Determination of sexual dimorphism in humans by measurements of mandible on digital panoramic radiograph

V. Sairam, M. V. Geethamalika, Praveen B. Kumar, G. Naresh, Gareema P. Raju

Abstract

Background: Identification of sex is the first step in forensic science obtained from skeletal remains. Mandible, being a strong bone that is difficult to damage and disintegrate, is an important tool in sex determination. The present study is aimed to assess, compare, and evaluate the mandibular measurements as seen on digital panoramic radiographs to analyze their use in sexual dimorphism assessment. **Materials and Methods:** This retrospective study was conducted using digital panoramic images of 100 each in both genders. Mandibular measurements were carried out utilizing RadiAnt DICOM Viewer 2.2.9 (32 bit) software (Medixant Company, Poland) and subjected to statistical analysis. **Results:** Descriptive statistics for all the parameters on the right and left sides of mandible in both males and females were analyzed. Inferential statistics were performed using *t*-test to compare males and females with different variables. A statistical significance of $P < 0.001$ has been demonstrated for all the variables (except linear measurement of mandibular foramen). All variables showed increased measurements in males than in females. The accuracy of sex determination in mandibular ramus measurements is 79.5% on right side and 77% on left side, where as, in linear mandibular measurements it is 76% on right side and 79.5% on left side. **Conclusion:** Mandibular measurements on digital radiograph are useful in sex determination, and this study can be compared with other similar studies.

Keywords: Digital panoramic radiograph, forensic science, mandibular measurements, sexual dimorphism

Introduction

In forensic examination, identification of sex is the preliminary process as age and stature are dependent.[1] According to Sassouni V (1963), two group techniques to identify humans are classified as reconstructive group method, wherein there are no clues or identities of bodies, and comparative group technique in which the ante- and post-mortem records were compared, and radiology plays an important role in this technique.[2] To investigate sex reliably, the body remnants and level of dimorphism play a decisive role. In mass disasters, sex determination greatly depends on the available skeletal fragments for analysis, the greater the intact skeleton the greater the reliability.[3,4] Pelvis, skull, and mandible bones are frequently used in gender determination, among which mandible bones are preferred as they are compact, least destructible, and have high strength. It shows sexual dimorphism because size, shape, and masticatory forces exerted on the mandible are different in males and females.[1]

The present study was conducted to evaluate the efficacy of mandibular measurements in gender determination by evaluating and comparing measurements of mandibular ramus seen on digital panoramic radiographs. The study also aimed at the prediction of the validity of the linear measurements of mandible observed on digital panoramic radiographs.

Materials and Methods

A retrospective study was conducted using panoramic radiographs of 100 each in both genders taken using Kodak 8000C digital panoramic and cephalometric system (75 kVp, 10 mA, 13.9 s). Inclusion criteria: Panoramic radiographic images with intact dentition were considered.

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Exclusion criteria: Panoramic images with pulpal pathologies and bony lesion were excluded from the study.

Mandibular measurements were carried out using RadiAnt DICOM Viewer software (Medixant Company, Poland) using digital panoramic radiographs. The measurements were made with the agreement of two observers and subjected to discriminant function analysis.

The following parameters were measured.

Mandibular ramus parameters

The terms used in mandibular ramus parameters include:

- Tubercle: A small bony elevation of inferior margin of ramus of the mandible
- Coronion: The craniometric landmark on coronoid process of the mandible
- Maximum ramus breadth (MxRB): Measured from anterior most point of the ramus and line connecting the posterior most point on condyle and angle of mandible
- Minimum ramus breadth (MiRB): Smallest anteroposterior breadth of the ramus
- Condylar height (CH)/maximum ramus height: Ramus height of the mandible from the superior most point on condyle to the tubercle or most projected part of the lower border of the ramus
- Projective height of ramus (PHTR): Point between the highest part of the mandibular condyle and lowest border of the bone
- Coronoid height (CoH): Measurement from coronion and lower part of the bone [Figure 1].[1,3]

Linear measurements of mandible

- *D*1: It is the vertical distance of the most inferior point of the image of the inferior edge of the mental foramen to the image of the inferior limit of the mandibular base at the shortest line connecting the alveolar crest and the inferior limit of the mandibular base, passing through the center of the mental foramen
- *D*2: It is the vertical distance of the most superior point of the image of the superior edge of the mental foramen to the image of the superior limit of the alveolar crest at the shortest line connecting the alveolar crest and the inferior limit of the mandibular base, passing through the center of the mental foramen
- *D*3: It is the vertical distance of the most inferior point of the image of the mandibular notch to the image of the most superior point of the image of the superior edge of the mandibular foramen at the line connecting the most inferior point of the image of the mandibular notch and the inferior edge of the mandibular ramus, passing through the center of the mandibular foramen
- *D*4: It is the vertical distance of the most inferior point of the image of the mandibular notch to the image of the inferior edge of the mandibular ramus, passing through the center of the mandibular foramen [Figures 2 and 3].[5]

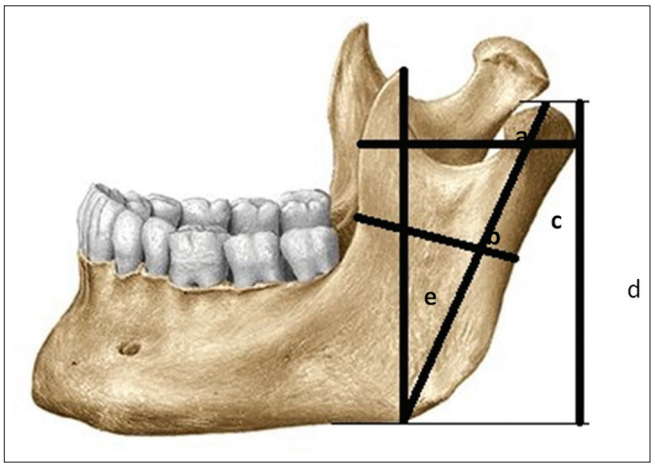

Figure 1: Mandibular ramus measurements

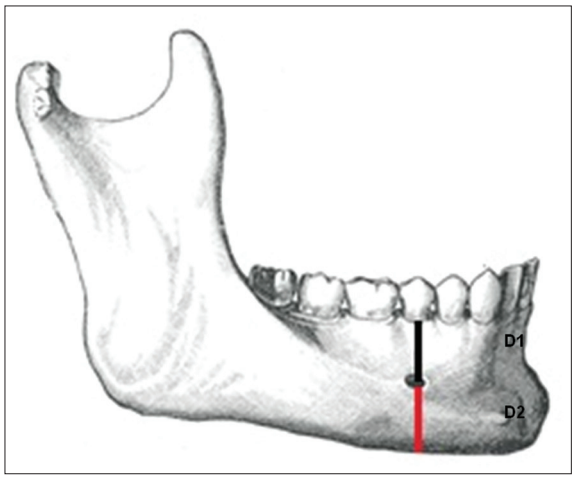

Figure 2: Linear mandibular measurements showing D1 and D2

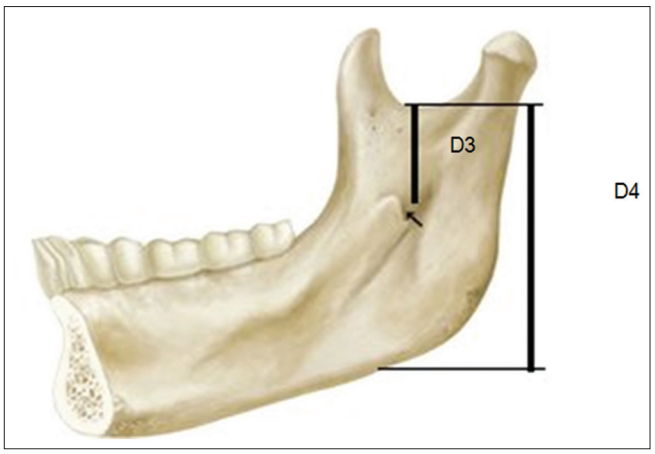

Figure 3: linear mandibular measurements showing D3 and D4

The mandibular measurements are shown in panoramic radiograph in Figure 4.

Results

Statistical analysis

Discriminant function analysis was used to determine variables that discriminate between male and female and is increasingly utilized for sex determination from skeletal measurements.

Mandibular ramus measurements

Descriptive statistics for all the parameters of mandibular ramus on the right and left sides of the mandible in both males and females were analyzed. The mean values of all the variables were higher in males as compared with females. Inferential statistics were performed using independent *t*-test to compare males and females with different variables. The statistical analysis was performed using IBM SPSS, Version 20.0. Armonk, NY: IBM Corp. 2011. A statistical significance of $P < 0.001$ has been demonstrated for all the variables where men showed increased measurements as compared to females on both left and right sides [Table 1]. The *F*-statistic values indicated that mandibular measurements expressing the greatest sexual dimorphism were PHTR followed by CH and CoH on both right and left sides [Table 1]. Mean values of males and females were represented in the form of bar diagrams [Figures 5 and 6].

Linear discriminant analysis was performed to determine variables that discriminate between males and females. The higher/maximum value of the two equations is considered for classifying a given sample as male or female [Table 2]. The gender can be calculated from these functions by multiplying the values of mandibular ramus dimensions by the corresponding coefficients plus the constant which is the discriminant equation for that particular function.[3]

On the right side

D_{Male}: − 175.6300 + 2.3680 (MxRB) + 0.2560 (MiRB) + 2.0640 (CH) + 0.6130 (PHTR) + 1.4520 (CoH)

D_{Female}: − 148.0750 + 2.2010 (MxRB) + 0.1890 (MiRB) + 2.2130 (CH) + 0.1930 (PHTR) + 1.3830 (CoH).

On the left side

D_{Male}: − 157.4930 + 1.4510 (MxRB) + 1.3930 (MiRB) + 2.4600 (CH) + 0.0870 (PHTR) + 0.9840 (CoH)

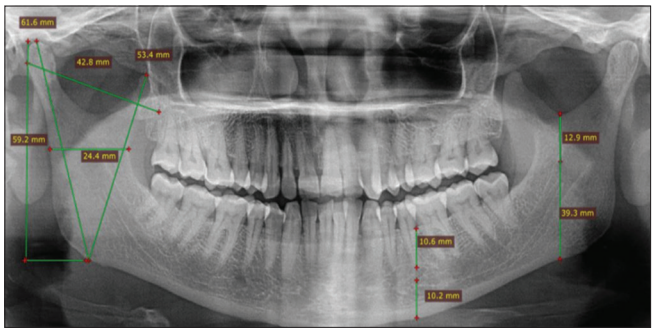

Figure 4: Mandibular measurements on digital panoramic radiograph

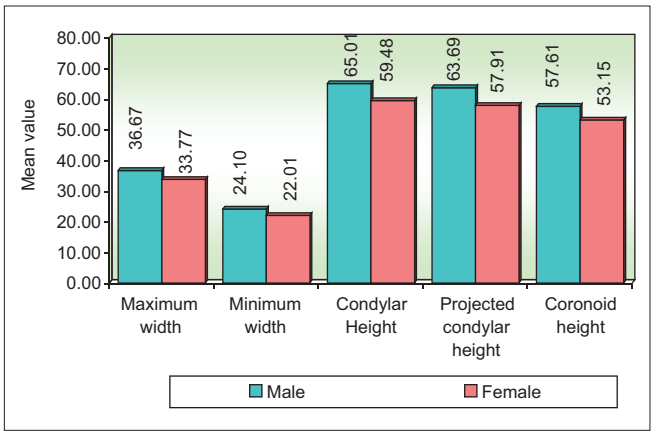

Figure 5: Comparison of males and females with different variables on the right side

Table 1: Comparison of male and females with different variables in both right and left sides by *t*-test

Sides	Variable	Males		Females		Sexual dimorphism	*t*	*F*	*P*
		Mean	SD	Mean	SD				
Right	MxRB	36.67	3.36	33.77	2.91	8.58	6.5250	42.5760	0.00001*
	MiRB	24.10	2.65	22.01	2.27	9.52	6.0023	36.0280	0.00001*
	CH	65.01	3.88	59.48	3.88	9.30	10.0817	101.642	0.00001*
	PHTR	63.69	4.00	57.91	3.82	9.97	10.4326	108.838	0.00001*
	CoH	57.61	4.56	53.15	3.92	8.38	7.4101	54.9090	0.00001*
Left	MxRB	37.49	3.55	35.00	3.18	7.11	5.2228	27.2770	0.00001*
	MiRB	24.69	2.53	23.25	2.47	6.19	4.0679	16.5480	0.0001*
	CH	65.71	4.43	59.65	3.74	10.17	10.4629	109.472	0.00001*
	PHTR	64.37	4.86	58.09	3.78	10.81	10.2029	104.099	0.00001*
	CoH	58.52	4.90	53.40	4.29	9.60	7.8734	61.9910	0.00001*

*Statistically Significant $P < 0.001$. MxRB: Maximum ramus breadth; MiRB: Minimum ramus breadth; CH: Condylar height; PHTR: Projective height of ramus; CoH: Coronoid height; SD: Standard deviation

D_{Female}: −132.5450 + 1.3910 (MxRB) + 1.3680 (MiRB) + 2.2900 (CH) − 0.0340 (PHTR) + 0.9100 (CoH).

For discriminating males from females, on the right side, maximum width, CH, and CoH are the important predictors which have the highest ranks based on the discriminant analysis, and minimum width and projected CH are the low-ranked predictors; whereas on the left side, CH, maximum width, minimum width, and CoH are the important predictors which have the highest ranks based on the discriminant analysis, and the low-ranked predictor was projected CH.

The standardized and unstandardized discriminant function coefficients, structure matrix, and group centroids were shown in Table 3. On the right side, males have a mean of 0.7960 while females produce a mean of −0.7960. On the left side, males have a mean of 0.7670 while females produce a mean of −0.7670. Cases with scores near to a centroid are predicted as belonging to that group.

With all the variables in consideration, 79.5% on the right side and 77% on the left side of the cases were classified correctly and the accuracy can be increased by repeated iterations.

Table 2: Linear discriminant functions for the right and left sides

Variables	Males		Females	
	Right	Left	Right	Left
Constant	−175.6300	157.4930	−148.0750	−132.5450
MxRB	2.3680	1.4510	2.2010	1.3910
MiRB	0.2560	1.3930	0.1890	1.3680
CH	2.0640	2.4600	2.2130	2.2900
PHTR	0.6130	0.0870	0.1930	−0.0340
CoH	1.4520	0.9840	1.3830	0.9100

MxRB: Maximum ramus breadth; MiRB: Minimum ramus breadth; CH: Condylar height; PHTR: Projective height of ramus; CoH: Coronoid height

Linear measurements of mandible (the mental and mandibular foramen vertical positions)

The mean values of linear measurements of mandible of overall values for *D*1, *D*2, *D*3, and *D*4 were significantly higher in males when compared to females. Inferential statistics were

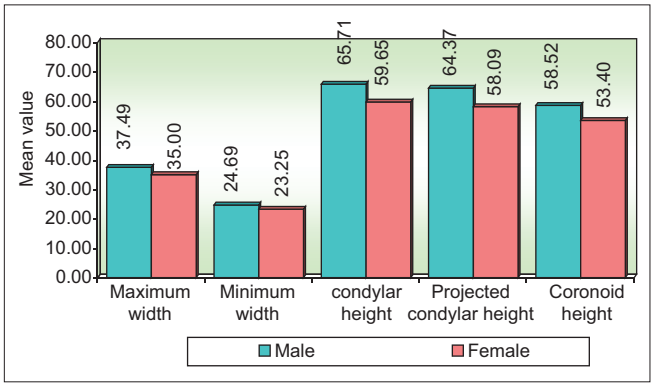

Figure 6: Comparison of males and females with different variables on the left side

Table 3: Unstandardized, standardized coefficients, structure matrix, and centroids for both right and left sides

Variables	Unstandardized		Standardized		Structure matrix		Group centroids	
	Right	Left	Right	Left	Right	Left	Right	Left
MxRB	0.1050	0.0390	0.3310	0.1320	0.5790	0.4820	+0.7960	+0.7670
MiRB	0.0420	0.0160	0.1040	0.0410	0.5330	0.3750	−0.7960	−0.7670
CH	−0.0930	0.1110	−0.3620	0.4540	0.8950	0.9650		
PHTR	0.2640	0.0790	1.0310	0.3430	0.9270	0.9410		
CoH	0.0430	0.0480	0.1850	0.2210	0.6580	0.7260		
Constant	−17.3050	−16.2660						

MxRB: Maximum ramus breadth; MiRB: Minimum ramus breadth; CH: Condylar height; PHTR: Projective height of ramus; CoH: Coronoid height

Table 4: Comparison of males and females with linear measurements on the right and left sides by *t*-test

Sides	Variables	Males		Females		Sexual dimorphism	*t*	*F*	*P*
		Mean	SD	Mean	SD				
Right	*D*1	10.35	1.84	8.60	1.50	20.45	7.4090	54.8940	0.00001*
	*D*2	17.27	2.62	15.58	2.28	10.85	4.8672	23.6890	0.00001*
	*D*3	12.49	2.37	11.98	2.55	4.21	1.4474	2.0950	0.1494
	*D*4	45.93	4.60	42.59	3.41	7.83	5.8249	33.9300	0.00001*
Left	*D*1	9.78	1.94	8.29	1.40	18.01	6.2542	39.1150	0.00001*
	*D*2	17.66	2.55	15.68	2.16	12.63	5.9275	35.1350	0.00001*
	*D*3	12.61	2.80	11.98	2.44	5.27	1.6988	2.8860	0.0909
	*D*4	46.76	3.64	42.49	3.41	10.05	8.5616	73.3010	0.00001*

*Statistically Significant $P < 0.001$. SD: Standard deviation

performed using *t*-test to compare males and females with different variables. A statistical significance of $P < 0.001$ has been demonstrated for all the variables except *D*3.

The mean values of the left side were slightly greater than the right side except for *D*1 [Table 4].

When comparing males and females, the linear measurements on the right and left sides expressing the greatest sexual dimorphism were *D*1 and *D*2. The mean values of males and females were represented in the form of bar diagrams [Figures 7 and 8].

Linear discriminant analysis was performed to determine variables that discriminate between males and females. For classifying a given sample as male or female, the higher/maximum value of the two equations is considered [Table 5].

The standardized and unstandardized discriminant function coefficients, structure matrix, and group centroids were shown in Table 6. On the right side, males have a mean of 0.7840 while females produce a mean of −0.7840 whereas on the left side, males have a mean of 0.8010 while females produce a mean of −0.8010. Cases with scores near to a centroid are predicted as belonging to that group.

With all the variables in consideration, 76% on the right side and 79.5% on the left side of the cases were classified correctly into specific gender and the accuracy can be increased by repeated iterations.

Table 5: Linear discriminant functions for both right and left sides

Variable	Males		Females	
	Right	Left	Right	Left
Constant	−106.8510	−111.1370	−87.1960	−89.5800
*D*1	4.5860	3.1870	3.8030	2.6420
*D*2	3.1830	2.4470	2.7700	2.1060
*D*3	1.3270	0.2660	1.2660	0.3230
*D*4	2.0310	3.0610	1.9250	2.8000

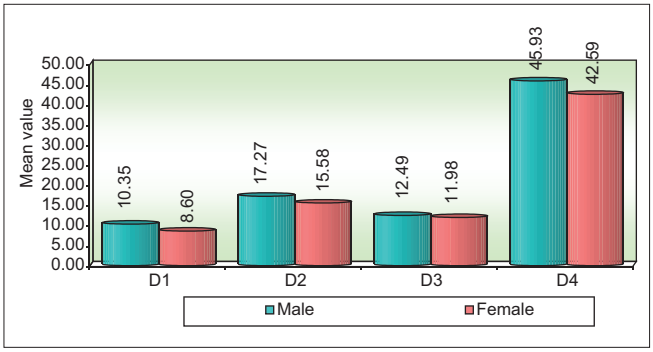

Figure 7: Comparison of males and females with linear measurements on the right side

Discussion

Identification of sex based on measurements and morphometry is accurate and can be used in the determination of sex from the skull.[6] Mandibular bone was used for the analysis because this bone is often recovered and it is largely intact. In this study, mandibular measurements were subjected to discriminant function analysis. The principal advantages of panoramic images are their broad coverage, low patient radiation dose, the short time required for image acquisition, and also the contrast and brightness enhancement. The limitations of panoramic images are magnification and geometric distortion, the vertical dimension in contrast to the horizontal dimension is little altered, and this technique is quite sensitive to positioning errors because of relatively narrow image layer. However, in our study, this limitation did not affect our results since all images were uniformly magnified.[2] Inbuilt system magnification is 1.14 (Kodak 8000C).

Each of the variables measured on the mandible using panoramic radiograph showed statistically significant sex differences between sexes, thus expressing a strong sexual dimorphism. In this study, the mandibular ramus measurements demonstrated the greatest univariate sexual dimorphism in terms of PHTR followed by CH. With all the variables in consideration, 79.5% on the right side and 77% on the left side of the cases were classified correctly into specific gender. The linear measurements of the mandible demonstrated the greatest sexual dimorphism in terms of *D*1 and *D*2. With all the variables in consideration, 76% on the right side and 79.5% on the left side of the cases were classified correctly into specific gender.

Earlier studies on mandible by Morant *et al*. (1936), Martin (1936), and Hrdlicka (1940) have found that the sexual differences were highest in height of the ramus, which is comparable with the present study results.[1,7] A study by Humphrey *et al*. found that mandibular condyle and ramus are the most sexually dimorphic than that of other measurements of mandible because of the greatest morphological changes in size and growth.[7]

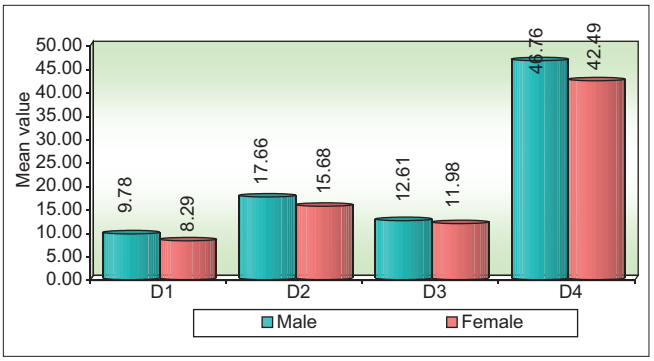

Figure 8: Comparison of males and females with linear measurements on the left side

Table 6: Unstandardized, standardized coefficients, structure matrix, and centroids for both right and left sides

Variables	Unstandardized		Standardized		Structure matrix		Group centroids	
	Right	Left	Right	Left	Right	Left	Right	Left
*D*1	0.4990	0.3400	0.8380	0.5740	0.6680	0.5520	0.7840	0.8010
*D*2	0.2640	0.2130	0.6470	0.5040	0.4390	0.5230	−0.7840	−0.8010
*D*3	0.0400	−0.0360	0.0970	−0.0950	0.1310	0.1500		
*D*4	0.0680	0.1630	0.2730	0.5740	0.5250	0.7560		
Constant	−12.5310	−13.4520						

According to Giles, mandibular ramus height, MxRB, and MiRB are highly significant, with an accuracy of 85%.[8] Steyn and Iscan achieved an accuracy of 81.5% with mandibular parameters.[9] Saini *et al*. reported that mandibular ramus measurements showed statistically significant values and the greatest sexual dimorphism in terms of CoH followed by CH and achieved an overall accuracy of 80.2%.[3] Abu-Taleb and El Beshlawy Taleb found statistically significant higher mean ramus values, with condylar and CoHs being the best predictors for sex determination and overall accuracy of 79.6%.[10]

Yousue and Brooks, Souaga *et al*., Freitas, Al-Khateeb *et al*., Amorim *et al*.,[11] and Şahin *et al*. found that there was a significant difference in the location of the mental foramen according to gender and that the measurements were relatively higher in men, which was in agreement with the present study findings.

According to Thakur *et al*., the distance between the superior margins of the mental foramen to the inferior border of the mandible (SM-IB), the distance between the inferior margins of the mental foramen to the inferior border of the mandible (IM-IB), and the distance between the superior margin of the mental foramen to the alveolar crest (SM-AC) showed statistically significant values and helps in discriminating males from females.[12] According to Chandra *et al*., the superior border of the mental foramen to the lower border of the mandible (SL) and the inferior border of the mental foramen to the lower border of the mandible (IL) values showed highly significant differences for gender determination.[13] The results attained in the present study showed better correlation with other previous similar studies that were mentioned above.

Conclusion

Mandible can be considered as a beneficial tool in gender determination since it possesses resistance to damage and disintegration process. The results of the study were comparable with other similar studies and showed that the mandibular measurements could be used for sex determination. Hence, it is suggested that mandibular ramus and vertical mandibular measurements using panoramic radiographs can be used for gender determination in forensic analysis.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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