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3D Scan Analysis of Exemplar Bitemark on Inanimate Objects

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ABSTRACT

Aim: To compare existing technique of bitemark analysis, the manual docking technique with a new novel technique using 3D scans of the bitemark region and subjecting them to overlay comparison using algorithms. Using the 3D scans, study of time related distortions in the bitemark region, with algorithm based overlay.

Methodology: 30 bitemark were obtained on an inanimate object (apple) and on putty material. The dental casts of the same subjects were recorded and used for the comparison analysis. The bitemark on either material were manually docked with the dental casts of the respective subject. The 3D scans of the bitemark and dental casts were obtained for analysis using algorithm based overlay. Time related distortion (over 7 days) was analysed in the bitemark region using the algorithm based overlay of the scans obtained on day 1 and day 7.

Results: The manual docking analysis results depict excellent match of the dental cats of the subject with the bitemark region, however, manual interference was seen to be high and hence not relevant. The 3D docking analysis on an inanimate object(apple) showed 80% samples to be" most likely" match with the respective dental cast . The 3D docking analysis of the bitemark on putty showed 63.3% match to be "high certainty" match with the dental casts. Comparison of the distortion seen in both the material was seen to be high in the bitemark on apple; putty depicting negligible distortion.

Conclusion: The newer technique of optical 3D scan analysis using algorithm based overlays shows promise and helps minimize manual interferences. Material such as Putty shows less distortion over time and can be an excellent choice for recording and storage of the bitemark samples.

Key Words: Bitemark, Child abuse, Comparison analysis, 3D scan, Overlay

INTRODUCTION

Child abuse is an issue that has been the apex of discussion since many decades.[1-5]However; the rate of increasing incidences of this situation is highly alarming. The innumerable challenges in preventing the different forms of abuse are many. The lacunae may be the barriers in recognising and identifying the signs and symptoms the victim presents with. Amongst the many forms of abuse, the physical form of abuse is rampant and most commonly overlooked. This may be followed by child neglect.

Physical abuse ranges from bruises to lacerations, sometimes even fracture of the extremities. Orofacial injuries are also common features.[1-5] Bitemark injuries found on the victims can be offensive wound whereas when found on the suspect may be inflicted while defending oneself from the offender. These injuries may prove to be an effective tool/ clue to identify the perpetuator.

Bitemark are defined as "a pattern produced by human or animal dentitions and associated structures capable of being marked by these mean's"[4,5]

A bitemark is also defined as a physical alteration in or on a medium caused by the contact of teeth.

The branch of forensics that deals with the legal aspects of professional dentistry with emphasis on the identification of victims/ suspects using dental records and dental unique features is termed as Forensic Odontology.[4,5,6] With the evo-

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lution of a formal board, the identification, analysis of the bitemark was discussed at length and universal identification techniques were identified.

Bitemark appears as an oval/circular patterned injury consisting of two symmetrical U shaped arches separated at their bases. Depending upon the nature of the biting action, there may be distinct singular bitemark or multiple bitemark which can be difficult to positively identify. Delay in identifying the bitemark can also lead to misdiagnosis of a bitemark as any other skin injury. Thus it is impertinent that the process of identifying and analysis of a bitemark injury should begin at the first appearance. Details can often be lost in the process of wound healing in the living individuals or decomposition of the dead tissue.[6,8,10]

METHODOLOGY

Bitemark from the participants of the study were obtained on perishable item like apple and putty (dental elastomeric material)

Children between the age group of 10 to 12 years were selected.

MATERIALS USED

1. Apples
2. Regular body addition silicone impression material(putty material)
3. Alginate impression material
4. Dental stone type 3
5. A rubber ball to simulate curved anatomy of human body.
6. ABFO no 2 scale[8]
7. Digital camera
8. 3D optical scanner(ATOS)

METHOD

Each child was instructed to sit down in an upright position or 'coachman position'.[4,8]

They were asked to bite into the apple with the upper anterior, in an incisive action. (Fig 1)

A second bite from the same child was obtained on the putty material wrapped on the rubber ball. The putty material was manipulated according to the manufacturers' instruction. It was then rolled in an even layer onto the rubber ball. The patient was then instructed to bite into the putty material. (Fig 2).

Thus two bite marks were obtained from each child.

To compare these bitemark, the dental cast of these patients were obtained. An alginate impression of the upper dentition was taken, which was poured with the dental stone type 3. The dental cast now served as a comparison record of the subject. (Fig 5)

The analysis of the bitemark began with the scanning of the bitemark on the apple and on the putty material. (Fig 9, 9.a, fig 10, 10.a)

A 3D optical scanner was used to scan the bitemark from various angles and obtain a 3D image of the bitemark. (Fig 8)

The dental casts also were scanned for a comparison.(Fig 11, 11.a) The dental casts were marked at the distal incisal edges with corresponding colour codes. (Fig 14)

Black: midline

Red: distobuccal edge of left central incisor

Blue: distobuccal edge of left lateral incisor

Green: distobuccal edge of right central incisor

Yellow: distobuccal edge of right lateral incisor

Similar corresponding marks have been placed on the apple bitemark and the putty bitemark. (Fig 12, fig 13)

Identification of match of the bitemark on the corresponding colour codes on the dental casts was done. ICP (Iterated Closest Point) algorithm was used to align the scans of the incisal edges of the dental casts with the bitemark on the apple and bitemark on putty, independently. The algorithm aligned the incisal edges of the bitemark into the bitemark on the apple simulating the docking procedure which is done manually.[8] The alignment was done to align the scans at midline by default.(Fig 15, fig 16)

The bitemark on the apple and putty material were scanned on day 7 in similar manner as on the day 1, using the same 3D Optical Scanner. This was done to assess the distortion in the bitemark region in the both the material.

These scans were imported into the MeshLab software.

To study the distortion, using the 3d scans, the bitemark on apple (day 1) was aligned with the bitemark on apple (day 7) in a similar manner as in that of identification. The colour codes stated earlier were applied and the identification points were duly marked.

The scans were then aligned using the ICP (Iterated Closest Point) algorithm. The mean distance between the identification of the corresponding points were calculated. A summation of these was considered the average distortion that occurred from the day1 to the day 7.

RESULTS

Comparison of the manual docking analysis and the 3D overlay docking analysis (apple) cannot be statistically computed since the manual docking analysis gave result of uniform scoring of "2= high degree of certainty" (table 1)

Matching (Agreement) of results between 3D Overlay Docking - Dental Cast to Apple and 3D Overlay Docking – Dental Cast to Putty:

The agreement between 3D Overlay Docking – Dental Cast to Apple and 3D Overlay Docking – Dental Cast to Putty was found to be negative and very weak and also not statistically significant (P>0.05).(table 2.a , table 2.b)

The comparison of the 3D overlay technique in apple and 3D overlay technique in putty showed the relation to be weak and not statistically significant. The 3D scans of the apple bitemark and the putty bitemark when aligned with the dental casts have been shown to be of good forensic relevance. Though the putty material registered more dental features than the apple, the alignment with the dental cast of each of this material was not statistically different (p=0.0.075). (Table 4)

The comparison of the 3D overlay docking in apple when compared with the other technique showed statisticalsignificance with manual docking analysis (p=0.002) and the 3D overlay docking in apple (p=0.000).

The mean distortion in the bitemark in apple was seen to be 0.65mm, whereas in the bitemark in putty it was 0.20 mm at day 7. Amean difference of 0.45 mm was observed and it was found to be significant. (Table 3)

DISCUSSION

Bitemark on an abused child can often be misdiagnosed. Children present with various cutaneous injuries and presentations. Injuries can be due to fall/trauma, fight with the sibling or simply due to any blunt object. The differentiation of the injury as a bitemark is often based on the dental features. The incisal edges present as rectangular or square impressions and the canines present as triangular impressions. They typically present as oval or elliptical pattern with the teeth impressions at the periphery of the bitemark. The number of teeth that are imprinted can depend on many factors such as the force of biting, position of biter/victim, and the topography of the body part where the bite is being registered.[19,20]

In this study, bitemark were obtained from each participating individual on two materials – apple and putty material wrapped on a rubber ball. The materials chosen were seen to simulate the topography of the human body. Thus when the subjects were asked to bite on the materials, bitemark produced simulated a bitemark on the skin.

The bitemark obtained were scanned using a 3D optical scanner. The scans were imported into MeshLab and aligned using ICP (Iterated Closest Point) algorithm. 3D overlay docking of the dental cast with the bitemark on the apple was done. The link between the dental cast and the bitemark on apple was seen to be "most likely to the biter" in 80 % of the match analysis; 20 % of the matches were observed as "can't be ruled out". No sample match showed any match of "high degree of certainty".[8] The link between the 3D scan of the bitemark on the putty and the 3D scan of the dental cast were observed as "most likely to be the biter" in 63.3% of the match, whereas 36.7 % were observed to be of the grade "can't be ruled out".[8]

The incisal edges of the dental cast and the bitemark in apple and in putty were color coded with the corresponding colors. The alignment of the scans were done in a manner to have the incisal edges of the dental cast dock into the bitemark on apple and putty respectively. The observer recorded the observations as per the guidelines of the American Board of Forensic Odontology.[8]

Comparison of matching efficiency of the 3D scans of the apple bitemark and the 3D scans of the putty against each other in terms of reliability was carried out by Post- Hoc test, wherein the 3D docking analysis of the dental cat with the bitemark on apple was found to be of highest reliability. The second best reliable match was seen in the 3D docking analysis of the dental cast with the bitemark on the putty. The third best reliability in the match was seen with the manual docking analysis. The least significant reliability was seen in the hand traced overlay analysis of bitemark.

Though photographs are ideal for documenting the bitemark, it has limitations.[8,12,16] The analysis of bitemark by an expert is often delayed, even with strict adherence to the guidelines by the ABFO. Preservation of the bitemark in its actual life-size form with minimal manipulation, displacement and distortion is of prime importance.[20,30] In this study, the bitemark on putty showed minimal distortion at day 7.

ABFO recommends the recording of impressions of the bitemark with polyvinyl silicone impression materials (light and regular body putty impression materials) and a stone cast of the bitemark can be obtained. The stone casts can thus be stored as evidence.[19]

CONCLUSION

This study compares the existing techniques of analysing bitemark and a new technique for the same, in terms of their reliability. The bitemark recorded and analysed by the manual docking was seen to demonstrate errors, which could be attributed to the manual errors. This was overcome in the 3D

scan overlay technique where the computer aided matching was done by use of algorithm for aligning the 3D scans of the objects

The 3D format can be stored as life size and can be accessed and analysed at any point of time. Hence it is an excellent way to store physical evidences of bitemark area.

The bitemark in apple demonstrated large secondary distortions when compared to the putty material and that was found to be statistically significant. Hence the actual bitemark on skin, which could undergo distortions which are time related, can be replicated in materials such as Poly vinyl silicone material (putty) which also mimics the elastic property of the skin.

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RESULTS

Table 1A: Distribution of Bitemark In Apple- Manual Docking Analysis (Apple)

Score	Manual Docking Analysis
0	0
1	0
2	100%

(2= high degree of certainty; 1= most likely; 1= can't be ruled out)

The total number of samples (n=30) matched with the respective dental cast with a score of "2= high degree of certainty" in the manual docking analysis.

Table 2A: Distribution of Bitemark in Apple-3D Overlay Docking (Apple)

Distribution Score	3D Overlay Docking Analysis
0	20%
1	80%
2	0

(2= high degree of certainty; 1= most likely; 1= can't be ruled out)

Table 2B: Distribution of Bitemark in Putty- 3D Ovrelay Docking

Distribution Score	3D Overlay Docking Analysis
0	0
1	63.3%
2	36.7%

(2= high degree of certainty; 1= most likely; 1= can't be ruled out)

Table 3: Distortion in the Two Bitemark Media- Apple and Putty

Group	Number of Samples	Mean±Sd	t- value	Significance
Bitemark in Apple	30	.65997500 ± 1.343408358	2.691	0.012
Bitemark in Putty	30	.20447853 ± .046294393	24.192	0.000

Table 4: Comparison of 3D Docking in Apple and 3D Docking in Putty

Technique	Mean±SD	"F"	p value
3D-Overlay Docking (Apple)	0.80±0.40[f]	58.40	0.00
3D-Overlay Docking(Putty)	1.63±0/49		

METHOD OF OBTAINING BITEMARK

Figure 1: Obtaining bitemark on apple.

Figure 2: Obtaining bitemark on putty material placed on a rubber ball.

Figure 3: Photograph of bitemark on apple.

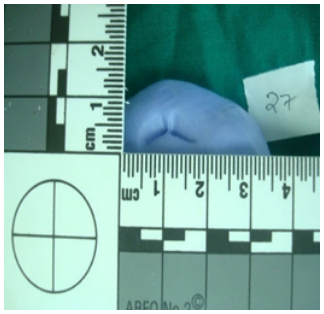

Figure 4: Photograph of bitemark on putty material.

Figure 5: Dental cast (prepared with dental stone type2).

TECHNIQUE OF BITEMARK ANALYSIS – MANUAL DOCKING ANALYSIS.

Figure 6: Dental cast docking into the Bitemark on apple. (Sample no 31).

Figure 7: Dental cast docking into the Bitemark on apple. (Sample no 18).

TECHNIQUE OF BITEMARK ANALYSIS – 3D OVERLAY DOCKING.

Figure 8: Optical scanner (3D).

Figure 9: Scanning of bitemark in apple.

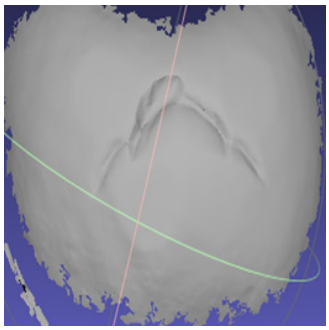

Figure 9a: 3D scan of bitemark in apple.

Figure 10: Scanning of bitemark in putty.

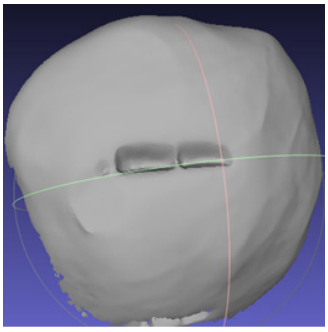

Figure 10a: 3D scans of bitemark in putty.

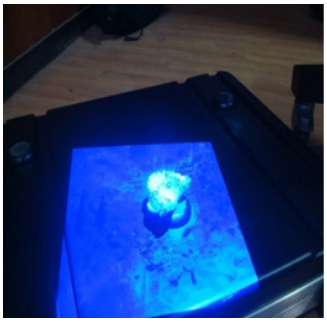

Figure 11: Scanning of dental cast.

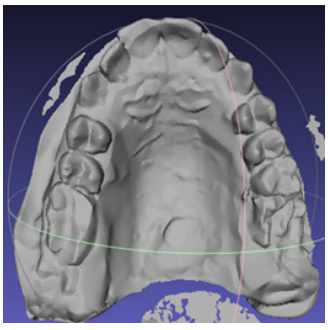

Figure 11a: 3D scan of dental cast.

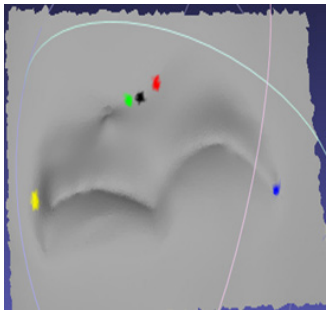

Figure 12: Colour coding in the bitemark in apple.

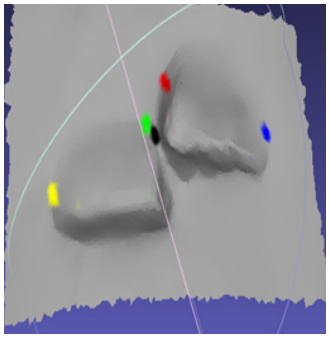

Figure 13: Colour coding in the bitemark in putty.

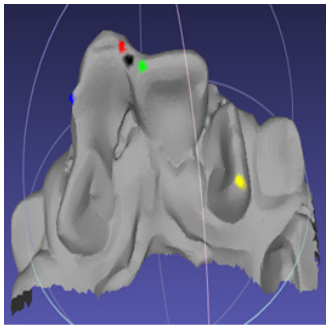

Figure 14: Colour coding in the dental cast

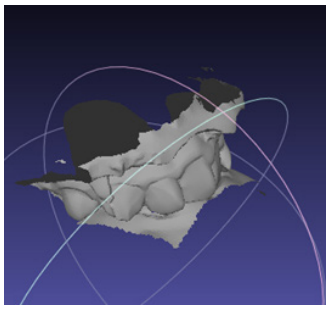

Figure 15: 3D overlay of dental cast on bitemark in putty.

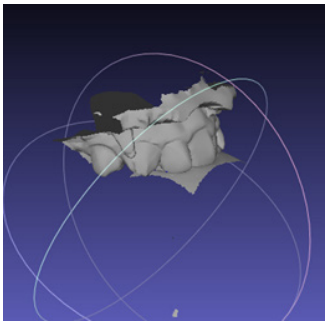

Figure 16: 3D overlay of dental cast on bitemark in apple.