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Computer Assisted 2D and 3D Comparison of Bite Mark Evidence and Tooth Exemplars

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TECHNICAL REPORT
September, 1997

Submitted by:
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Executive Summary

Research was completed by Dr. Sweet at the Bureau of Legal Dentistry (BOLD), University of British Columbia to evaluate the application of recent developments in personal computer graphics for the preservation and analysis of human bite marks and specifically, to develop protocols to share and electronically transmit data among other workers. This multi-phase project studied a series of bite marks and recorded them digitally, developed conventional two-dimensional overlays of dental casts, generated and compared three-dimensional digital models, and investigated transmitting digital images to co-workers for evaluation. Successful 2-D overlays were produced with off-the-shelf graphics software and transmitted via conventional modem to other workers. Production of three-dimensional digital models proved more of a challenge and was deemed to be impractical with currently available off-the-shelf software.

Sommaire

Le Dr Sweet du Bureau of Legal Dentistry (BOLD), a l'Université de Colombie-Britannique, a termine ses recherches qui visaient à évaluer l'application de developpements récents en infographie à la conservation et à l'analyse de marques de morsure humaine et plus specifiquement, à l'elaboration de protocoles pour partager par voie electronique des données avec d'autres travailleurs. Ce projet à phases multiples a consisté à etudier une série de marques de morsure et à les enregistrer numeriquement, à produire une image bidimensionnelle des empreintes dentaires, à produire et à comparer les modeles numeriques tridimensionnels et à etudier la transmission d'images numeriques à des collègues, pour evaluation. On a réussi à obtenir des images 2-D à partir de logiciels graphiques commerciaux et à les transmettre par modem traditionnel à d'autres travailleurs. Les modèles numeriques tridimensionnels se sont révélés plus difficiles à obtenir et ne pourraient être obtenus facilement avec les logiciels commerciaux actuels.

Computer Assisted 2–D and 3–D Comparison of Bite Mark Evidence and Tooth Exemplars

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Final Report

September 20, 1997

A research contract between Her Majesty the Queen, in right of Canada and the University of British Columbia was executed on March 15, 1996. This contract was established to provide specific computer hardware and software as outlined in the grant application by Dr. David Sweet. The research was to be undertaken at the UBC Faculty of Dentistry for a period of one-year. Dr. Sweet acquired equipment and software from the University Bookstore in order to take advantage of discounted pricing opportunities provided to full-time members of the University's faculty. Data collection was not completed within one-year and a six-month extension was granted. The final report was to be submitted by September 30, 1997.

Outcome: A research contract was executed by the signatories on March 15, 1996. The final report was due on or before September 30, 1997.

Objectives

The research initiative was comprised of four different but parallel objectives:

1) record a series of bite marks in digital format along with dental study casts from suspects of varying ethnicity, gender and age.

2) produce conventional two-dimensional comparison overlays at varying degrees of magnification using objective computer methods.

3) evaluate the use of available computer software for 3–D bite mark comparison.

4) attempt to transmit electronically digital data from bite marks and suspects to other forensic odontologists.

Equipment

The computer hardware and software was ordered on March 25, 1996. Subsequently, it was learned that several items were not available from Apple Canada Ltd. on the required date.

A high-resolution printer, monitor, and accessory drive were delivered on April 23, 1996 along with the software applications. A flatbed scanner and keyboard were delivered on April 24, 1996. The computer (with additional random access memory (RAM) and video memory, graphics accelerator card, and other required options) was received on April 30, 1996.

Outcome: Computer equipment was not functional until April 30, 1996, six weeks after the commencement of the contract.

Software Conflicts

As can be expected with any new computer hardware/software configuration, especially installations involving such advanced technology, several software conflicts were discovered during early testing. Additionally, the computer manufacturer released several operating system upgrades shortly after the date of manufacture of this hardware. These upgrades, which enable the computer to interpret, diagnose and repair certain software conflicts, were downloaded directly from the World Wide Web. Once installed and configured, the system performed as expected.

Outcome: System software upgrades were downloaded from Apple's website and used to update the computer's operating system to reduce software conflicts. The system was functioning at optimum levels by May 28, 1996, ten weeks after the commencement of the contract.

Hardware Conflicts

It became apparent that despite the presence of 32 MB of RAM the tasks assigned to Adobe Photoshop during this research project required additional memory. On July 2, 1996, 32 MB of interleaved, paired DIMM RAM were added. This brought the total memory on board to 64 MB.

Outcome: Additional random access memory was installed July 2, 1996 to increase the computing power and speed of the graphical interface.

Software Limitations

Limitations of Spectacular Infini-D software for three-dimensional rendering were discovered. Bite mark injuries on curved surfaces were not able to be reproduced in the computer with the necessary accuracy or predictability to meet the imposed error thresholds. However, two-dimensional images from digitized photographic evidence were produced with better than anticipated results. As a result, the three-dimensional aspects of the current project were disregarded until improved 3-D software is available.

Outcome: The three-dimensional aspects of the project were abandoned due to limitations of current software.

RESULTS

Part One

A total of 54 human bite mark injuries were digitally recorded using the computer hardware and software provided. These images established the database of unknown bite mark exhibits. Individual reference scales were simultaneously input to the database to enable metric analysis of each injury and verification of the dimensional traits of the work product. The injuries spanned the complete range of bite marks as seen in actual forensic case work. Contusions, abrasions, and lacerations are examples of the traumatic injuries observed. Please see Appendix 1.

A total of 513 sets of dental exemplars were digitally recorded into a known suspect database. Each exemplar was comprised of a full-arch upper and full-arch lower dental study cast.

Distribution of these data was as follows:

	GENDER	
Class	Number	Percent (%)
Male	219	43
Female	294	57

ETHNICITY

Class	Number	Percent (%)
Caucasoid	235	45.8
Mongoloid	123	24.0
Negroid	155	30.2

CHRONOLOGICAL AGE

Class (yrs.)	Number	Percent (%)
10-15	61	11.9
16-20	50	9.7
21-25	49	9.6
26-30	47	9.2
31-35	60	11.7
36-40	59	11.5
41-50	93	18.1
51+	94	18.3

Outcome: A database of bite mark injuries (n= 54), which is subcategorized by severity of injury, was established. A large database of suspect dental exemplars (n= 513), which is subcategorized according to gender, ethnicity and chronological age, has been established.

Part Two

A specific protocol was developed and refined to fabricate accurate and reproducible bite mark comparison overlays using the supplied computer equipment. Conventional techniques used by forensic dentists to produce these overlays include many subjective methods. The computer-based technique developed during this project was compared to five conventional techniques. The computer-based technique was determined to be more accurate than the other methods to a statistically significant degree.

Dental exemplars were scanned into the computer database using the flatbed scanner. The biting edges of the teeth were selected and transferred to an additional layer (called

overlay) using Adobe Photoshop graphical software. A 2-pixel wide line tracing the perimeter of the biting edge of each tooth was constructed using the Tools palette. The image of the ABFO no. 2 reference scale was transferred to the overlay layer to verify relative enlargement of the final image at output. The image was printed on acetate transparency film using a high-resolution laser printer. Please see Appendix 2. This transparent product, which contains hollow volumes of the biting edges, is used to compare the sizes, shapes and configuration of the suspect's teeth to photographs of bite mark injuries enlarged to the same degree.

Statistical results:

1. Comparison of area and rotation of four upper and four lower anterior teeth among five overlay production methods (MANOVA Test Statistic Chi and P-values):

	AREA	ROTATION
Test Statistic Λ	436.83	91.32
P-value	< 0.0001	< 0.0001

2. Mahalanobis Distances for each overlay production method compared to the computer-based method:

	AREA		ROTATION	
	Mahalanobis Distance	P-value	Mahalanobis Distance	P-value
Hand Drawn vs. Computer-based	138.53	< 0.0001	16.64	< 0.03
Wax vs. Computer-based	136.07	< 0.0001	16.51	< 0.04
Xerox vs. Computer-based	533.21	< 0.0001	15.63	< 0.05
Radiographic vs. Computer-based	17.08	0.15	28.37	< 0.0004

Outcome: A method to produce very accurate and reliable bite mark comparison overlays was developed and refined. Comparison of this computer-based method to other common overlay production methods showed that this technique is far superior in terms of both objectivity and accuracy.

Part Three

This project objective was not completed due to the lack of availability of suitable three-dimensional imaging software.

Initially, it was thought that software such as Spectacular Infini-D which incorporates spline-based modeling tools for 3-D rendering and animation could be adapted for use in this project. However, early testing of this software application identified significant limitations in the ability of the software to accurately reproduce the contours, curvatures and surface details of human skin. Three-dimensional imaging is a rapidly expanding field in computer science. It is suspected that the next generation of this software may provide a suitable platform to allow reproduction of tissue samples in a digital context.

Part Four

Experiments were conducted using both real and simulated forensic cases to assess the efficacy of transmitting digital images of human bite marks and suspects' exemplars between forensic odontologists. Collaborations were undertaken between Dr. Robert E. Wood (Toronto, ON), Dr. C. Michael Bowers (Ventura, CA) and Dr. Gary L. Bell (Seattle, WA). Digital images of evidentiary photographs and dental study casts were transmitted electronically as attachments to electronic mail messages. In each case the images were successfully received, viewed, and printed. One of the most significant results of this part of the project was the fact that this electronic transmission of forensic data was successful across computer platforms. Drs. Bowers and Bell were able to accept and handle data generated on the Macintosh computer equipment provided in this project using their IBM-based personal computers. Please refer to Appendix 3 and 4 of this report.

Outcome: Electronic transmission of important key materials from human bite mark forensic cases was possible. This enabled experts separated by large geographic

distances to rapidly and effectively share information and expertise, even across different computer platforms (Macintosh versus IBM-based). It is suspected that this technology can be shared with individuals working in other related forensic disciplines.

Conclusions

1. Using current computer technology it is possible to digitally capture photographic evidence from human bite mark injuries and dental exemplars from suspects. The images are extremely accurate and reproducible.
2. Production of a database of dental exemplars, in digital format, allows forensic dentists to use a dental line-up for blind testing purposes. Exemplars from suspects in actual cases can be inserted into a group of several other individuals of similar age, race, gender and dental traits.
3. Certain anthropomorphic traits recorded in the dental exemplar database appear to provide opportunities to study the uniqueness of the human dentition. This will form the basis of ongoing research with respect to this database.
4. Accurate, objective comparison overlays can be produced using Adobe Photoshop computer software. Currently, this is the most accurate bite mark comparison overlay production method available.
5. Bite mark exhibits (photographic evidence) and suspect exemplars (digital images of dental study casts) can be transmitted as attachments to electronic mail messages over large geographic distances to enable collaboration between experts.

Acknowledgments

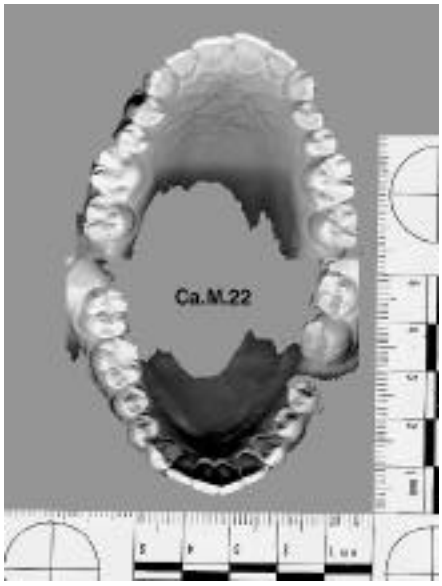
Dr. Sweet is grateful to the Canadian Police Research Centre for its generous support and assistance to purchase the computer hardware and software needed to complete this project. In particular, the efforts of Glenn Carroll and Nick Cartwright are recognized.

For their efforts as research assistants responsible for collecting, interpreting and entering data, the assistance of Mark Parhar, Juliana Ng, and Juliana J. Kim is also gratefully acknowledged.

Appendix 1

Figure 1 – Examples of bite mark photos recorded digitally into computer database.

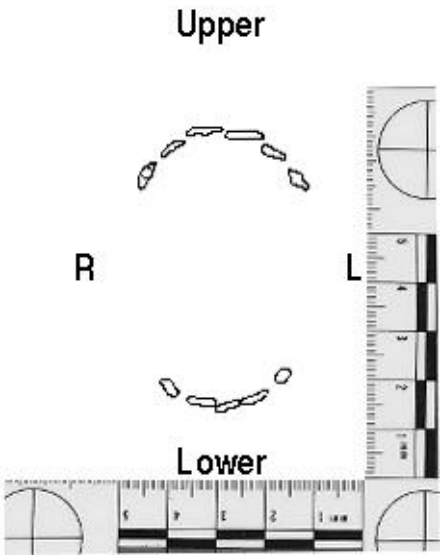
Figure 2 – Examples of dental exemplars recorded digitally into computer database.



Appendix 2

Figure 3 – Digitally recorded dental study casts from bite mark suspect.

Figure 4 – Bite mark comparison overlay produced using Adobe Photoshop.



Appendix 3

Forensic Services

C. Michael Bowers DDS, JD
2284 S. Victoria Ave. Suite 1-G, Ventura, CA 93003
voice: 805-642-0381
fax: 805-656-3205
email: cmbowers@aol.com

May 13,1997

Dr. David Sweet
Bureau of Legal Dentistry Laboratory
146-2355 East Mall
Vancouver, BC V6T 1Z4

Dear Dr. Sweet,

I would like to comment concerning the value of images transfers between experts via the Internet. The various cases we have exchanged over the past two years have dealt with injury patterns on human skin. The ability to transfer digitized images of a wound is a powerful tool in allowing independent review and consultation of this form of forensic evidence. The additional ability of electronically transferring a **1:1** image of a suspect(s) dentition completes the equation.

I have found this means of communication to be both timely efficient, and of high clarity.

Your research in creating a database of dental information is a most rational and practical use of methods currently available. The determination of the dental variables present in the human population requires this type formalized and science-based study. Ethnicity, age, and gender characteristics must be collated into a workable image archive. The existing information is colloquial, very limited in size and proper analysis.

Please communicate my comments to anyone interested in this process

Regards,

Mike Bowers

Mike Bowers DDS, JD

Appendix 4

Department of Dentistry,

Chief:
Dr. W.G. *Maxymiw*

Dental and Maxillofacial Radiology:
Dr. *R.E. Wood*

Oral Medicine and Pathology:
Dr. L, Lee

Craniofacial and Ocular Prosthetic unit:
Dr. *A. Cheng*
Dr. J. D. Anderson
Ocularist
Ms. D. *Archibald*
Anaplastologist
Mr. D. Morrison

Consultants:
Oral Surgery
Dr. G. Baker
Dr. J. Symington
Research
Dr. G. Bradley

Appointments
Ms.B.Legere
946-2198
Department Secretary
Ms. *A, Dias*
946-4511

Ontario Cancer Institute / Princess Margaret Hospital

Institut du Cancer de l'Ontario Hôpital Princess Margaret

Dr. D. Sweet,
Director, Bureau of Legal Dentistry,
University of British Columbia,
146-2355 East Mall
Vancouver British Columbia
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re: electronic transmission and analysis of bite marks

Dear Dr. Sweet,

Thank-you for the opportunity of responding to your question regarding the utility of electronic internet transmission of images of bite marks. As you are well aware we have transmitted bite marks, intraoral dental radiographs and pattern injuries mimicking bite marks as well as case work-ups and photo-overlays. I see this as a particularly good use of this resource because it allows rapid transmission of suspicious markings to experts in the field who are geographically distant. Further, I have found the images to be crisp, clear and as good (if not better) than photographic images transferred via conventional mail. I see this area as a great opportunity for future forensic activity and believe it could be easily adapted for fingerprint and other identification methods.

I believe improvements could be made in the following areas:

1. encryption of the images to prevent interception and increase security,
2. direct real-time quick conferencing from centre to centre via a combined e-mail telephone or dual e-mail linkage,
3. multiple scanned images or stereo scanning of images to allow depth perception of suspects models with respect to analysis of depth of bite.

Sincerely, and with respect,

R.E. Wood D.D.S., M.Sc., Dip. O.R., Ph.D. (Odont), F.R.C.D.(C.)
Consultant to the Chief Coroner of Ontario
26 Grenville St., Toronto, Ontario

Appendix 5

Paper submitted to Journal of Forensic Sciences on subject of bite mark comparison overlays produced using techniques developed in this project. This technique was compared to several common techniques currently in use by North American forensic dentists.

Accuracy of Bite Mark Overlays: A Comparison of Five Common Methods to Produce Exemplars from a Suspect's Dentition

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