

A comparative study to investigate the effect of orthodontic treatment on the uniqueness of the human anterior dentition



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ABSTRACT

AIM: The human dentition contains many features which can be used to identify an individual from the dentition or from bite marks created and bite mark evidence may be used to link a suspect to a crime. The aim of this research was to investigate the effect of orthodontic treatment on the uniqueness of the human anterior dentition by comparison of the number of dental shape matches between pre- and post-treatment dental casts for a group of patients who have undergone orthodontic treatment (dental braces) to improve the alignment of their teeth.

METHOD: This comparative study utilised pre- and post-orthodontic treatment dental casts from 36 patients. The dental casts were scanned and the anterior 6 teeth landmarked with 24 landmarks in total. The dental casts were divided into 4 groups: pre-orthodontic upper jaw (maxillary) and lower jaw (mandibular) and post-orthodontic maxillary and mandibular. Partial and full Procrustes analyses were undertaken to investigate the similarity between dental casts within each group and whether any of the comparisons were similar enough to be classified as a match. A landmarking repeatability study performed on a set of digitised dental casts determined the error of the landmarking procedure and allowed a proposed match threshold to be established.

RESULTS: Orthodontic treatment reduced the uniqueness, and increased the similarity, between dentitions, as evidenced by a reduction in the maximum partial Procrustes distances in the post-orthodontic dental cast groups. None of the dental cast comparisons in the pre- or post-orthodontic maxillary or mandibular groups were classified as a match with the partial Procrustes analysis. However, many false positive matches (between 35 and 61) were identified within the post-orthodontic maxillary and mandibular groups using the full Procrustes analysis.

CONCLUSIONS: Orthodontic treatment reduced the uniqueness of the human anterior dentition between different patients. There were no matches identified with the partial Procrustes analysis, but a large number of false positive matches were identified using the full Procrustes analysis. It is therefore proposed that full Procrustes analysis is unsuitable for this type of work and that only partial Procrustes analysis should be utilised.

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1. Introduction

Bitemark evidence is the most common form of dental evidence presented in criminal court (Rai et al. [1]). It is well known that during a variety of crimes such as sexual attacks and rape, assailants often bite their victims as an expression of rage, dominance and animalistic behaviour (Webb et al. [2]). Similarly, defensive bitemarks may be left on an assailant by the victim, providing evidence of contact (Furness [3]).

Over the past century bitemark evidence has been used to obtain numerous criminal convictions but, unfortunately, there have also been at least 24 known cases of wrongful conviction based on bitemark evidence and this has called its validity into question (Lussenhop [4]).

The uniqueness of the human dentition has been investigated and debated for decades but there has been little research dedicated to orthodontic (“fixed brace”) treatment and bitemark analysis. As orthodontic treatment aims to reduce irregularities within the dentition, it can also create occlusal similarities between the dentitions of different orthodontic patients. These similarities may cause the dentitions to be less distinguishable than before treatment and may potentially cause the bitemarks they create to be indistinguishable.

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Typically, bitemarks are caused by the anterior six teeth (Riviello [5]) and a match is only possible if there are individual characteristics present in the dentition which are translated and recorded accurately in the bitemark. If these individual characteristics are not present, or if they are not recorded accurately in the bitemark, the overall forensic importance of the bitemark is reduced (Rothwell cited in Sweet and Pretty [6,7]).

Previous studies investigating the uniqueness of the human anterior dentition include those by Kieser et al. [8] and Sheets et al. [9] who utilised a combination of analytical techniques, such as Procrustes analyses and principal component analyses. Kieser et al. [8] concluded that the incisal edges of the anterior dentition are unique. However, the study by Sheets et al. [9] identified increased numbers of matches between dentitions of orthodontically treated patients and subsequently concluded that the anterior dentition may not be unique.

2. Aim

The aim of this study was to investigate the effect of orthodontic treatment with dental braces on the uniqueness of the human anterior dentition by comparison of the number of dental shape matches between the pre- and post-treatment dental casts.

3. Patients and methods

This research utilised the pre- and post-treatment dental casts from 36 patients who had undergone a course of orthodontic treatment with fixed dental braces at the Eastman Dental Hospital, UCLH Foundation Trust and who had been discharged from the department (144 dental casts in total). A 3D dental cast scanner (Ortho Insight 3D™ Scanner by Motion View Software) was used to scan and digitise the dental casts, which were then landmarked using a bespoke landmarking software program developed by the University College London Hospital Medical Physics department.

Patients who had completed treatment between 1999 and 2013 and who were presented as examination cases were identified from the hospital laboratory records. The cohort consisted of examination cases in order to ensure that the orthodontic treatment had been completed to a high quality of finish. The pre-orthodontic and post-orthodontic dental casts were retrieved and unsuitable cases were excluded based on the criteria shown in Table 1. A total of 36 patients were selected, providing two maxillary (upper jaw) and two mandibular (lower jaw) dental casts for each patient (144 dental casts in total).

The dental casts were scanned using the Ortho Insight 3D™ Scanner and the images saved in STL format. Customised software was then used to landmark the incisal edges of the anterior six teeth on each digitised dental cast with the most mesial, distal, medial labial and medial palatal/lingual points on each tooth (Fig. 1). This was a similar landmarking system to that used by Kieser et al. [8].

3.1. Repeatability study

In order to ascertain the intra-operator repeatability of this method, the anterior six teeth (canines and incisors) of one

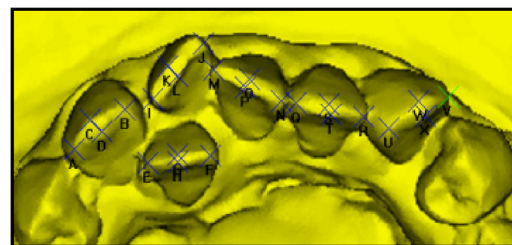


Fig. 1. Screenshot of a landmarked digitised dental cast showing the 24 landmarks placed on the anterior six teeth.

maxillary and one mandibular dental cast were landmarked 10 times each, with a minimum wash out period of 24 h between landmarking sessions. The dental casts used for the repeatability study met the inclusion/exclusion criteria but were not included in the main study.

3.2. Statistical analysis

The standard deviation of each landmark from the repeatability study was used as a measure of the repeatability of the landmarking procedure.

A partial and a full Procrustes analysis were then performed on the landmarked dental casts from the main study and on the repeatability study data. Procrustes analysis was used as it provides a measure of the similarity between two shapes, which contain landmark points (Gower [10]). The partial Procrustes analysis maintains information regarding shape and size of the dental casts. For the full Procrustes analysis, in addition to translation and rotation of one dental cast about another, size scaling is also conducted. This removes some information about the differing sizes of the dental casts and allows comparisons based purely on the shape of the teeth and dental arches. Both analyses were undertaken to determine the number of matches and to determine which was most suitable for this type of comparative work.

The Procrustes distance provides a measure of the similarity between the landmarks of two dental casts, with lower scores indicating greater similarity and higher scores showing less similarity. In the case of the partial Procrustes analysis, this distance is in the same units as the measurement system used (mm) and in the case of the full Procrustes analysis, the distance is an arbitrary measurement, with no units.

4. Results

4.1. Repeatability study

The standard deviations (SDs) for each landmark over the 10 landmarking procedures ranged between 0.093 mm and 0.288 mm for the maxillary landmarks and between 0.085 mm and 0.331 mm for the mandibular landmarks. This showed good repeatability for landmark placement.

Table 1

Inclusion and exclusion criteria for the dental casts.

Inclusion	Exclusion
<ul style="list-style-type: none"> Completed orthodontic treatment Discharged patients Undamaged pre- and post-orthodontic dental casts available Unrestored maxillary and mandibular canines and incisors 	<ul style="list-style-type: none"> Developmental absence/hypodontia of the maxillary or mandibular canines or incisors Dental anomalies e.g. transposition of teeth, microdontia etc. Dental casts with damaged maxillary or mandibular canines or incisors Partially erupted maxillary or mandibular canines or incisors

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