Analysis of the positions of anterior teeth in orthodontically treated and untreated population: A proof of uniqueness

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Abstract

Aim: To compare the uniqueness of human dentition in both orthodontically treated and untreated populations and evaluate the reliability of bitemark analysis.

Materials and Methods: A total of 1464 maxillary and mandibular casts were fabricated from orthodontically treated and nontreated population. After careful examination of the study teeth, 326 nontreated maxillary cast (Group 1), 333 nontreated mandibular cast (Group 2), 336 orthodontically treated maxillary cast (Group 3), and 320 orthodontically treated mandibular casts (Group 4) were selected for the analysis. For uniformity, the sample size of 320 was selected from each group for comparison.

Results: The arch width was a major cause of variance. In Group 1, only 6.87% of similarity rate was seen, whereas in Group 3, the match rate increased to 55% showing similarity. In Group 2, only 1.87% similarity and Group 4 showed 42.7% match rate.

Conclusion: The human dentition may be unique, but it loses its uniqueness once any dental treatment is carried out.

Keywords: Bitemark uniqueness, dental uniqueness, orthodontic treatment

INTRODUCTION

Human bite marks have gained wide acceptance in the field of criminal justice based on the assumption that human dentition is unique in terms of characteristics and that the asserted uniqueness can be replicated in the bitten material.[1]

Commonly transparent overlays are used to record the biting edges of the suspect’s teeth for further evaluation. Impression of the bitten area may also be made when tooth indentations are present.[2] The examination of bite marks currently relies on morphometric analysis, which involves the comparison of the characteristics of suspect’s teeth with full scale photographs of the injury.[3]

The objective of the current study is to adjudge the uniqueness of human dentition in both orthodontically treated and untreated populations. It aims to evaluate the reliability of bitemark analysis and to show that despite the common accepted concept of “bite mark’s uniqueness,” in reality there is a considerable overlap in bite mark patterns amongst populations.

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MATERIALS AND METHODS

The present study was carried out on casts retrieved from the archives from the department of orthodontics. The casts used for the study were selected randomly comprising of both genders. Maxillary and mandibular casts of orthodontically treated and nontreated dentition with full complement of anterior teeth, i.e. central incisors, lateral incisors and canines and with no dental treatment done on the study teeth were included. Dentitions having missing anterior tooth/teeth, retained deciduous anterior tooth/teeth, mixed dentition, esthetically treated or restored anterior tooth/teeth, dental caries associated with anterior tooth/teeth, fractured anterior tooth/teeth and developmental anomaly like peg-shaped lateral and mesodens were excluded.

The total study cases consisted of 1464 maxillary and mandibular casts fabricated from both an orthodontically treated population and a nontreated (specifically study teeth) population. After careful examination of the study teeth, 326 nontreated maxillary cast (Group 1), 333 nontreated mandibular cast (Group 2), 336 orthodontically treated maxillary cast (Group 3) and 320 orthodontically treated mandibular casts (Group 4) were selected for the analysis.

To maintain uniformity, the sample size of 320 was selected from each group for the comparison of the data. The casts were scanned on Hewlett-Packard scanjet G–2410 along with an American Board of Forensic Odontology (ABFO) number #2 reference scale. The casts were scanned and landmarks were placed using TpsDig232 software[4] [Figure 1] and were analysed using IMP Coord_Gen software. [5]

RESULTS

The analysis was first carried out for the sample of 30 (each group) to deduce mean threshold value. Intra-operator error measurement for landmark placement resulted in a Procrustes distance threshold of 0.03 [Table 1]. This value was taken twice the root-mean-square of distances of specimens about their mean, which is analogous to a standard deviation measurement in univariate systems. This was taken as the minimum shape difference below which two samples were considered a match. The measurement error in this study was very small, thus the measurements of this study were accurate and considered reliable.

A complete analysis involving all the study cases (320 in each of the 4 groups) was thereafter undertaken.

The root mean square (RMS) scatters were measured in Procrustes distances. In Procrustes units, the RMS scatter is dimensionless. The results of the RMS scatter measurements were further used to establish the match criterion for the dentitions. Twice the RMS distance of the scatter of specimens about the average of many repeated measurements was considered the match criterion. With this criterion and the software MatchMaker, which is incorporated in the IMP Coord_Gen 8 software, it was possible to search for matches when the matches were searched, it was found that the RMS value for maxillary non treated dentition was 0.113, orthodontically treated maxillary dentition was 0.046, mandibular non treated dentition was 0.136 and orthodontically treated mandibular dentition was 0.051 [Table 2]. This shows there are more matches in orthodontically treated population because match criteria value (RMS scatter) was lesser for orthodontically treated population.

The landmarks for each dentition overlapped with limited spread as evident by the Clustering (nonuniform distribution) of the data points [Table 3]. Among the nontreated maxillary and orthodontically treated maxillary,

Table 1: Intra operative error measurement to establish procrustes distance threshold (n=30)

| Group   | RMS scatter in procrustes | Twice the RMS distance of the scatter |
|---------|---------------------------|-------------------------------------|
| Group 1 | 0.0165                    | 0.033                               |
| Group 2 | 0.0177                    | 0.035                               |
| Group 3 | 0.0151                    | 0.030                               |
| Group 4 | 0.0148                    | 0.029                               |
| Procrustes distance threshold (mean) | | 0.0317 |

RMS: Root mean square

Table 2: Root mean square scatter about the mean for each group (n=320)

| Group (n=320) | RMS   |
|--------------|-------|
| Group 1      | 0.113 |
| Group 2      | 0.136 |
| Group 3      | 0.046 |
| Group 4      | 0.051 |
22 and 176 dentitions matched, respectively ($n = 320$) resulting in a match rate of 6.87% and 55%, respectively. Clustering of the data points is evident in the Procrustes plots [Figures 2 and 3]. Among the nontreated and orthodontically treated mandibular, 06 and 152 dentitions matched, resulting in a match rate of 1.87% and 42.7%, respectively. Clustering of the data points is evident in the Procrustes plots [Figures 4 and 5]. Hence, orthodontically treated population showed a high match rate of 55% and 42.7% in both maxillary and mandibular dentition.

The histogram appears similar to a Poisson distribution, with few specimen pairs at very small distances, a large number at intermediate values and long tail at large distances. The bold (red) vertical line on the histogram indicates the error measurement threshold established. As measurement error increases, and the threshold moved to the right, large numbers of dentitions were considered a match. The x-axis on the histogram is a measure of similarity, with most similar dentitions to the left, and less similar to the right. The shift can be easily seen in the histogram of group 1 [Figure 6a] to group 3 [Figure 6b] and group 2 [Figure 7a] to group 4 [Figure 7b].

Principal component analysis (PCA) of the nontreated population showed that arch width is the biggest variable. PCA plots in which the first axis are plotted horizontally representing degree of arch curvature and second axis is plotted vertically represents movement of central incisors and lateral incisors. This can be visualized by plotting the relative shifts of point. Figures 8a, 8b, 9a and 9b, show the two principal dental variables for Group 1 and 2 are curvature of the arch, and facial movement of central incisors. Figures 10a, 10b, 11a and 11b show the variation for Group 3 and 4 is due to lateral movement of anterior teeth.

The variance measure is the summed squared Procrustes distances of all specimens in a group from the mean of that group divided by ($n$-1), where $n$ is the number

### Table 3: Match rates (%)

| Sample size | Similar dentitions | Percentage |
|-------------|--------------------|------------|
| Group 1     | 320                | 22         | 6.87       |
| Group 2     | 320                | 06         | 1.87       |
| Group 3     | 320                | 176        | 55.0       |
| Group 4     | 320                | 152        | 42.7       |
of specimens. The shape variance within each group was calculated [Table 4]. The variation was less in dental shape among the orthodontically treated groups (Group 3 – 0.0021 and Group 4 – 0.0026) in comparison to nontreated groups (Group 1 – 0.0128 and Group 2 – 0.0186).

**DISCUSSION**

Bite marks are the representative patterns left on an object or tissue by the dental structures of an animal or human. Teeth have different arrangements leading to the distinctiveness of human dentition from animal dentition. The capability of the dentition to transfer a characteristic pattern to human skin and the ability of the skin to maintain that uniqueness has still not been scientifically established. By establishing the uniqueness of the biter’s teeth and then applying those unique properties to the bite pattern, many judicial cases can be solved leading to the perpetrator’s conviction.[6]

The uniqueness of human dentition can get altered due to any dental treatment which alters the arrangement or shape of the tooth. The bite marks of the same individual show changes in the postorthodontic treatment casts as compared to the preorthodontic treatment ones. Restorations involving the occlusal 2/3rd of the crowns, extractions, implants and prosthetic work will also alter the bite marks. All these factors need to be taken into consideration while doing the analysis and therefore detailed dental records of the suspect and the victim also need to be considered.[7,8]

The philosophy for orthodontics is to achieve the correct occlusal relationship.[9] In an individual, the ideal relationship of teeth within each arch is generally a smooth curve.[10] Houston et al. in 1992 suggested each arch is regular with the teeth at ideal mesiodistal and buccolingual inclinations and having correct proximal relationship at each interdental contact area.[7]

In the present study, the uniqueness of human dentition in both the maxillary and mandibular dentitions, in both orthodontically treated and nontreated populations was analyzed using integrated morphometric software for coordinate the generation in which manual placement of landmarks as Cartesian coordinates was done and comparison between the dentition’s spatial relation was recorded. Cartesian coordinates are measurement points, the so called landmarks. Landmarks have a position (two or three coordinates) and a name, expressing some sort of homology across all measured specimens.[11‑13]

Morphometrics is the quantitative study of biological shape, shape variation and covariation of shape. *Landmark-based geometric morphometrics* involves analyzing shape in terms of a landmark configuration (a constellation of discrete anatomical loci, each described by 2-or 3-dimensional Cartesian coordinates).[12]

To estimate a potential measurement error, repeated landmarks were placed on one image of each group and the RMS scatter was determined [Table 1]. The RMS of repeated measurements is measured in Procrustes distance. Procrustes distance is a measure of the closeness in shape of Procrustes superimposed specimens and is recognized as a general purpose measure of the specimen’s similarity in the geometric morphometric analysis. Procrustes method is based on the least-squares estimation of translation, rotation and scaling.
parameters that align sets of landmark coordinates for pairs of specimens. The smaller the Procrustes distance the more precise is the landmark placement.\[^{14-17}\]

For the analysis and visualization of the variation, PCA using IMP Coord_Gen 8 software was performed. PCA is a simple, nonparametric method of retrieving relevant information from complex data sets, so that the maximum variability is visible.\[^{18}\]

The teeth selected for the study were central incisors, lateral incisors and canines as these teeth make contact with the skin during a bite. The casts were scanned along with ABFO scale placed in the center. A total of 12 landmarks were placed on the mesio-incisal and disto-incisal angle of the anterior teeth of each image. Two digital scales of 8 cm were placed along the ABFO scale.

The results of this study showed that the arch width was a major cause of variance. The relative labial shift was evident in all the groups [Figures 8-11]. Among the 320 cases of nontreated maxillary dentitions (Group 1), only 22 matches were found with 6.87% of similarity rate, whereas in the sample size of 320 orthodontically treated maxillary dentitions (Group 3), the match rate increased to 55% with 176 cases showing matched dentitions. In nontreated mandibular dentitions (Group 2), only 06 matches were found with a match rate of 1.87%, whereas 152 similar dentitions were found in orthodontically treated mandibular dentitions (Group 4) with 42.7% match rate [Table 3].

When intergroup data were studied a significant variation was found within the two groups (Group 1 and 3, Group 2...
and 4) which was similar to the results of a previous study done in 2011 by Sheets[14] thus revealing that orthodontic treatment decreases the variance in anterior dentition as it increases the match rates. Variation was also seen within the Groups 2 and 4 (nontreated and orthodontically treated mandibular dentition, respectively); however, it was not marked [Table 4]. The variation seen in the match rates of maxillary and mandibular nontreated dentition was noticeable, but it was an expected finding due to the higher incidence of crowding in the lower arch. A previous study done on both the arches had similar results.[11]

Hence, we can say from our study that human dentition may be unique, but it loses that uniqueness once any dental treatment involving the maxillary or mandibular anterior teeth is carried out. Hence, investigating officers should take a detailed dental history specifically of orthodontic treatment before considering the individual as a candidate for bite mark analysis.

**CONCLUSION**

The use of unique features and morphological variations of the teeth in personal identification is well accepted in forensic examinations and in the court of law. In spite of advances in the leading identification techniques such as DNA profiling, fingerprints and facial reconstruction, the comparison of dental records play an important role in the identification of the deceased in mass fatality incidents such as air plane crashes and natural disasters. However, in the determination of uniqueness of human dentition, one should be careful about population specificity as different population show varying degree of variations in dental traits.[19,20]

Scientific evidence for the uniqueness of human dentition was not detected in the current study. The populations included both orthodontically treated (high degree of dental alignment) and nontreated population where maxillary and mandibular dental casts were used.
Further researches using increased number of landmarks are necessary. The current findings indicate that in forensic investigations, bitemark analysis can be performed in closed populations. Furthermore, selection of dentition should be based on distinctive features of individual tooth or dentition characteristics to allow decisions based on the exclusion or inclusion of suspect associated with legal issues. The use of advanced techniques such as three-dimensional imaging and scanning at the crime scene or disaster zone for transferring data to the main server for detailed analysis should be used to increase the reliability of bitemark analysis.[21]

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Conflicts of interest
There are no conflicts of interest.

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