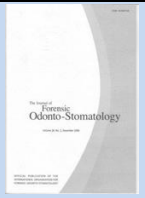


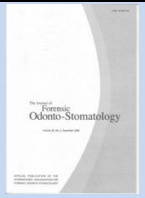

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SECTION IDENTIFICATION

Personal Identification in Forensic Science Using Uniqueness of Radiographic Image of Frontal Sinus

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ABSTRACT

Frontal sinus pattern matching is a useful means of forensic identification. By the use of radiographs forensic scientists have recognized that there are diverse anatomical variations in the structure of the frontal sinus. Radiographs are a diagnostic tool, widely used in dental practices, hospitals and other health disciplines. Most health institutions possess the facility to store radiographs over long periods of time. Frontal sinus pattern matching technique can be applied in cases where ante mortem frontal sinus radiographs are available and dental matching cannot be carried out. Frontal sinus pattern matching technique may also be used to corroborate identifications based on other techniques such as fingerprints, teeth, or circumstantial evidence. The present study was carried out to assess the effectiveness of using the radiographic image of the frontal sinus for personal identification in studied population group. The results concluded that the appearance of the radiographic image of the frontal sinus is unique for each individual. On this evidence it is proposed that frontal sinus pattern matching can be used for personal identification when other methods have failed.

***KEYWORDS*:** frontal sinus, postero-anterior skull radiograph (PA skull radiograph), personal identification forensic science.

INTRODUCTION

"The dead cannot cry out for justice, it is the duty of the living to do so for them." - Lois MeMaster Bujold".

Identity is the set of physical characteristics, functional or psychic, normal or pathological, that defines an individual. Since time immemorial, human identification has proven to be one of the most challenging tasks faced by mankind.[1] The application of radiology in forensic sciences was introduced in 1896, just one year following the discovery of X-rays by Roentgen where he used X-rays to demonstrate bullets lodged within the brain.[2] Radiographic analysis, in which ante mortem and post-mortem X-rays are compared, is frequently used for human identification purposes.[3] Radiographs obtained for diagnostic and clinical purposes always include skeletal features. The skeleton usually survives both natural and unnatural abuse or violation and is available for radiographic examination in most circumstances. It is often possible to obtain both ante mortem and post-mortem radiographs in cases where identification is required.[4] It is possible to use many different components of the skeleton for pattern matching in a similar way that finger prints are used for purposes of identification.[4,5]

Anatomically frontal sinus growth is completed before the age of 20 years and remains stable thereafter[6]. Additionally the anterior wall of the frontal sinus is thick and resistant to injury.[7]

Different radiographs can be used to study the pattern of the frontal sinus including both PA skull and Lateral skull views. Pattern matching is possible using both PA film projections (Caldwell orientation and Water's view). The Caldwell view allows better viewing of the frontal sinus, compared to Water's view which gives a slightly foreshortened image.[8] Hence this study was undertaken to determine the uniqueness of the radiological image of the frontal sinus for personal identification in a studied population group using the PA skull radiograph.

MATERIAL AND METHODS

109 individuals were randomly selected from OPD. The purpose of the study was explained to each of them and individual written and informed consent was obtained. Individuals less than 20 years of age, individuals with a history of trauma or surgery to the frontal sinus or individuals with pathology destroying or encroaching within the frontal sinus, were excluded from the study. A PA skull radiograph was taken of those individuals who met these initial criteria. Subsequently 9 of these individuals were excluded because of the absence of frontal sinuses or the presence of a unilateral frontal sinus demonstrated on the PA skull radiograph.

PA skull radiographs of the selected patients were taken after following all radiation protection measures using a Cephalometric machine (planmeca proline ec panoramic x-ray and cephalostat cm manufactured in Helsinki, Finland) with variable exposure parameters based on the manufacturer's guidelines. The patients were positioned facing the cassette with the head tipped forwards to ensure that the sagittal plane was perpendicular to the cassette and the floor, and that the cantho-meatal line was perpendicular to the cassette. The patient's head was stabilized in this position using the ear rod of the machine. Accepted protocols for exposure parameters were followed. The radiographs were taken and developed by a single operator using conventional techniques to minimize any margin of error. PA skull radiographs with the frontal sinus outlined clearly were selected for the study. The selected radiographs were traced manually using tracing paper and pre-defined metric variables were measured by both the researcher and an observer to minimize

inter-observer error and to check inter-observer variability.

A baseline was drawn across the superior margin of the orbits. A tangent was drawn to the baseline, segmenting the sinus area into quadrants. The tangent was located at the midpoint between two vertical orbital lines drawn at the most medial point of each orbit. The outline of the sinus above the baseline was traced by both the researcher and the observer. Variables of frontal sinus which were measured in this study were divided into (shown in fig. 1):

I) General sinus variables which include-
Number of complete sinus cavities,
Number of partial sinus lines,
Maximum overall height above baseline (Baseline-C),
Maximum overall width (A–B)

II) Variables on left side which include-
Number of complete sinus cavities left of septum,
Number of partial sinus lines in main cavity,
Number of scalloped arcades on main cavity,
Maximum height of quadrant above baseline (Baseline-C),
Maximum height of main cavity above baseline (Baseline-C),
Maximum width of main cavity from tangent line (G-A),
Maximum width of main cavity (F–A)

III) Variables on right side which include-
Number of partial sinus lines in main cavity,
Number of scalloped arcades on main cavity,
Maximum height of quadrant above baseline (Baseline-D),
Maximum height of main cavity above baseline (Baseline-D),
Maximum width of main cavity from tangent line (G-B),
Maximum width of main cavity (E-B).

A partial sinus line (shown by yellow arrow in figure 1) is defined as any line 1 mm or longer extending from the border of the cavity into the cavity area, but not completely dissecting the cavity into two cells. A scalloped arcade (shown by red arrow in figure 1) occurs any time the edge of a cavity arcs inward, then back out again; the change of direction (continuity) of the edge marks the end of one scallop and the beginning of another.[5]

To check for uniqueness of each sinus and to assess the role of the frontal sinus in forensic radiology, superimposition of both radiographs and tracings was carried out to ascertain whether the radiographic outline of any one sinus matched to any other included in the same study sample. Following measurement of all the metric variables including sinus, skull width and overall height in centimeters, data was tabulated, entered into Microsoft Excel and analyzed by SPSS Ver. 20.0.0 software. An independent sample t-test was used to check inter-observer variability.

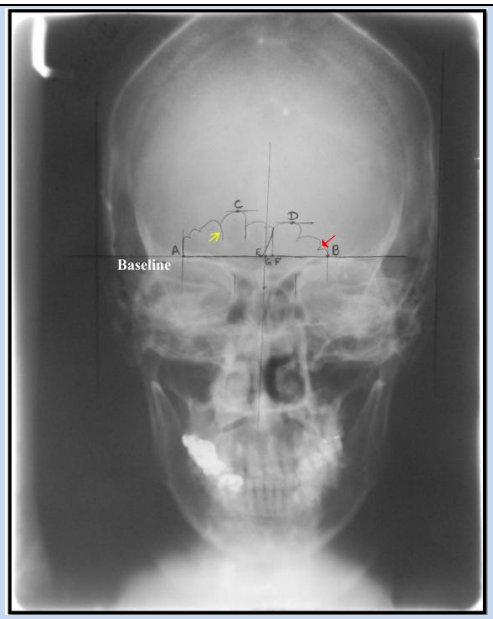

Fig.1: Traced PA skull radiograph showing borders of sinus and metric variables. Red arrow – indicates scalloped arcade. Yellow arrow indicates-partial sinus line on left side. Point A to B- maximum width of frontal sinus. Baseline to point C - maximum height of frontal sinus.

RESULTS

In this study 109 PA skull radiographs were captured of which 9 were excluded from the study. 6 were excluded because of the absence of frontal sinuses and 3 were excluded because of the unilateral presence of a single sinus.

Thus prevalence of absence of the frontal sinuses in this study was 5.50% and the prevalence of a single unilateral sinus was 2.75%. The study sample comprised 60 males and 40 females. Measurement of all of the metric variables was carried by one researcher and one observer. To check inter-observer variability an independent sample t- test was applied. Results of the independent sample t- test were non-significant for all of the metric variables confirming no significant inter-observer variability. The maximum height and the maximum width of the frontal sinus for the given sample varied between 0.2cm to 3.1cm and between 2.5cm to 9.3cm respectively. Both the maximum height and maximum width of the frontal sinus was found to be a unique feature for each individual. The discrete frequency distribution for both maximum height and the maximum width were prepared separately. The different values of height and width occurred with much less frequency but still uniqueness was maintained by considering each value separately. The number of partial sinus lines also showed a great deal of variation ranging from 0 to 12. The number of scalloped arcades on both the right and left side varied from 0 to 7. To evaluate the forensic significance of radiographic images of the frontal sinus a "traced" radiograph was superimposed upon another "traced" radiograph from the same study. An assessment of any patterns of similarity and meaningful relationship that may exist between the two "traced" radiographs was made by both the researcher and the observer The superimposition procedure relied on the outline of sinus and on various other parameters including the height and width of the sinus, the number of partial sinus lines and number of scalloped arcades. It was found that not all of the parameters of either of the two superimposed radiographs matched exactly i.e. 100% matching was not observed. Against this background it

can be convincingly stated that, the radiographic appearance of the frontal sinus in each individual is different and unique. Accordingly the radiographic appearance of the frontal sinus can be therefore used as a feature of uniqueness in forensic science in cases of human identification.

DISCUSSION

Forensic personal identification, using appropriate techniques, is a fundamental scientific discipline used in the identification of the living, recently deceased and compromised human remains. It is often used as a tool in crime scene investigations.

Scientific identification of human remains can be accomplished by a variety of methods including fingerprint, dental, anthropological, genetic and radiological examinations.[4] DNA analysis is well recognized as a method of verification of identity of an unknown person but is expensive and not always suitable in cases of mass disaster.[9] The use of radiographs in cases of both routine and mass disaster eventualities is well recognized and has shown to be effective, swift and relatively easy to implement.[6] The first recorded use of radiographic techniques for the purposes of identification was reported by Schuller in 1921. Radiographically assisted dental identification may be either comparative or reconstructive.[10] It has been reported that some 72% of positive identifications in modern forensic science have been obtained by comparing ante mortem and post-mortem radiographs.[4]

Anatomically, the frontal sinuses can be defined as pneumatic cavities covered by mucosa, located between the internal and external cortical bones of the frontal bone.[11] Sinuses remain stable throughout life after age of 20 years. As a consequence the age at which the ante mortem radiograph was captured does not matter provided the individual was at least 20 years of age at the time.[6] The thick bone of the anterior wall of the sinus and its curved convexity are the first barrier to the effects of cranial trauma and the ability to resist fracture. Considerable force of up to 1600 foot pounds of impact is required to fracture the anterior wall of the frontal sinus. This is almost twice as much as it takes to fracture the parasymphyseal area of the mandible and 50 % more than required to fracture the malar eminence of the zygoma.[7] In consideration the present study was designed to evaluate the role of the radiographic image of the frontal sinus for purposes of personal identification and explore the possibility of its uniqueness in studied population group.

A total 109 PA skull radiographs were taken in this study. Thus prevalence of absence of the frontal sinuses was 5.50% and the prevalence of a single unilateral sinus was 2.75%.

Results from other similar studies are shown in table-1; there is close correlation with the results of this present study.

Table 1 – Bilateral absence and unilateral agenesis of frontal sinus in different studies

Other similar studies	Bilateral absence	Unilateral agenesis
Aydinlioğlu et al.[12] (2003 in Turkish population	3.8%	4.8%
Çakur B et al[13] (2011)	0.73%	1.22%
Fatu et al[14] (2006)	5%	1.6%
Danesh-Sani SA[15] (2011)	8.32%	5.66%
Present study	5.50%	2.75%

The outline of the frontal sinus was traced and metric variables were measured on all of the PA skull radiographs. The data relating to the metric variables included

the total number of right & left partial sinus lines, the deviation of the septum, the maximum height and width of the sinus on both sides, the number of scalloped arcades on the right and left hand sides and the maximum width from the tangent was recorded by one researcher and one observer to check inter-observer variability. To evaluate the forensic significance of radiographic images of the frontal sinus a "traced" radiograph was superimposed upon another "traced" radiograph from the same study. An assessment of any patterns of similarity and meaningful relationship that may exist between the two "traced" radiographs was made by both the researcher and the observer The superimposition procedure relied on the outline of sinus and on various other parameters including the height and width of the sinus, the number of partial sinus lines and number of scalloped arcades. It was found that not all of the parameters of either of the two superimposed radiographs matched exactly i.e. 100% matching was not observed. Against this background it can be convincingly stated that, the radiographic appearance of the frontal sinus in each individual is different and unique. Accordingly the radiographic appearance of the frontal sinus can be therefore used as a feature of uniqueness in forensic science in cases of human identification. Application of this technique could be particularly relevant in cases of mass disaster or in cases where the skull is available and other methods of identification are either inappropriate or unavailable.

Similar results were obtained in previous studies by Marlin DC et al.[16], 1991; Reichs KJ[17], 1993; Quatrehomme G et al.[5], 1996; Nambiar P et al.[18], 1999; Kirk NJ et al.[19], 2002. Marlin DC et al demonstrated the use of frontal sinus morphology in the identification of 4 human remains.[16] Kirk NJ et al demonstrated the validity of frontal sinus pattern matching by comparing ante-mortem and post-mortem radiographs in 39 cases for forensic identification. The uniqueness of the morphology of the frontal sinus offers an opportunity to use this feature for personal identification in forensic medicine.[19]

CONCLUSION

This study shows that the frontal sinus of each individual is unique and, as a consequence, frontal sinus pattern matching can be useful as a technique in some cases of forensic identification.

A future development could be the establishment of a numerical classification system akin to that used in fingerprint analysis.

This would facilitate the adoption of a standardized approach using the metric variables of the frontal sinus for human identification.

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