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Original Article

Software Assisted Profiling of Dentition in Human Identification

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Abstract

Forensic odontology is an integral part of forensic science that utilizes unique characteristics of human dentition. Dental remains withstand degradation better than other human remains. This study aimed to determine human identity by using the various predetermined parameters of dental morphology using their digital smile photographs and confirming by means of Adobe Photoshop CC software. The study also aimed to compare and identify the most used parameter of the dental morphology in the human identification process.

This retrospective study was conducted in the Department of Oral & Maxillofacial Pathology, Microbiology and Forensic Odontology, I.T.S Dental College Hospital & Research Centre, Greater Noida, UP, India. A sample of 50 subjects (25 males and 25 females) aged between 20 and 40 years were included in the study.

Two sequential techniques were followed. Dental casts and pictures were analyzed by 3 blind observers by comparison of dental traits and then confirmed by superimposition using Adobe Photoshop CC. Positive identification was achieved by application of two techniques. ICC Multiple Raters and ICC Two Raters were applied to analyze the stratum of agreement between the observers.

By analyzing the parameters specified by three blind observers, the combination of Central and Lateral Incisor morphology emerged as the most used parameter in the identification process. When dental records are not available, dental comparison of postmortem findings with antemortem photographs of people displaying uncommon dental features visible

Keywords: Forensic Sciences, Forensic Odontology, Smile, Photograph, Antemortem, Postmortem.

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بين موجودات الأسنان ما بعد الوفاة مع الصور المأخوذة للأشخاص قبل الوفاة والتي تظهر أشكال غير مألوفة للأسنان في صور ابتسامة الأشخاص قد تزيد من احتمال تحديد الهوية.

الكلمات المفتاحية: علوم الأدلة الجنائية، طب الأسنان الشرعي، ابتسامة، صورة، قبل الوفاة، بعد الوفاة.

1. Introduction

Forensic odontology is a branch of dentistry which deals with the proper handling and examination of dental evidence and the proper evaluation and presentation of dental findings in the interest of justice [1]. Routine identification task is a simple one-to-one matching process; however, this is not the case in mass disasters. Government authorities, and all other agencies involved in human identification, face a huge challenge in cases of mass disasters and mutilation [2].

The identification of dental remains is of primary importance when the deceased person is skeletonized, decomposed, burned or dismembered. The most significant base of forensic identification is the principle of individuality and relative durability [3]. Enamel, the hardest tissue in the body, along with other dental material, would endure peri and post-mortem damage. Dental identifications have always played a key role in natural and manmade disasters and in particular the mass casualties normally associated with aviation disasters. Because of the lack of a comprehensive fingerprint database, dental identification continues to be crucial worldwide [4]. In the absence of dental documentation, photographs of the victim's smile can play an important role.

Teeth are one of the excellent post-mortem aids for identification, with enough data to make a meaningful comparison [5]. Treatment given by a dentist is the biggest contribution to the uniqueness of an individual dentition and is the key to the identification of the oral cavity. Den-

in smiles taken from photographs may increase the probability of identification.

تنميط الأسنان بمساعدة البرمجيات لاستعراف الإنسان المستخلص

يعد طب الأسنان الشرعي جزء لا يتجزأ من علوم الأدلة الجنائية والذي يستخدم الخصائص الفريدة لعملية التسنين عند البشر. كما أن أسنان الإنسان تصمد أمام تأثير عوامل التآكل والتحلل أكثر من البقايا البشرية الأخرى. هدفت الدراسة إلى تحديد الهوية البشرية باستخدام المعايير المختلفة المحددة مسبقاً لمورفولوجيا الأسنان (علم تحديد شكل الأسنان) باستخدام الصورة الرقمية لابتسامة الشخص، والتأكيد من خلال برنامج تحرير الرسومات وتعديل التصوير الرقمي المنتج بوسطة شركة أدوبي المسمى Adobe Photoshop CC. كما هدفت الدراسة إلى المقارنة والتعرف على المعيار الأكثر استخداما من معايير مورفولوجيا الأسنان في عملية تحديد الهوية البشرية.

وقد أجريت هذه الدراسة بأثر رجعي Retrospective study، في قسم أمراض الفم والفكين، وعلم الأحياء الدقيقة وطب الأسنان الشرعي، ومستشفى كلية طب الأسنان I.T.S ومركز البحوث، في منطقة نويدا الكبرى، يوتار براديش في الهند. وشملت الدراسة عينات من 50 شخصاً (25 ذكور و 25 إناث) تتراوح أعمارهم بين 20 و 40 سنة.

تم اتباع نوعين من التقنيات المتعاقبة. حُلِلَت عينات الأسنان والصور من قبل ثلاثة من المراقبين بنظام التعمية، من خلال مقارنة مع سمات الأسنان ثم تم تأكيد ذلك من خلال التركيب باستخدام برنامج تحرير الرسومات والصور من شركة أدوبي. وقد حُدِدَت العينات بشكل إيجابي من خلال تطبيق التقنيتين المتعاقبتين. طبقت تقنية ICC متعدد التقييم، و ICC ثنائي التقييم لتحليل مستوى الاتفاق بين المراقبين.

من خلال تحليل المعايير التي حددها ثلاثة مراقبين بنظام التعمية، كان أكثر المعايير استخداما في عملية تحديد الهوية هو توليفة القواطع المركزية والوحشية. وعند عدم توفر السجلات فإن المقارنة

tal treatment comprises an optimal source of antemortem (AM) data, such as radiographs, plaster models, and personal files. However, in some situations, disaster victims do not have dental records, making it necessary to search for AM data from personal belongings. In this context, photographs of a victim's smile play an important role in showing part of the victim's dentition in different periods of life, additionally allowing for further comparisons with postmortem (PM) data [6].

Improvements in digital technology and software have greatly improved analysis and processing techniques for imaging and management of photographic data. Specifically, the direct comparison of morphological dental traits, dental superimposition, and the analysis of the incisal contours of the anterior teeth are commonly applied techniques with scientific validation [7].

Thus, the aim of the present study is to test the validity of using photographs of an individual's smile to make a positive identification of their dentition from dental remains using manual observation and superimposition using image editing software.

2. Materials and Methods

A group of 50 individuals (25 males and 25 females) participated in the study after giving their informed consent.

2.1. Inclusion and Exclusion Criteria

1. Photographs showed the anterior teeth.
2. Photographs were extracted from the social media websites with the prior consent of participants so as to simulate a case of a forensic investigation.
3. Participants were within the age group of 20-40 years.
4. Individuals who did not show teeth while smiling were excluded.
5. Individuals with all the anterior teeth extracted were excluded.

The study was divided into two stages: 1) collection of images (smile photographs) and 2) comparison of the images with the dental casts taken from the participants.

To simulate the autopsy of the jaws, impressions of maxillary and mandibular jaws were taken and poured into a dental cast. The smiling photograph of the individual was extracted from the social media website simulated as AM evidence.

Thereafter, two techniques were followed to compare the photographic data with the casts: 1) A manual comparison and 2) Superimposition using image editing software.

2.2. Manual Comparison

A visual examination of photographs and casts was performed by three observers, blindly using the dental traits. Each observer attempted to successfully match the photographs with their corresponding casts.

The postmortem image of the cast reproduced the same anatomical and morphological outline along with same angulation of the anterior teeth as that of the antemortem im-

Figure 1- *Antemortem Image*.

Figure 2- *Postmortem cast Image*.

age as shown in Figure-1, 2. This comparison between photographs and casts was based on the following parameters:

1. No. of teeth present
2. Analysis of dental crown morphology
3. Position and angulation of the teeth in the dental arches
4. Presence of dental interventions
5. Oral pathologies if present.

2.3. Superimposition

The technique of superimposition was done using an image editing software package. In the present case, Adobe Photoshop CC was used. The PM photographs in frontal view were clicked, estimating the original position of the camera distance with the AM image. This was done multiple times until an image close enough to superimpose was obtained. It was then cropped allowing only the teeth portion. The size and reduction of the AM and PM, preserving the aspect ratios of photographs, was standardized using the same software and then the superimposition was done by adjusting the angulations using the FREE TRANSFORM tool as shown in Figures-3, 4.

3. Results

Regarding the manual comparison, the parameters were evaluated so as to identify the most used parameter in iden-

Figure 3- *Initial Superimposition.*

Figure 4- *Final Superimposition.*

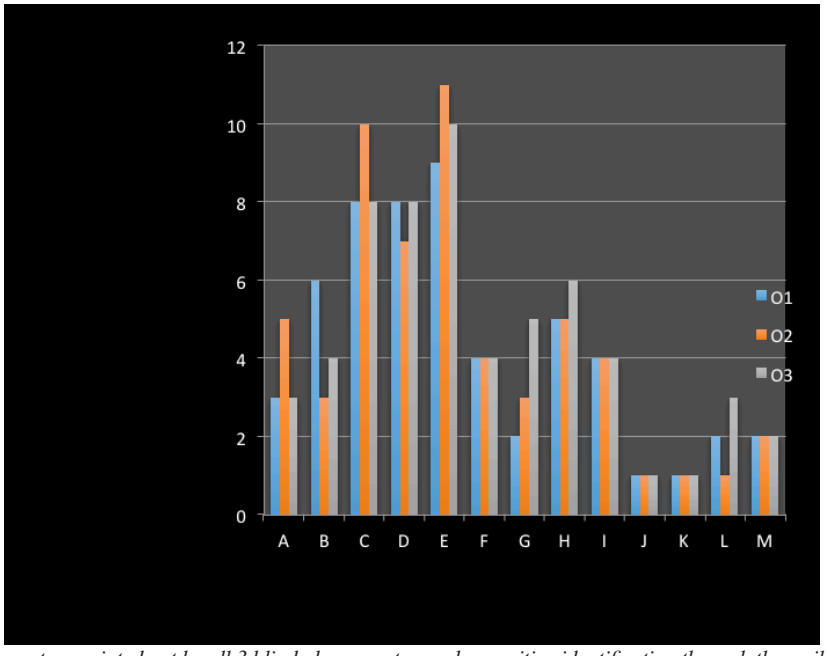

Figure 5- *Parameters pointed out by all 3 blind observers to reach a positive identification through the smile photographs.*

Table 1- *The parameters pointed out by all 3 blind observers to reach a positive identification through the smile photographs.*

Parameters	Observer 1 (O1)	Observer 2 (O2)	Observer 3 (O3)
Central Incisor Angulation: (A)	3	5	3
Lateral Incisor Angulation: (B)	6	3	4
Central Incisor Morphology Only:(C)	8	10	8
Lateral Incisor Morphology Only:(D)	8	7	8
Central and Lateral Incisor Morphology Combination: (E)	9	11	10
Diastema: (F)	4	4	4
Central, Lateral and Canine Morphology: (G)	2	3	5
Canine: (H)	5	5	6
Interdental Spacing, Generalized, Localized): (I)	4	4	4
Retained Deciduous: (J)	1	1	1
Partly Erupted Permanent Teeth: (K)	1	1	1
Not able to identify manually:(L)	2	1	3
Missing:(M)	2	2	2

*SD, standard deviation; * significant p > 0.001; Min, Minimum; Max, maximum.*

Table 2- *ICC Multiple Raters (Inter class correlation for three observers) to analyze the stratum of agreement between the observers.*

ICC Multiple Raters(Inter class correlation for three observers)		
	Single measures	**Average measures**
ICC (95% CI) :	0.911 (0.797, 0.969)	0.969 (0.922, 0.989)
Prob > F :	0.000	

tification. It was clearly noticeable that the most used parameter was the combination of Central and Lateral Incisor morphology (E) as shown in Figure-5.

The parameters pointed out by all 3 blind observers to reach a positive identification through the smile photographs are shown in Table-1. On an average, 96% of the cases were correctly identified by the 3 blind observers.

ICC Multiple Raters (Inter class correlation for three observers) was applied to analyze the stratum of agreement between the observers, as shown in Table-2.

The value of single measure, which is the index for reliability and consistency of one single rater, is 91.1%. This

is very high. The value of average measure, which is the index of inter-reliability and consistency of different raters averaged together, is 96.9%. This shows that there is a strong correlation between the 3 observers. As the Prob> F and the value is 0, we can reject the null hypothesis with extremely high confidence, above 99.99%.

ICC Two Raters was also done to analyze the stratum of agreement between O1-O3, O1-O2 and O2-O3. In O1-O3, the value of single measure is 92% while the value of average measure is 95.9%. In O1-O2, the value of single measure is 89.9% while the value of average measure is 94.7%. In O2-O3, the value of single measure is 91.6%, while the value of average measure is 95.6.

Thus, the statistical analysis showed that there was a strong correlation between O1-O3, O1-O2, and O2-O3. As the Prob> F and the value is 0, we can reject the null hypothesis with extremely high confidence - above 99.99%. It was observed that most of the values specified by O1-O3, O1-O2, and O2-O3 fall between the standard deviation.

Thus, from the given statistical analysis it can be concluded that there is strong correlation between O1, O2, and O3.

4. Discussion

The oral cavity can be described as a window to changes occurring in the human body; almost all systemic variations show manifestations orally. These variations include changes seen in the body due to disease, injury, and death. The diversity of dental characteristics is wide, making each dentition unique [9]. A good quality antemortem smiling photograph (showing teeth) may prove useful for the comparison process or as an aid via dental superimposition.

The forensic identification through photographs of the smile facilitates the comparative analysis between antemortem and postmortem features of individuals who for any reason do not have their identity established through fingerprint analysis. Therefore, the dental remains are more relevant, reliable, safe, and have a high specificity in providing evidence of an individual in the identification process [10].

In this study, we successfully identified the individual's by matching smile photographs (AM data) with the dental casts (PM data). Miranda et al. described a case in which selfie photographs were used to identify a carbonized body, by using the smile line and image superimposition. They concluded that it was possible to make a positive identification of a carbonized body by using selfie photographs [11].

Other studies and case reports have recently been published by Silva et al. (2015) in which they used smile photographs for the identification of an unknown identity [5,10]. Bollinger, (2009) used the Grin-Line Identification Technique which may assist medical examiners and coroners in making identifications or exclusions [8].

However, in the previous literature, no study has been done in which manual and software assisted techniques were used collectively highlighting the specific parameters used in the identification process. Also, no such study has been done in which the results were evaluated by 3 blind observers. This makes our study the first one to draw attention to the most specific parameter in the identification of an individual.

By analyzing the results, out of 12 parameters, a combination of central and lateral incisor morphology was the most seen parameter for the identification and this result was followed by: -

Central incisor > lateral incisor > canine > lateral incisor angulation > central incisor angulation > diastema =

interdental spacing > central incisor, lateral incisor and canine morphology > missing tooth.

From the results, it is quite apparent that the most important teeth for the identification of the individual are incisors. There is also a possibility that the most exposed teeth in a smiling photograph are incisors, but the variability in each individual is extensive. On an average, 96% of the cases were correctly identified by the 3 blind observers. This is suggestive that the parameters followed are extremely supportive in forensic identification in cases where soft tissues are completely destroyed and teeth are the only remnants left.

5. Conclusion

Forensic odontology, as one of the primary identification methods, is a dynamic field which has developed in recent past [12]. A successful conclusion can be brought only if the identification strategy is properly planned by selecting the appropriate forensic diagnostic tools and involving a team of well-trained key experts [13,14]. Developing an automated digital dental identification system is a demanding challenge at present [15].

For positive identifications, different forensic disciplines must work together and follow identification protocols [16,17]. There is a need to establish a cooperative system taking into account cultural and religious backgrounds [18]. Further research is required with larger samples for the definite improvement in the accuracy of the identification process.

Conflict of Interest: The authors declare no conflict of interest.

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