronological age for females ranges from 17 to 54 years and the predicted age for females ranges from 16 to 55 years



Graph 5: The chronological age for males ranges from 17 to 54 years and the predicted age for male ranges from 16 to 55 years



Graph 6: The age of male ranges from 17 to 54 years and the average residual age is ±6 and 11.66% patients show residual age ±15

after the age of 21 years when the wisdom teeth also complete their development, there arises a need for an optimal age estimation procedure. With advancing age, there is a reduction in the size of the pulp due to secondary dentin deposition, and a measurement of this reduction can also be used as a parameter to assess the age of the individuals, both in the living and dead.[8-11] In the present study, the pulp/tooth ratio of the maxillary lateral incisor was taken for the estimation of age because the tooth would be the one with large pulp area and single canal. Although maxillary canine suffice this

Table 1: Distribution of subjects

Age group	Male	Female
15-24 years	15	15
25-34 years	15	15
35-44 years	15	15
45-54 years	15	15
Total	60	60

requirement best, they exhibit the presence of secondary canal occasionally.

Materials and Methods

The present study was carried out in Department of Oral Medicine and Radiology in I.T.S Dental College and Hospital, Greater Noida. The ethical committee of the institute approved the study. The study group consists of

Table 2: Age estimation for females

Model summary

Model	*R*	R^2	Adjusted R^2	SE of the estimate	Change statistics				
					R^2 change	*F* change	df1	df2	Significant *F* change
Model 1	0.785	0.616	0.609	6.521	0.616	93.027	1	58	0.001

Coefficients

Model	Unstandardized coefficients		Standardized coefficients	*t*	Significant	95.0% CI for B	
	B	SE	β			Lower bound	Upper bound
Model 1							
Constant	56.076	2.460		22.797	0.000	51.152	61.000
Ratio	−36.411	3.775	−0.785	−9.645	0.000	−43.967	−28.854

Residual statistics

	Minimum	Maximum	Mean	SD	*n*
Predicted value	20.62	50.08	33.78	8.188	60
Residual	−14.988	12.082	0.000	6.465	60
Standard predicted value	−1.608	1.991	0.000	1.000	60
Standard residual	−2.298	1.853	0.000	0.991	60

SD: Standard deviation, SE: Standard error, CI: Confidence interval

Table 3: Age estimation for males

Model summary

Model	*R*	R^2	Adjusted R^2	SE of the estimate	Change statistics				
					R^2 change	*F* change	df1	df2	Significant *F* change
Model 1	0.835	0.698	0.693	6.433	0.698	133.893	1	58	<0.05

Coefficients

Model	Unstandardized coefficients		Standardized coefficients	*t*	Significant	95.0% CI for B	
	B	SE	β			Lower bound	Upper bound
Model 1							
Constant	60.880	2.512		24.238	0.000	55.852	65.908
Ratio	−46.278	3.999	−0.835	−11.571	0.000	−54.284	−38.272

Residual statistics

	Minimum	Maximum	Mean	SD	*n*
Predicted value	17.31	55.10	33.45	9.691	60
Residual	−17.102	14.984	0.000	6.378	60
Standard predicted value	−1.665	2.234	0.000	1.000	60
Standard residual	−2.659	2.329	0.000	0.991	60

SD: Standard deviation, SE: Standard error, CI: Confidence interval

Table 4: Age estimation irrespective of sex

Model summary

Model	*R*	R^2	Adjusted R^2	SE of the estimate	Change statistics				
					R^2 change	*F* change	df1	df2	Significant *F* change
Model 1	0.806	0.649	0.646	6.535	0.649	218.363	1	118	<0.05

Coefficients

Model	Unstandardized coefficients		Standardized coefficients	*t*	Significant	95.0% CI for B	
	B	SE	β			Lower bound	Upper bound
Model 1							
Constant	58.243	1.770		32.904	0.000	54.738	61.748
Ratio	−40.874	2.766	−0.806	−14.777	0.000	−46.351	−35.396

Residual statistics

	Minimum	Maximum	Mean	SD	*n*
Predicted value	18.44	53.14	33.62	8.853	120
Residual	−16.408	15.069	0.000	6.508	120
Standard predicted value	−1.715	2.205	0.000	1.000	120
Standard residual	−2.511	2.306	0.000	0.996	120

SD: Standard deviation, SE: Standard error, CI: Confidence interval

Table 5: Age estimation

Model summary

Model	*R*	R^2	Adjusted R^2	SE of the estimate	Change statistics				
					R^2 change	*F* change	df1	df2	Significant *F* change
Model 1	0.807	0.652	0.646	6.538	0.652	109.539	2	117	<0.05

Coefficients

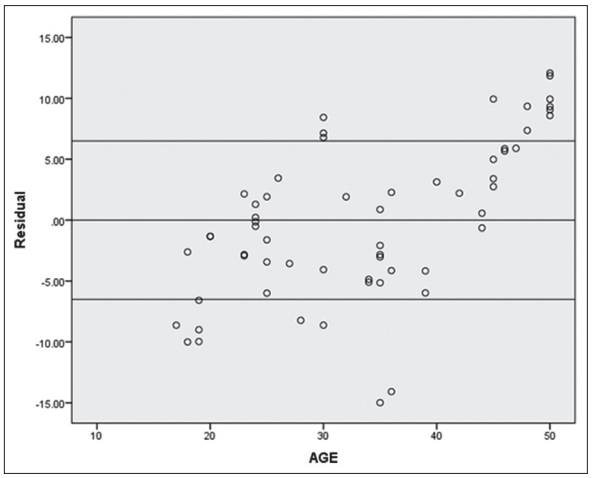
Model	Unstandardized coefficients		Standardized coefficients	*t*	Significant	95.0% CI for B	
	B	SE	β			Lower bound	Upper bound
Model 1							
Constant	58.881	1.894		31.082	0.000	55.129	62.633
Ratio	−40.993	2.770	−0.808	−14.799	0.000	−46.479	−35.507
Sex	−1.134	1.195	−0.052	−0.949	0.345	−3.500	1.233

Residual statistics

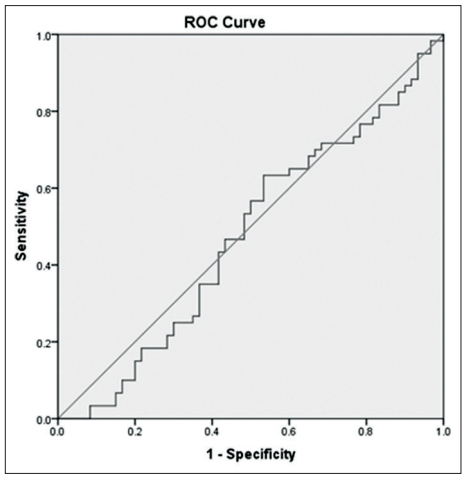
	Minimum	Maximum	Mean	SD	*n*
Predicted value	18.96	52.63	33.62	8.871	120
Residual	−17.027	15.620	0.000	6.483	120
Std. predicted value	−1.652	2.143	0.000	1.000	120
Std. residual	−2.604	2.389	0.000	0.992	120

This shows that the age prediction is more accurate in female individuals in compression to male individuals. SD: Standard deviation, SE: Standard error, CI: Confidence interval

randomly selected sample of 120 (60 males and 60 females) individuals [Graph 1], within the age group of 15–54 years grouped as: 15–24 years, 25–34 years, 35–44 years, and 45–54 years [Table 1]. Patient with clinically present completely erupted maxillary lateral incisor, either both or one which are normal in occlusion without any clinical or radiographic evidence of caries or restoration or any wasting disease, any trauma, and periapical pathology were included in the study. Patients with clinically missing maxillary lateral incisors, the absence of caries/periodontal diseases/wasting diseases, with developmental dental anomalies (dentinogenesis imperfecta, amelogenesis imperfecta, regional odontodysplasia) were excluded from the study. Patients on long-term corticosteroid therapy or suffering from diseases that could cause root canal calcification (e.g., atherosclerosis and arthritis) and any kind of calcification in the pulp chamber/canal were excluded from the study. Pregnant females were also excluded from the present study.



Graph 7: Scatter plot diagram represents the pulp/tooth ratio variance in respect to age and sex



Graph 8: Receiver operating characteristic curve plot against the specificity and sensitivity

Method

After taking the informed consent from the patients, intraoral periapical radiographs were obtained from the patients attending the attending the daily OPD of I.T.S Dental college and research center from 15 to 54 years of age who were divided into four groups irrespective of sex using bisecting technique under aseptic measures. After exposure, the image was saved. After exposure, the image was saved.

Each file was numbered consecutively from 1 to 120, being part of a blind setup. All measurements were carried out by the same observer with ample experience of this technique. Since being able to replicate measurements reliability is an essential component of any metric study, tests for intraobserver error were performed.

Image analysis

Radiographic image was saved as a high-resolution JPEG file on a desktop computer and imported to the Adobe Photoshop CS6 image-editing software program (Adobe Systems Incorporated, San Jose, CA, USA). Next, the image file was opened; the working area was enlarged and zoomed in. Brightness/contrast and sharpness, if needed, were adjusted. The polygonal lasso tool was selected from the toolbar.[9]

To select the entire incisor area, it was necessary to click on the incisor image to set the starting point of the incisor shape; then, the cursor was moved to a close point of the tooth profile and clicked again. A straight line from the first point selected was drawn. Clicking continued to set endpoints for subsequent segments along the incisor profile. The selected area was copied and pasted on a new layer, which was added to the active working area superimposed on the incisor image. This new layer, renamed as "INCISOR," was added to the layer palette.[9]

To select the pulp chamber area, it was necessary to proceed as previously for the entire incisor, following the pulp chamber profile with the polygonal lasso. A minimum of 10 points was also marked on the pulp outline although up to 15 points were marked in some cases. The pulp chamber selection was copied, pasted to a new layer, and renamed as "PULP CHAMBER." The new "PULP CHAMBER" layer contained only the incisor pulp chamber area pixels, as the "INCISOR" layer contained the pixels for the entire incisor area.[9]

To know how many pixels there were in each layer, the histogram palette (windows > histogram) was activated and the "PULP CHAMBER" layer was selected by double-clicking on the layer name; the SELECTED LAYER was chosen and double-click on the histogram image was made. The number of pixels was shown in the "PULP CHAMBER" layer in the histogram palette. This value represented the first required variable (pulp chamber area). Next to be selected was the "INCISOR" layer, and double-click was made on the histogram image. The number of pixels contained in the entire incisor represented the second required variable.[9]

Statistical analyses

Analysis of variance (ANOVA) was applied to study interactions between age, incisor, and sex. To evaluate the accuracy of a regression model, the known age of each individual was compared with estimated age by the mean prediction error method, which represents the mean of the absolute values of the differences between chronological and estimated ages (residuals).[9]

Results and Discussion

The results of the present study show that the pulp/tooth ratio of maxillary lateral incisor decreases as the age increases because of deposition of secondary dentin on the walls of pulp chamber with increase in age resulting in narrowing of the pulp chamber. In particular, the results also show different kinds of aging: straight lines for men and women and a uniformly slower rate in women. Previous studies on other single-root teeth have shown that sex has no significant influence on age estimation whereas the pulp/tooth ratios of female incisors are significantly smaller than those of men.

Pulp/tooth ratio – The mean of pulp/tooth ratio estimated in this study is 0.625. Mean for male and female individuals is 0.5927 and 0.6123, respectively, with standard deviation 0.5927 and 0.22489 for male and female, respectively [Graphs 2 and 3].

Age estimation for females – The correlation between age and pulp/tooth ratio was statistically significant ($r = 0.785$), ($r^2 = 0.616$), and ($P = 0.000$).

On applying ANOVA, keeping age as dependent variable and pulp/tooth ratio as constant predictors, the significance level is 0.000 which is highly significant [Graph 4].

Equation: Predicted age = 56.08 − 36.411 × RA [Table 2].

Age estimation for males – The correlation between age and pulp/tooth ratio was statistically significant ($r = 0.835$), ($r^2 = 0.698$) and ($P = 0.000$). On applying ANOVA, keeping age as dependent variable and pulp/tooth ratio constant predictors, the significance level is 0.000 which is highly significant [Graphs 5 and 6].

Equation: Predicted age = 60.880 − 46.28 × RA [Graph 6 and Table 3].

Age estimation irrespective of sex – Independent samples test showed that the correlation between age and pulp/tooth ratio was statistically significant ($r = 0.806$), ($r^2 = 0.649$), and ($P = 0.000$) [Graph 7].

On applying ANOVA, keeping age as dependent variable and pulp/tooth ratio as constant predictors, the significance level is 0.000 which is highly significant.

Equation: Predicted age = 58.24 − 40.87 × RA [Table 4].

Age estimation – The correlation between age and pulp/tooth ratio was statistically significant ($r = 0.807$), ($r^2 = 0.652$), and ($P = 0.000$).

On applying ANOVA, keeping age as dependent variable and pulp/tooth ratio as constant predictors, the significance level is 0.000 which is highly significant.

Equation: Predicted age = 58.881 − 40.99 × RA − (1.134 × g) [Table 5].

"g" = Gender of subject (0 = female and 1 = male).

This shows that the age prediction is more accurate in female individuals in comparison to male individuals.

The residual age in subgroup III and IV show more variance than in the case of subgroup I and II. Four patients in subgroup IV and 3 in subgroup III show age variance of +8 to +15 years.

The residual age in subgroup IV shows more variance than in the case of subgroup I, II, and III.

In this study, the formula predicted for maxillary lateral incisor gave a standard error of estimation of ±6 years when compared to the study conducted by R. Cameriere on lateral and central incisors, i.e., ±6.64 years.

Correlation between pulp/tooth ratio and sex

The receiver operating characteristic curve plot against the specificity and sensitivity to know whether the sex of the person can be determined by the pulp/tooth ratio of maxillary lateral incisor or not. Linear plotting on the graph [Graph 8] signifies that there is no statistically significant relation present between pulp/tooth ratio and sex of the individuals. The predicted age in females using this method shows less variance in comparison to males. It can be due to the presence of estrogen receptors in human odontoblasts, which may cause enhancement of dentin formation in female results in narrowing of the pulp chamber.[12] However, there was no significant correlation present between the genders of the person with the pulp/tooth ratio; therefore, sex determination cannot be done on the basis of pulp/tooth ratio. In a study conducted on 111 patients using cone beam computed tomography (CBCT) images of monoradicular tooth by Star *et al*, concluded that the variability in age explained by the pulp/tooth volume ratio is gender independent and highest for incisors, followed by premolars and canines. They demonstrated that the observed relation between the pulp/tooth volume ratio and age was stronger for women than for men, but that the difference in relation was neither significant ($P = 0.86$) nor did they observe any significant interaction between tooth types and sex ($P = 0.50$).[13]

As regards the meaningfulness and usefulness of these results in the legal sphere, this research shows promising results for noninvasive dental age estimation by the use of dental radiographs from maxillary lateral incisor although a more population-specific equation must be generated to improve its accuracy. However, other methods available till date such as menarche, voice change, height, and weight are not much efficient to determine the age of the patient as accurately as radiographic methods such as dental and skeletal maturity indicators. In unidentified deceased individuals, this method would be useful in conjunction with age indicators in other areas of the body.

Conclusion

Our study was based on the estimation of the chronological age of an adult from measurements of pulp/tooth ratio obtained from periapical radiovisiograph of maxillary lateral incisor. From the results of this study, it may be concluded that the use of this method in maxillary lateral incisors and the application of the new regression formulae on data obtained from radiovisiography lead to accurate age estimation, if at least the selection criteria are respected and good quality radiovisiographs with clear radiological images are used.

Further studies on larger sample size are required to know the correlation between sex and pulp/tooth ratio and effect of estrogen on pulp/tooth ratio with increasing age. Future research modifying the presented technique together with expected further improvements in periapical radiography by direct digital radiography or by CBCT may provide an easy and optimized dental age estimation technique. The higher image quality of this technique will probably narrow age estimation error and improve dental age estimation. In addition, further studies on different types of teeth and on different population group can facilitate the development of multiple regression models that could possibly enhance age prediction.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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