BIOMECHANICAL APPROACH TO HUMAN BITEMARK RECONSTRUCTION

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ABSTRACT

This paper investigates the changes in upper and lower dental bite records that occur when the anterior teeth occlude into a three-dimensional rather than a flat object. Methods: anterior bite registrations were obtained from 20 volunteers with full and unrestored dentitions. As a three-dimensional, life-like bite target we cast a silicone replica from the impression of an actual arm, fitted with a rigid bony interior. Each participant was asked to bite into a single layer of softened bite registration wax wrapped around the same location on the fake arm, as well as into a flat wafer of the same material. Upper and lower bite registrations were then scanned in the same location on a flat bed scanner. We analysed the sizes of the different bite marks by means of landmark- and semi-landmark analysis to calculate Procrustes distances between tooth outlines. In order to analyse shape variation between the two types of bite registration we carried out principal components analyses on the partial warp scores. These were derived from partial Procrustes coordinates aligned by means of thin-plate spline decomposition based on a bending energy matrix.

Our results show that there are significant differences in the shape of the upper or lower teeth when they occlude into a flat or three-dimensional target.

We conclude that the use of a traditional flat bite registration in human bitemark reconstruction and analysis has to be seriously questioned.
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Keywords: tooth shape, bitemarks, odontology

INTRODUCTION

A bitemark is the physical end-product of a complex set of events that occur when human or animal teeth are applied to the skin or foodstuff. Odontologists have traditionally based their analyses of bitemarks on the subjective visual comparison of a purported injury on the skin or food with photographs and study models of the biter's teeth. This method relies heavily on two premises; firstly, that skin can faithfully capture details of the indenting occlusal surfaces of the teeth and secondly, that the anterior dentition is unique with respect to size, shape or arrangement of the teeth.[1,2,3] However, despite computational advances, bitemark analysis continues to rely on the two-dimensional analysis of three-dimensional events.[4,5] This paper investigates the differences in upper and lower dental bite records that occur when the anterior teeth occlude into a three-dimensional rather than into a flat object.

MATERIALS AND METHOD

Anterior bite registrations were obtained from 7 volunteers with full and unrestored dentitions. As a three-dimensional, life-like bite target we cast a silicone replica from the impression of an actual arm, fitted with a rigid bony interior (Fig.1). Each participant was asked to bite into a single layer of softened bite registration wax wrapped around the same location on the fake arm, as well as into a flat wafer of the same material (Fig.2). Upper and lower bite registrations, as well as the occlusal surfaces of upper and lower dental casts of each participant were then scanned in the same location on a flat bed scanner. We analysed the sizes of the different bite marks by means of landmark- and semi-landmark analysis to calculate Procrustes distances between tooth outlines. In order to analyse shape variation between the two types of bite registration we carried out principal components analyses on the partial warp scores. These were derived from partial Procrustes coordinates aligned by means of thin-plate spline decomposition based on a bending energy matrix.

Fig.1: A three-dimensional, life-like bite target cast as a silicone replica from the impression (top) of an actual arm (bottom), fitted with a rigid bony interior.

RESULTS AND DISCUSSION

Fig.3 shows the results of a relative warp analysis of the upper dentition. There is poor association between the three variables; occlusal surface, squash bite and arm bite (m_{12}= 0.6334; p = 0.1257, based on 10000 permutations). In contrast, lower teeth show a significant association between these variables (m_{12}= 0.8614; p = 0.0154, 10000 permutations).

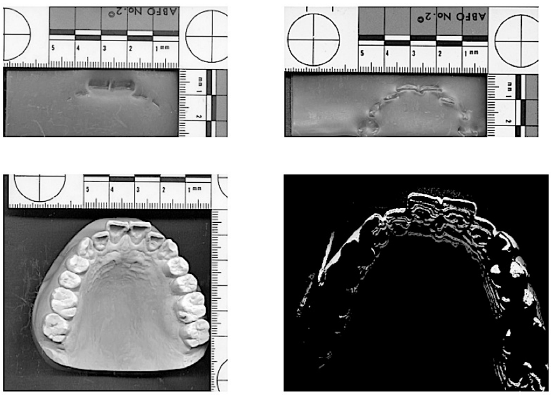

Fig.2: *Top left - arm bite in wax, right squash bite; Bottom left - biter's model, right - laser reconstruction of anterior teeth.*

Irrespective of the sophistication of the method used, bitemark analysis rests on two premises; firstly, that each individual's teeth are unique and secondly, that the material bitten can accurately convey an impression of the biting tooth surfaces.[2,3] This project tests the hypothesis that teeth leave the same impression on a surface, irrespective of its three dimensional shape of the object bitten. Our results show that while for each jaw, occlusal surfaces, squash-bites and arm-bites were highly co-ordinated there were notable differences in the shape imprinted by the upper teeth when they occluded into a flat or a three-dimensional target.

Jaw opening obviously varies with differences in size and consistency of the object bitten. Hence large, tough objects will require a large jaw opening.[6] Early studies have speculated that the extent of vertical separation of the teeth and jaws beyond the freeway space my have a marked effect on magnitude and path of biting force.[7,8] Recently, Haggman-Erikson and Eriksson[9] have shown that during biting and chewing, there was a degree of neck extension that was highly coordinated with jaw opening. Larger head movements were correlated with larger size and harder texture of the bolus. The implication for human bitemarks is clear; the larger the three dimensional object bitten and the tougher it is, the more the neck will flex as the jaw opens and consequently, the more the mandibular path will be altered during forceful closing. Clearly, this means that two joints are operational; the TMJ as well as the atlanto-occipital joint. By extension a squash bite registration only records a bite resultant from the mandible closing at the TMJ, and disregards the trajectory travelled by the teeth when both the jaw and the neck moves during hard biting on a large object. The small shift in head position seen before the start of a forceful bite on a large object implies that the upper teeth are repositioned in an anticipatory position, relative to the lower anterior teeth. This could correspond to our finding of a poor association between the three mandibular variables; occlusal surface, squash bite and arm bite. Taken together, we conclude that the use of a flat bite registration such as a squash-bite in human bitemark reconstruction and analysis may have to be questioned.

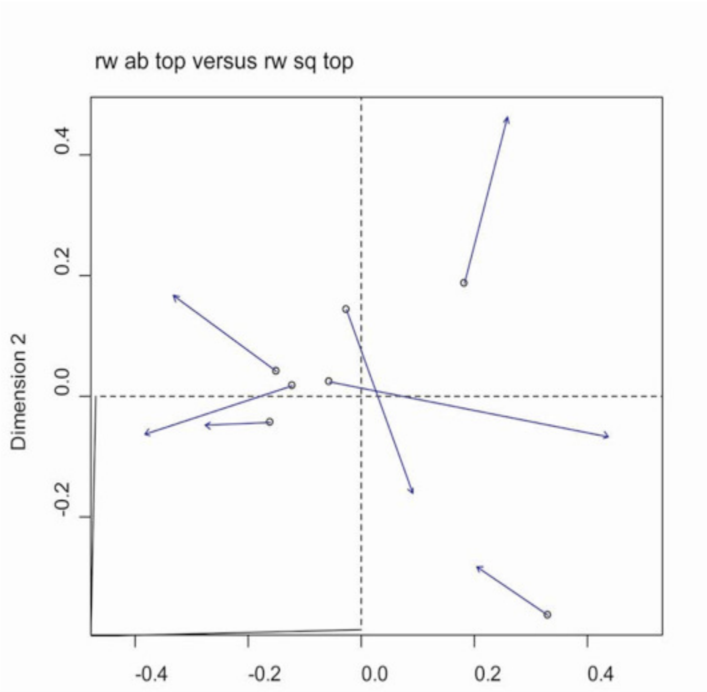

Fig.3: *Relative warp analysis of bites by upper teeth. ab: arm bite; m: model; sq: squash. Poor association (m_{12} = 0.6334; p = 0.1257, based on 10000 permutations).*

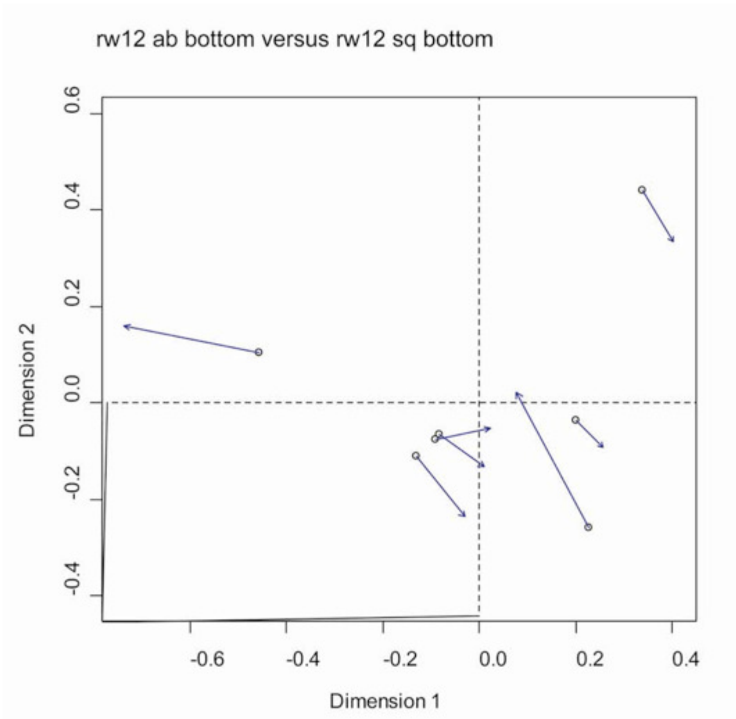

Fig.4: *Relative warp analysis of bottom bite. ab: arm bite; m: model; sq: squash. Significant association (m_{12} = 0.8614; p = 0.0154, 10000 permutations).*

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