Research Article

Reliability of photogrammetry to assess frontal facial proportions in comparison with anthropometry

Swetha Sridharan, S. Aravind Kumar*

ABSTRACT

Background: One of the most important factors in the planning of orthodontic treatment and the assessment of treatment changes is to evaluate the soft tissue. For this purpose, quantitative assessments of soft tissue have been performed using lateral cephalometric radiographs classically, and several cephalometric analyses have been developed and proposed. It is not possible to evaluate the soft tissues from the frontal view using cephalometric radiographs. In addition to cephalometric radiographs, soft tissue evaluation has been carried out by means of different methods such as anthropometry, two- or three-dimensional photogrammetry, and three-dimensional imaging techniques. Among these methods, two-dimensional photogrammetry has the advantage of being a basic, non-invasive, cost-effective, and quick method that requires minimal time and equipment in the assessment of soft tissue. **Aim:** This study aims to assess the reliability of photogrammetry in assessing the frontal facial proportions in comparison to anthropology. **Materials and Methods:** Frontal photographs of 18 male and 18 female healthy young adults were taken in natural head position and frontal facial proportions were assessed in software on the photograph, and real-life measurements were taken on the subject using Vernier calipers. Two indices were assessed upper face-to-face height index and lower face-to-face height index. An independent sample *t*-test was used to assess the difference among the two methods used. **Results:** No statistically significant difference between manual and photogrammetric measurements was seen. **Conclusions:** Photogrammetry can be effectively used as an alternative to anthropometry when similar technique is used for acquiring the photograph of the subjects.

KEY WORDS: Anthropometry, Frontal facial proportions, Orthodontic diagnosis, Photogrammetry, Reliability of photo

INTRODUCTION

Measurements from standardized photographs are termed as photogrammetry. For the past few decades, photogrammetry has been widely used by specialists that have impact on facial structures such as orthodontists, oral surgeons, prosthodontists, and plastic surgeons. Routine photogrammetry compliments the narrative of a patient's case file, but it is considered useless unless the prints are of standardized sizes and views.

One of the most important factors in the planning of orthodontic treatment and the assessment of treatment changes is to evaluate the soft tissue. For this purpose, quantitative assessments of soft tissue have been performed using lateral cephalometric radiographs classically, and several cephalometric analyses have been developed and proposed. It is not possible to evaluate the soft tissues from the frontal view using cephalometric radiographs. In addition to cephalometric radiographs, soft tissue evaluation has been carried out by means of different methods such as anthropometry, two- or three-dimensional photogrammetry, and three-dimensional imaging techniques. Among these methods, two-dimensional photogrammetry has the advantage of being a basic, non-invasive, cost-effective, and quick method that requires minimal time and equipment in the assessment of soft tissue. Orthodontists also realized the close relationship between occlusion and facial beauty. Esthetic harmony became one of the major objectives of orthodontic treatment. Since it is impossible to quantify an attribute like beauty, the science of orthodontics concentrated on quantifying various linear measurements in assessing the proportions of pleasing faces.[1]

With the advent of cephalometrics, the emphasis shifted for a short period to the assessment of bony

Access this article online

Website: jprsolutions.info | ISSN: 0975-7619

Department of Orthodontics, Saveetha Dental College and Hospital, Saveetha University, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamilnadu, India

***Corresponding author:** Dr. Aravind Kumar S, Professor and Head, Department of Orthodontics, Saveetha Dental College and Hospital, Saveetha University, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamilnadu, India. E-mail: aravindkumar@saveetha.com

Received on: 19-08-2018; Revised on: 24-09-2018; Accepted on: 23-10-2018

foundation of the face and positions of teeth. However, it was soon realized that correction of hard tissues to the normal values need not always brings about an improvement in the facial esthetics. In this context, soft tissue assessment gets a priority over hard tissue assessment. Photographic evaluation of orthodontic patient has assumed considerable importance as an essential aid in treatment planning since it depicts a very close representation of the appearance of the person. It pasteurizes how a face actually looks and is, therefore, superior in this respect to cephalogram which gives only the facial outline. Therefore, it becomes necessary to supplement the cephalometric analysis with photographic evaluation.

The notion that accurate measurements could also be obtained from standardized photographs was proposed in the 1940s.[2]

Photogrammetry has been introduced as an alternative to direct measurements to obtain distances between facial landmarks using both two-dimensional and three-dimensional methods. Obtaining measurements from photographs are less intrusive to the patient, more cost-effective, provide a permanent record of the face that can be accessed at a later time, and offer consistency in longitudinal studies in which different observers with different direct measuring techniques might participate.[3-5]

Tanner and Weiners examined the reliability of the technique and concluded that although photogrammetry of the trunk and limbs was just as accurate as direct body measurements, facial measurements were not as reliable. They explained that the posing errors were of a greater magnitude than the increments of growth because, in their study, no steps were taken to accurately position the head. They thought that standardized positioning of the face would have significantly improved the reliability of the measurements.[6]

Gavan *et al*. pointed to the shortcomings of using photographs as sources of anthropometric data including photographic processing errors (shrinkage), lighting differences, and size distortions caused by the enlargement of structures at different distances from the camera. They presented techniques to minimize these problems, but their expressed concern was that the data obtained from the two-dimensional photographs were not as accurate as measurements made directly. Although valid, this concern is not applicable if the data collected would be specifically used for two-dimensional applications.[7]

The application of photogrammetry in orthodontics was first proposed by Stoner,[8] who compared pre- and post-treatment profiles with ideal profiles.

Stoner described the use of photographs to assess the changes in the profile after orthodontic treatment.[8,9]

Ricketts later identified recurring ideal mathematical relationships in facial dimensions, as well as in nature and art.[10] Until the introduction of computerized imagery, two-dimensional linear data of this type were of little use to the clinician. Advances in computer technology, however, have provided the orthodontist with a new tool with which to study craniofacial growth. Computer imaging now allows the orthodontist to digitize, measure, display, and manipulate these images.

Photogrammetry is increasingly being employed to assess facial characteristics.[11-15] It is reported to be valid for many measurements,[4,16] reliable[4,11-14,17] and is a practical approach to clinical analyses and comparison (Edler 2006, Sim 2000, Muradim 2007).

Most of the studies about soft tissue evaluation on standardized two-dimensional life-sized photographs reported the assessment or comparison of racial characteristics, differences between genders, and treatment changes.[13,16-18,20-22,29] Only one study concluded the reliability of reference distances for facial asymmetry assessment.[19] Since then, researchers have never attempted to study the reliability of reference distances that can be used for photogrammetric assessment. Nonetheless, such information is important for clinicians because the reliability of the measurements obtained from the photographs depends on the reliability of the reference distances used on photographs.

The aim of this study is to assess the reliability of photogrammetry in assessing the frontal facial proportions in comparison to anthropology in Indian adult population.

MATERIALS AND METHODS

Random sample of 36 Indian individuals with Indian grandparents was included in the study. The following were the inclusion and exclusion criteria.

Inclusion Criteria

- 18 males and 18 females between the ages of 18–25 years.
- Angle's Class I molar occlusion with acceptable crowing (Little's irregularity index score of <3).
- Normal growth and development with well-aligned maxillary and mandibular dental arches.
- Full complements of permanent teeth irrespective of the third molar status.

Exclusion Criteria

- Individuals with Angle's Class II or Class III molar relation.
- Indian individuals without Indian grandparents.
- Individuals who underwent previous orthodontic or

prosthodontic treatment.
- Individuals who underwent maxillofacial or plastic surgery.
- Individuals having any facial asymmetry or trauma.
- Asymmetry, malformations, syndromes, and anomalies.
- Mixed ethnicity.

Direct Measurement

Direct measurements on each subject's face were done with a Vernier caliper in centric relation, relaxed lip posture, natural head orientation, and standing position. Three frontal distances were measured directly. The parameters measured are shown in Figure 1. The distances measured include as follows:
- Upper face height - N-Sto
- Lower face height - Sn-Gn
- Total face height - N-Gn.

Indirect Measurements

Photographic setup consisted of a tripod (PHOTRON TRIPOD STEDY 450; PHTSTD-45: 1725 star house, Hong Kong) that held a digital single lens reflex camera (Canon, model EOS 700D; EF-S 18-55 IS II; Shimomaruko, Tokyo, Japan). The tripod controlled the stability and the correct height of the camera according to the subject's body height. This ensured a correct horizontal position of the optical axis of the lens (The CanonEF-S, 18–55 mm lens f/3.5–5.6 wide angle to midtelephoto zoom 35 mm equivalent focal length of 28.8–88 mm). A 88 mm focal lens was selected to maintain the natural proportions. Flash was not used; natural light was used as a source of light for image capture.

The camera was used in its manual mode; the shutter speed was 1/125/s and the opening of the aperture f/11. The subject was positioned on a line marked on the floor and framed alongside a vertical metallic centimeter scale. The scale allowed measurements at life size (1:1). Subjects were first instructed to a stand with their eyes looking forward to a vertically standing mirror on the side for a natural head posture and then turn their whole body 90° to face the camera with the lip relax. The photo was then taken in natural head posture. The lips should also be relaxed, adopting a normal position. The operator ensured that the patient's forehead, neck, and ears were clearly visible during the recording [Figure 2].

The photographic records, 35 mm slide format, were cropped using the Adobe Photoshop CS6 and were digitized and analyzed using the FACAD (version 3,4,0,3; copyright©: llexis AB 2010; 3.4.0.3A) software program for the Windows operating system. The program was previously customized with the landmarks used in this investigation.

The software calculated all measurements once they were identified on each landmark record, which had previously been digitized and scaled to life size. All the manual procedures were undertaken by the same operator.

Landmarks used in the study were as follows:
- Nasion (N): The point of greatest convexity in the midline between the forehead and nose.
- Subnasale (sn): The point at which nasal septum merges with upper cutaneous lip in the midsagittal plane.
- Stomion (sto): The midpoint of the lowermost point of the upper lip.
- Gnathion (gn): The most anterior and inferior part of the midpoint of chin.

Index used in the study was as follows:
- Upper face-face height index (N-Sto/N-Gn × 100).
- Lower face-face height index (Sn-Gn/N-Gn × 100).

To determine the differences of reference distances between the female and male subjects, independent sample *t*-test was used. For the frontal measurements

Figure 1: Anthropometry

Figure 2: Photogrammetry

in both sexes, differences between the values measured on the subject's face and photograph were calculated with repeated measure analysis of variance. The reliability of the method was analyzed using Dahlberg's formula, ME = $\sqrt{\sum(x_1-x_2)^2/2n}$[18] to determine the difference between two measurements made at least a month apart.

RESULTS

The mean values for the upper and lower face height index obtained by manual and photogrammetric methods are given in Table 1 and are shown in Figures 3 and 4. Statistical analysis revealed that there was no statistical difference between the manual and photogrammetric measurements.

For the upper face-face height index, P = 0.08 in male and 0.07 in female which was not statistically significant. For the lower face-face height index, P = 0.08 in male and 0.09 in female which was also not statistically significant. These values indicate that there was no difference in the two methods used.

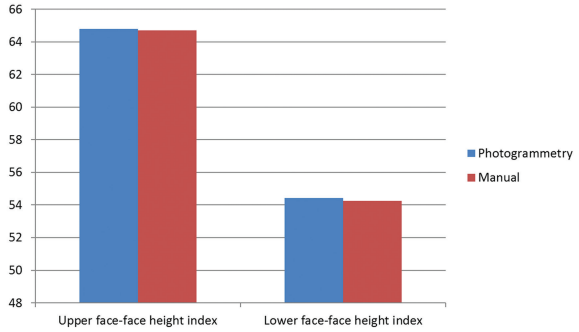

Figure 3: The measurements in male

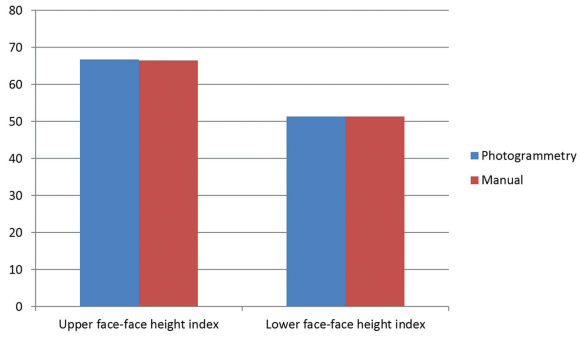

Figure 4: The measurements in female

DISCUSSION

The aim of orthodontic treatment is not only to achieve good function but also to improve the appearance.[19] Therefore, one of the most important parts in the planning of orthodontic treatment is evaluation of the soft tissues.[20]

Two-dimensional photogrammetry has been used for evaluating the soft tissues in orthodontic treatment. The method was shown to be sufficiently reproducible since it was simple to achieve in a conventional setting, without the need for special equipment.[27,28] Several authors have published the profile and frontal characteristics of the face by collecting the data through anthropometric measurements[6-10] or using three-dimensional imaging techniques.[15,19,23-26,32] The determination of the reliability of two-dimensional photogrammetry for soft tissue evaluation might provide clinicians the ability to assess soft tissue from frontal views after orthodontic treatment.

The nature of the frontal facial proportions is affected by many factors including ethnicity. As the proportions vary according to malocclusion type, the present study used only Class I subjects. The inclusion criteria and methodology were orientated to identify normative values that can assist in diagnosis and treatment planning for Indian young adults seeking orthodontic treatment or orthognathic surgery. On the other hand, skeletal variations may exist in subjects with a Class I molar relationship. For example Scavone *et al.*,[21] reported that cephalometric values for a sample of subjects with normal occlusions showed variation far beyond the mean values which are often used as treatment goals. For this reason, in the present study, the selected subjects were also judged to have well-balanced faces.

This study was designed to classify the reliability of the two indices used for photogrammetric assessment on subjects' two-dimensional extraoral photographs obtained under three postural conditions (relaxed lip posture, natural head orientation, and standing position).

The current clinical interest in natural head position (NHP) derives from studies correlating NHP with craniofacial morphology, future growth trends, and respiratory needs. It has also been argued that NHP is the logical reference and orientation position

Table 1: Mean values

Parameter	Male			Female		
Parameter	**Photogrammetry**	**Manual**	***P*-value**	**Photogrammetry**	**Manual**	***P*-value**
Upper face-face height index	64.78±2.4z	64.7±2.65	0.08	66.73±2.06	66.55±1.96	0.07
Lower face-face height index	54.43±3.11	54.26±2.8	0.08	51.37±2.7	51.31±2.8	0.09

for craniofacial analysis and the publication of illustrations. Lateral cephalometric radiographs recorded routinely in NHP would be more meaningful for the clinician.[22] Individuals are presented as they appear in life when using NHP. Consequently, frontal profile photographs recorded routinely in NHP would be more clinically meaningful.[23]

Until now, there has been evidence about the usefulness of photographic assessment.[11,28,33-36] The usefulness of the patients' photographs is limited unless the prints are of standardized view and size. Farkas *et al*.[37] compared a large number of facial measurements taken from standardized photographs. Determination of absolute sizes on photographs necessitates the calibration of the image such as marking on the subject's face and using a millimeter ruler unless life-size photographs are used. In our study, a millimeter scale served as a standard of image calibration. To reduce method error, all measurements were made with each subject in natural head orientation,[31] centric relation, standing position, and relaxed lip posture.[30]

Photogrammetric analysis offers some advantages in terms of human frontal facial analysis. First, with photogrammetric analysis, angular measurements are not affected by photographic enlargement as in cephalometric analysis.[23] Thus, the technique can be used clinically for both pre-treatment planning and evaluation of a patient's post-operative results. Second, every profile fiducial point can be moved freely on a computer monitor using the cephalometric software program to determine the most appropriate profile points. Finally, photogrammetric analysis does not require expensive equipment and complex procedures, and it offers digitized results that are easily evaluated. Furthermore, the collected data can be arranged in unified charts.

The reliability of the investigator was excellent, indicating that soft tissue landmarks can be located consistently. The arguments for using the ear and eye are that the main development of these parts of the face occurs in the early ages and are stable during growing.[38,39]

Of the two parameters obtained from the frontal views, the difference between direct and indirect measurements was <1 mm in male subjects. In contrast to our results, Farkas *et al*.[37] and Tanner and Weiner[6] showed that the difference between the indirect and direct measurements was >1 mm. The difference in the other remaining parameters was <2 mm except for the parameter Go-Go in female subjects.

It must be kept in mind that all subjects were asked to look straight ahead to a distant point at eye level during the assessment. The use of a stable point might eliminate possible errors resulting from pupils and might give different results. Ras *et al*.[19] concluded that the best reference line among four reference distances (exocanthion-exocanthion, endocanthion-endocanthion, superalare-superalare, and cheilion-cheilion) was formed by the one which is perpendicular and bisects the line that connects the landmarks exocanthion. However, Farkas *et al*.[37] found that Ex-Ex was not reliable while En-En was reliable. Farkas *et al*.[37] stated that the magnitude of the error depends on the thickness of the soft tissue covering the bony landmark, and measurements of some landmarks (e.g., Al, Sa, and Sba) may not be precise if photographs are not sharp enough to allow accurate identification of these landmarks.

Our results showed that all of the measurements are reliable when compared with direct measurements. The measurement precision is important for evaluating the reliability of direct and indirect methods. In this study, the measurement precision was 1 mm. The reliability of our results depends on the clinic sense of the orthodontist. Furthermore, the results could change if life-sized photographs are used.

CONCLUSIONS

The measurements made from the manual method and photogrammetry did not show any significant difference in measuring the upper face and lower face indices among Indian male and female. Based on the results from our study, it can be concluded that photogrammetry can be used as an effective alternative to anthropometry when similar methodology is used for acquiring the picture.

REFERENCES

1. Fränkel R, Fränkel C. [Orthodontics in orofacial region with help of function regulators]. Inf Orthod Kieferorthop 1988;20:277-309.
2. McNamara JA Jr., Brust EW, Riolo ML. Soft tissue evaluation of individuals with an ideal occlusion and a well-balanced face. In: McNamara JA Jr., editor. Esthetics and the Treatment of Facial Form. Monograph 28, Craniofacial Growth Series. Ann Arbor, Michigan: Center for Human Growth and Development, the University of Michigan; 1993. p. 115-46.
3. Broadbent BH, Broadbent BH Jr., Golden WH. Bolton Standards of Dentofacial Developmental Growth. St Louis, Mo: CV Mosby; 1975.
4. Garner LD. Soft-tissue changes concurrent with orthodontic tooth movement. Am J Orthod 1974;66:367-77.
5. Roos N. Soft-tissue profile changes in class II treatment. Am J Orthod 1977;72:165-75.
6. Farkas LG. Anthropometry of the Head and Face in Medicine. New York: Elsevier North Holland Inc.; 1981. p. 285.
7. Uzun A, Akbas H, Bilgic S, Emirzeoglu M, Bostanci O, Sahin B, *et al*. The average values of the nasal anthropometric measurements in 108 young Turkish males. Auris Nasus Larynx 2006;33:31-5.
8. Chung C, Lee Y, Park KH, Park SH, Park YC, Kim KH, *et al*. Nasal changes after surgical correction of skeletal class III malocclusion in Koreans. Angle Orthod 2008;78:427-32.
9. Arslan SG, Genç C, Odabaş B, Kama JD. Comparison of facial proportions and anthropometric norms among Turkish

young adults with different face types. Aesthetic Plast Surg 2008;32:234-42.
10. Bozkir MG, Karakaş P, Oğuz O. Measurements of soft tissue orbits in Turkish young adults. Surg Radiol Anat 2003;25:54-7.
11. Zhang X, Hans MG, Graham G, Kirchner HL, Redline S. Correlations between cephalometric and facial photographic measurements of craniofacial form. Am J Orthod Dentofacial Orthop 2007;131:67-71.
12. Gavan JA, Washburn SL, Lewis PH. Photography: An anthropometric tool. Am J Phys Anthropol 1952;10:331-53.
13. Milosević SA, Varga ML, Slaj M. Analysis of the soft tissue facial profile of Croatians using of linear measurements. J Craniofac Surg 2008;19:251-8.
14. Stoner MM. A photometric analysis of the facial profile. Am J Orthod 1955;41:453-69.
15. Hajeer MY, Ayoub AF, Millett DT. Three-dimensional assessment of facial soft-tissue asymmetry before and after orthognathic surgery. Br J Oral Maxillofac Surg 2004;42:396-404.
16. Leong SC, White PS. A comparison of aesthetic proportions between the oriental and Caucasian nose. Clin Otolaryngol Allied Sci 2004;29:672-6.
17. Dimaggio FR, Ciusa V, Sforza C, Ferrario VF. Photographic soft-tissue profile analysis in children at 6 years of age. Am J Orthod Dentofacial Orthop 2007;132:475-80.
18. Scavone H, Zahn-Silva W, do Valle-Corotti KM, Nahás AC. Soft tissue profile in white Brazilian adults with normal occlusions and well-balanced faces. Angle Orthod 2008;78:58-63.
19. Ras F, Habets LL, van Ginkel FC, Prahl-Andersen B. Method for quantifying facial asymmetry in three dimensions using stereophotogrammetry. Angle Orthod 1995;65:233-9.
20. Fernández-Riveiro P, Suárez-Quintanilla D, Smyth-Chamosa E, Suárez-Cunqueiro M. Linear photogrammetric analysis of the soft tissue facial profile. Am J Orthod Dentofacial Orthop 2002;122:59-66.
21. Scavone H Jr., Trevisan H Jr., Garib DG, Ferreira FV. Facial profile evaluation in Japanese-Brazilian adults with normal occlusions and well-balanced faces. Am J Orthod Dentofacial Orthop 2006;129:721.e1-5.
22. Choe KS, Yalamanchili HR, Litner JA, Sclafani AP, Quatela VC. The Korean American woman's nose: An in-depth nasal photogrammatic analysis. Arch Facial Plast Surg 2006;8:319-23.
23. Honrado CP, Lee S, Bloomquist DS, Larrabee WF Jr. Quantitative assessment of nasal changes after maxillomandibular surgery using a 3-dimensional digital imaging system. Arch Facial Plast Surg 2006;8:26-35.
24. Guess MB, Solzer WV. Computer treatment estimates in orthodontics and orthognathic surgery. J Clin Orthod 1989;23:262-8.
25. Soncul M, Bamber MA. Evaluation of facial soft tissue changes with optical surface scan after surgical correction of class III deformities. J Oral Maxillofac Surg 2004;62:1331-40.
26. Nechala P, Mahoney J, Farkas LG. Digital two-dimensional photogrammetry: A comparison of three techniques of obtaining digital photographs. Plast Reconstr Surg 1999;103:1819-25.
27. Good S, Edler R, Wertheim D, Greenhill D. A computerized photographic assessment of the relationship between skeletal discrepancy and mandibular outline asymmetry. Eur J Orthod 2006;28:97-102.
28. Edler R, Wertheim D, Greenhill D. Comparison of radiographic and photographic measurement of mandibular asymmetry. Am J Orthod Dentofacial Orthop 2003;123:167-74.
29. Fernández-Riveiro P, Smyth-Chamosa E, Suárez-Quintanilla D, Suárez-Cunqueiro M. Angular photogrammetric analysis of the soft tissue facial profile. Eur J Orthod 2003;25:393-9.
30. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning. Part I. Am J Orthod Dentofacial Orthop 1993;103:299-312.
31. Lundström A, Lundström F, Lebret LM, Moorrees CF. Natural head position and natural head orientation: Basic considerations in cephalometric analysis and research. Eur J Orthod 1995;17:111-20.
32. Terajima M, Yanagita N, Ozeki K, Hoshino Y, Mori N, Goto TK, *et al*. Three-dimensional analysis system for orthognathic surgery patients with jaw deformities. Am J Orthod Dentofacial Orthop 2008;134:100-11.
33. Proffit W. Contemporary Orthodontics. St Louis, Mo: CV Mosby; 1986. p. 127-34.
34. Graber TM. Orthodontics; Principles and Practice. 3rd ed. Philadelphia, PA: WB Saunders; 1972. p. 275-88.
35. Robertson NR, Volp CR. Telecentric photogrammetry: Its development, testing, and application. Am J Orthod 1981;80:623-37.
36. Lauweryns I, van Cauwenberghe N, Carels C. Interobserver and intraobserver agreement of clinical orthodontic judgments based on intraoral and extraoral photographs. Angle Orthod 1994;64:23-30.
37. Farkas GL, Bryson W, Klotz J. Is photogrammetry of the face reliable? Plast Reconstr Surg 1980;66:346-55.
38. Farkas LG, Posnick JC, Hreczko TM. Anthropometric growth study of the ear. Cleft Palate Craniofac J 1992;29:324-9.
39. Sanchana B, Nithya J. Significance of maintaining dental records. Indian J Forensic Med Toxicol 2014;8:4-7.

Source of support: Nil; Conflict of interest: None Declared