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Evaluating Current Dental Imaging Modalities for Human Bite Mark

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ABSTRACT

Objective: This study evaluates the image acquisition efficacy of current available dental imaging modalities for human bite marks in forensic odontology. Dental casts were collected retrospectively from Riyadh dental Hospital.

Methods: Human bite marks were registered on different materials like pink wax, aluwax and Polyvinyl siloxane. These study casts with their corresponding bite marks were imaged and categorized into: (1) 2D imaging using digital cameras following the American Board of Forensic Odontology guidelines; (2) 2D CBCT imaging with Cone-beam computed tomography (CBCT); and (3) 3D imaging using CAD/CAM and CBCT. Sensitivity, specificity and receiver operating characteristics (ROC) curves were traced for observers in all the approach. Paired t-test and kapa tests were utilized for the inter-observer consistency. Each modality had a significant difference under the ROC plotted.

Results: The study observed that 3D CBCT imaging in comparison with the other imaging modalities had a marginally higher value of $P = 0.0002$. The kappa method for the inter-observer agreement was used to confirm this observation.

Conclusion: This study clearly shows the advantage of 3D imaging using CBCT in human bite mark imaging. Based on the results, a 3D forensic odontological image database collection with a gold standard is the future potential of this study.

Key Words: Technical evaluation, CBCT, ROC, CAD, CAM, Human bite marks

INTRODUCTION

Digital human bite mark image acquisition and analysis is a predominant feature in both forensic and biometric applications. Recently there has been a revolution in dental imaging technologies. The field of forensic odontology has benefited from the newer digital imaging modalities, especially with the realization of low dose 3D computed Tomography (CT), along with much such innovative imaging techniques.¹ These state of the art innovations in imaging in which digital data can be combined and manipulated can be utilized by experts to easily access and assess 3D simulations on the screen to accurately plan and follow up their clinical decisions over time.²

Bite mark injuries had always been of interest to forensic and judiciary system.³ Though human bite mark pattern comparisons have been a forensic tool and are accepted in the court of law, it always has been in debate due to the

intricate nature of the human skin in retaining the bite pattern.⁴ From the different types of imaging available, the 2D digital camera along with photo editing software has the currently accepted modality for bite mark image acquisition. All branches and application of dentistry have witnessed in recent decades the prodigious development of different imaging modalities. With these advances, the need for more precise diagnostic tools, especially imaging methods, have become mandatory.⁵ Correct use of newer radiographic techniques, where indicated, allows for better precision of forensic identifications. However, it is imperative to utilize these imaging modalities with the proper knowledge to extract the best advantage of these in the best practice of forensics. Since its introduction in CBCT has gained its notable place as a radiographic diagnostic tool among clinicians.⁶ This study evaluates the imaging accuracy and acceptance of the current available dental imaging modalities in imaging bite marks.

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MATERIALS AND METHODS

A total of 95 dental casts were collected retrospectively from Riyadh Elm University Hospital. Bite marks were

registered using different materials (Pink wax, aluwax and Polyvinyl siloxane). The study casts with their corresponding bite marks were imaged into 3 categories, as shown in Table 1.

Table 1: Categories of the imaging modalities evaluated in the study.

2D imaging		3D imaging	
Photographs	CBCT	CAD/CAM	CBCT
Photographed using digital cameras canon EOS 700D EFS 18-55mm and Sony Cyber-shot DCS-RX100 VI following the ABFO guidelines.	2D Scans of the casts were taken using CBCT, Galileos, Sirona, Germany. ⁷	3D Scans of the casts were taken using CAD/CAM, CEREC 3D, Sirona Dental Systems Germany. ⁸	3D Scans of the casts were taken using CBCT, Galileos, Sirona, Germany.

Data collection

The present study was carried out in the Riyadh Elm University (REU), Riyadh, Kingdom of Saudi Arabia, after being approved by the institutional review board of REU. Experimental bite marks were obtained from a total of 95 dental casts, collected retrospectively from REU dental hospital. The inclusion criterion for casts selection was the presence of all incisors and canine teeth to register the typical possible bite mark injury. The exclusion criterion in this study was missing and mobile anterior teeth, and diseases of teeth such as severe attrition of anterior teeth. This was done to eliminate the possibility of error in the impressions taken due to the underlying etiology.

Data preparation

The dental casts were made using alginate impression material (MA-A7100®, Major Dental, Italy) prepared according to the manufacturer's specifications and in conjunction with accepted dental laboratory techniques. From these casts, bite marks were registered using different materials, specifically, pink wax, aluwax and polyvinyl siloxane. This study casts with their corresponding bite marks were imaged into 3 categories. Both the dental casts and bite registrations were scanned using 3 types of dental imaging modalities.

2D Photographic Image acquisition

The dental casts, along with the bite registrations were photographed as in Figure 1(a) and (b), with Canon EOS 700D EFS 18-55mm and Sony Cyber-shot DCS-RX100 VI, respectively. The ABFO No. 2 scale was used while imaging. The graphic program Adobe Photoshop® was used in tracing the incisal edge contours and outlines from the casts. The metric features of the anterior teeth arches and the individual teeth were sent to expert oral radiologists to be accepted and analyzed for bite marks comparisons.

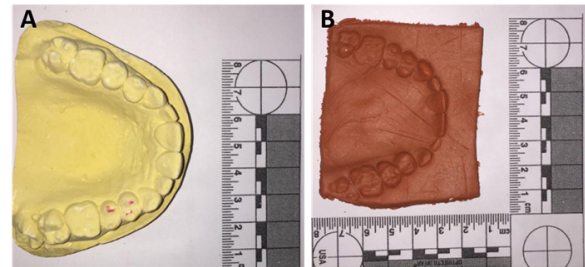


Figure 1: 2D photographs of the dental cast (A) and bite mark registration (B).

3D CAD-CAM image acquisition

The study casts and the registered bitemarks from it were imaged using the intraoral digital scanner CAD/CAM (CEREC 3D, Sirona Dental Systems GmbH, Germany) and with CEREC Software®, which is the software for digital acquisition and 3D design. It produced an image coloured by the variation of tissue color, as seen in Figure 2.

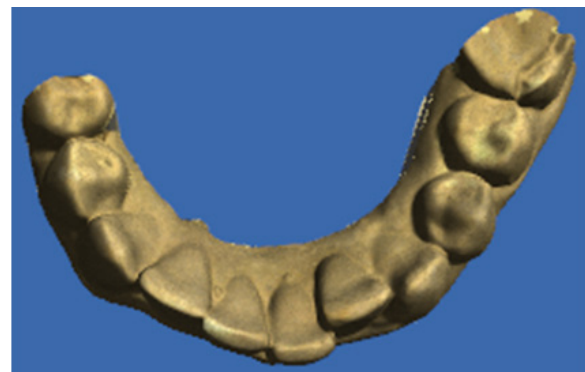


Figure 2: 3D image of dental cast from CAD/CAM

2D and 3D CBCT image acquisition

The 2D radiographic and 3D imaging capabilities of the CBCT equipment Galileos, Sirona, Germany was utilized. The bite marks from the dental casts were subjected to scan using the Sirona Gallelios CBCT machine. The param-

eters for exposure were 84 kVp, 14 mA, and 12 seconds, 401×401×401 pixels matrix, a voxel size of 200 µm, and a slice thickness of 1 mm. The study casts were also scanned individually with the same parameters as in the bite marks registered, and volumetric data were collected. Both the dental casts and bite registrations were analyzed through the tomographic slices and the 3D reconstructions.

SIDEXIS 4® software was used for analyzing the DICOM file which constituted the volumetric data of both casts and the bite marks. These DICOM images of bite mark registrations were constructed as in Figure 3 and were analyzed by four observers at different periods. The raters were all oral radiology specialists, and they independently evaluated the images in two different viewing sessions. The degree of confidence in the given images was marked by these experts. Their confidence in detecting the clarity and details of a bite mark in the given 2D and 3D images were rated using a five-point Likert scale, as given in Table 2.

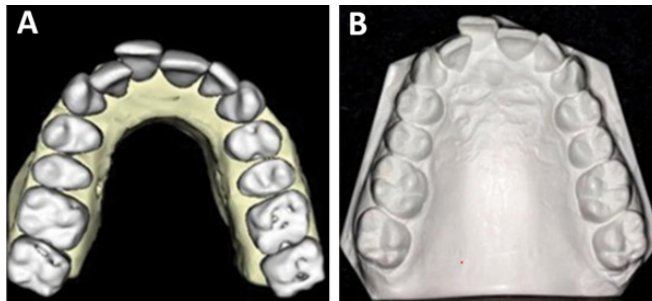


Figure 3: 3D image of the dental cast from CBCT scans (A) of the actual dental cast used (B).

Table 2: The 5-point scale used for evaluation of clarity and bite mark detail in the 2D and 3D images.

Scale	Description
1	Accurate for further analysis
2	Good for further analysis
3	Average for further analysis
4	Barely enough for further analysis
5	Not fit for further analysis

Statistical analysis

Statistical Package for Social Sciences (SPSS) version 21.0 was used in all the statistical observations in this study. The diagnostic accuracy of the three modalities (Photography, CAD/CAM and CBCT) was evaluated using the area under the receiver operating characteristic (ROC) and sensitivity and specificity values using analysis of variance. Interobserver agreement was analyzed by the kappa (κ) statistic.

RESULTS AND DISCUSSION

It was seen CBCT had a notably higher value than the other modalities with a remarkable difference in the areas under the ROC, as shown in Figure 4. All the imaging modalities had a similar result in specificity and table 3 shows the interrater compatibility using kappa statistics in assessing ease and clarity of bite marks from the images, by modality. 3D CBCT at 95% confidence interval(CI) had an impressive sensitivity compared to the other modalities for imaging.

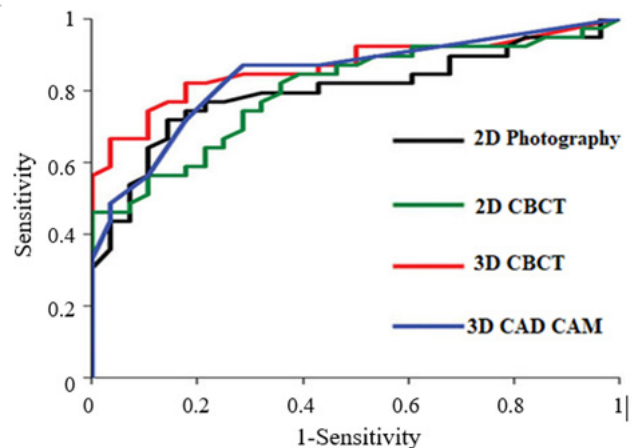


Figure 4: Receiver operating characteristic (ROC) curves for all 3 modalities

Table 3: Interrater agreement in assessing ease and clarity of bite marks from the images, by modality.

Imaging approach	κ (5 category scale) (95% CI)
CBCT 3D imaging	0.61 (0.57-0.65)
CAD CAM 3D	0.60 (0.55-0.64)
CBCT 2D imaging	0.27 (0.23-0.31)
2D photography	0.32 (0.28-0.35)

The 3D imaging function of CBCT proved to be marginally sensitive than the other two imaging modalities, as can be seen in Table 4. It was seen that there was room for 31% false negatives where a bite mark could be analyzed, even with a sensitivity of 69% in the case of CBCT. This points out that to improve the clarity of the bite mark details, it is necessary to refine the image acquisition and method of 3D CBCT.

Table 4: The area under receiver operating characteristic (ROC) curve, average sensitivity and specificity by modality

Imaging approach	ROC Area (95% CI)	Sensitivity (95% CI) (%)	Specificity (95% CI) (%)
CBCT 3D imaging	0.87 (0.79-0.89)	69.44 (60.41-78.47)	92.35 (82.22-100.0)
CAD CAM 3D	0.85 (0.77-0.88)	68.23 (65.11-74.36)	91.2 (90.06-98.18)
CBCT 2D imaging	0.71 (0.69-0.74)	51.85 (42.82-60.88)	83.65 (74.52-92.78)
2D photography	0.71 (0.68-0.73)	51.54 (42.51-60.57)	79.17 (70.04-88.30)
	P=0.0002	P=0.0174	P=0.1573

CONCLUSION

This study shows the advantage of 3D imaging using CBCT in human bite mark imaging. It is also seen from this study that 3D CAD/CAM is a very promising modality to explore in the bite mark identity studies. These modalities if explored and utilized well could be of greater assistance in legal and judicial aspects. In this study, it was shown that CBCT was efficient in yielding images with the finer level of detail needed to detect and compare human bite marks. CBCT imaging was shown to be more resourceful in bitemark imaging and thus if used wisely, CBCT 3D imaging could replace the conventional 2D bite mark imaging as an efficient forensic tool.

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Conflict of Interest

The authors involved in the current study does not declare any competing conflict of interest.

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