Virtual dental autopsy: undertaking forensic dental identification remotely using an intra-oral video camera

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KEYWORDS

Intra-oral video camera (IOVC), Human identification, Oral examination, Telehealth, Disaster victim, Forensic dentistry

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ABSTRACT

Introduction: The aim of this study was to evaluate whether a forensic odontologist working remotely could accurately undertake forensic dental identifications using videos produced by non-dental forensic staff operating an intra-oral video camera (IOVC). The study's aims were to assess the accuracy and time taken to perform remote forensic dental identifications in this manner.

Materials and methods: Eight cadavers from the Centre for Anatomy and Human Identification (CAHID), University of Dundee, UK, were examined by a forensic odontologist via a traditional dental examination. Their dental condition was recorded to serve as ante-mortem records for this study. Videos of each dentition were produced using an IOVC operated by a medical student. Post-mortem records were produced for each dentition from the videos by a remote second forensic odontologist who was not present at the traditional dental examination. The ante-mortem and post-mortem records were then compared, and identification was classified as positively established, possible or excluded.

Results: Established identifications were positively made in all eight cases although there were some non-critical inconsistencies between ante-mortem and post-mortem records. Before the second opinion, 85.6% of the teeth per study subject were charted consistently. After the second opinion, the percentage of consistency increased to 97.2%. Each video on average was about 4.13 minutes in duration and the average time taken to interpret and chart the post-mortem dental examination at the first attempt was 11.63 minutes. The time taken to chart from the videos was greater than is typical of a traditional dental examination.

Conclusion: This pilot study supports the feasibility of undertaking remote dental identification. This novel virtual dental autopsy approach could be a viable alternative to a traditional post-mortem dental examination, in situations where access to forensic dental services is difficult or limited due to geographical, logistical, safety, and/or political reasons.

INTRODUCTION

The term "virtopsy", a combination of the words "virtual" and "autopsy", was first coined by Thali *et al*[1] in 2003. The key concept behind "virtopsy" is to perform post-mortem examinations using non-invasive radiological techniques.[1,2] When this concept is applied to the field of Forensic Odontology, it not only encompasses the use of non-invasive radiological techniques[3-5] but also the use of digital dental technologies and teledentistry,[6-11] and rarely a combination of the two.[12]

Outside the forensic dental setting, there was an uptake of interest in teledentistry during the COVID-19 pandemic. Some healthcare organisations, such as the US Centres for Disease Control and Prevention,[13] advocated the adoption of teledentistry during the pandemic as a means of triaging dental patients to determine whether the patients needed to be physically seen at a dental clinic or not. The objective was to minimise the risk of COVID-19 transmissions between healthcare workers and patients, and reduce the overall burden on the healthcare system during the pandemic.[14] This was necessary during the COVID-19 pandemic as routine dental treatment (in particular aerosol-generating procedures) were deferred in many countries to reduce the risks of transmission.[15] Therefore, during the pandemic, teledentistry offered the ability to provide some form of dental care, even if it was just to provide symptomatic relief, which was better than no care at all;[13] especially for individuals and communities that were underserved before and during the pandemic.[15]

Even before the COVID-19 pandemic, the uptake of telehealth amongst dental professionals had generally lagged behind the medical profession.[16,17] This, in turn, meant that a sudden pivot to teledentistry during the COVID-19 pandemic posed significant challenges in catching-up the technical know-how and closing gaps in equipping when the global supply chains were disrupted.[13] Viewed from this perspective, perhaps then it is not surprising that teledentistry as applied to the field of Forensic Odontology (i.e. as a form of virtual dental autopsy) is also quite nascent. For instance, twenty years have passed since the first paper on “virtopsy” but there have been surprisingly few studies conducted[4,6,7,9-11] and an equally small number of reviews on virtual dental autopsy.[3,5,8,12,18,19] Furthermore, when it comes to the application of teledentistry/ digital dental technology in forensic dentistry, there is no single method that has been universally accepted, in part because of the cost of the equipment.[3]

The recent and arguably still ongoing experience of COVID-19 is a poignant reminder of the risks of infectious disease transmission in both the clinical and mortuary environments. The presupposition is that performing virtual dental autopsies can potentially reduce the number of persons required to physically handle remains with unknown infectious disease status,[12] and so reduce the risks of transmissions amongst forensic professionals. In addition, there may be occasions where access to forensic dental services is difficult or limited due to geographical, logistical, safety, and/or political reasons. In a mass fatality situation, the forensic odontologist(s) would most likely also be subjected to time restrictions, or pressure from the local and/or international community to undertake forensic identifications in an expedient but rigorous manner. There are also jurisdictions where the numbers of forensic odontologists are few and far between to undertake ‘peacetime’ coronial death investigations, and the manpower shortage is even more acutely felt when it comes to disaster victim identification.[20]

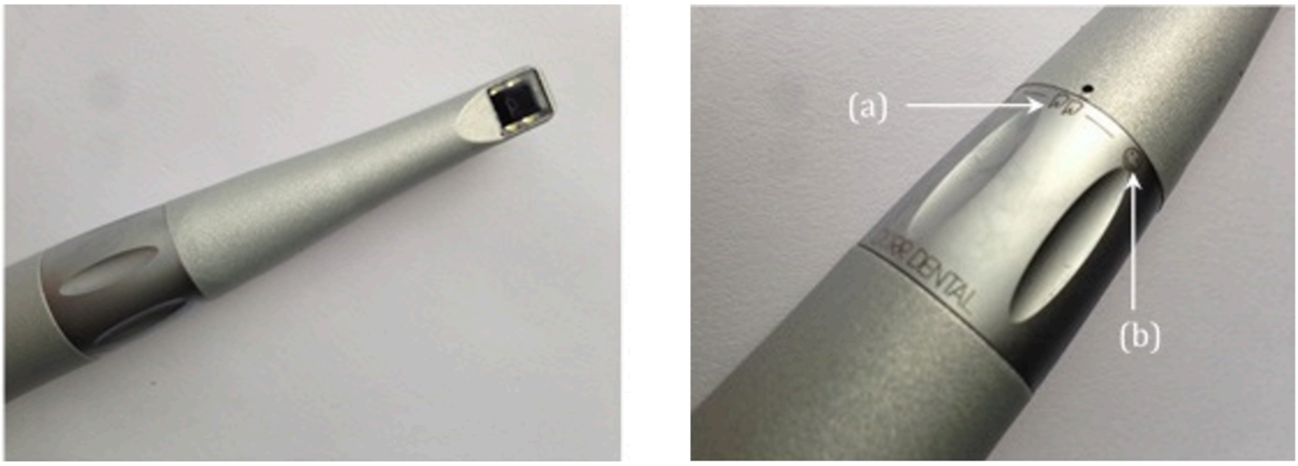
Another group has explored the feasibility of using non-dental forensic staff to capture forensic dental post-mortem images, which were then forwarded to a forensic odontologist who was remotely based.[6] In addition, other researchers have explored using intra-oral video camera (IOVC) systems to undertake virtual dental autopsy.[6,7,9-12] IOVCs were first introduced into clinical dentistry in 1987[8] and have since become increasingly adopted amongst dental professionals in developed countries. A typical IOVC setup consists of an intra-oral camera with a light source that is mounted on a handpiece that can capture, process, and display photographic images and/ or videos. Beyond capturing photos and videos, there are a range of clinical functions for IOVCs which include, but are not limited to, detecting dental caries[8,21] health education and promotion,[8,22] treatment planning,[23,24] and magnifying the field of vision for example to locate root canal orifices.[8]

This pilot study pushed the boundaries further by evaluating whether a forensic odontologist working remotely could accurately undertake forensic dental identifications using videos produced by a non-dental forensic staff operating an intra-oral video camera (IOVC). The study's aims were to assess the accuracy and time taken to perform remote forensic dental identifications in this manner. A The research question was in a mass fatality incident or remote scenario, are there any possible alternatives to a traditional post-mortem dental examination? In other words, can forensic dentists undertake dental identifications remotely?

MATERIALS AND METHODS

The intra-oral video capturing software (DBSWIN 4.4 Dental Image Processing and Archiving, Dürr Dental, Bietigheim-Bissingen, Germany) was first installed on a laptop (Samsung NP-R20 Intel® Core™2 CPU, Seoul, South Korea). Pre-testing of the software and intra-oral camera (IOVC; Dürr Dental, Bietigheim-Bissingen, Germany) (Fig. 1) was undertaken on two of the authors' (SM, GC) dentition to verify its image-capturing ability, video standards, and accuracy.

Figure 1. Left: Dürr Dental Intraoral Video Camera. Right: (a) Zoom setting for close up view of surfaces; (b) Overall view setting



Following ethical approval from the University of Dundee, a sample of eight cadavers was identified from the population available at the Centre for Anatomy and Human Identification (CAHID), University of Dundee. As the purpose of the study was to match ante-mortem and post-mortem dental records but not to identify the bodies, the identities of the cadavers remained anonymous and were instead randomly allocated a number for the purposes of this research (numbers 1-8). Eligibility for study inclusion was limited to cadavers with at least one tooth present in each quadrant of the mouth.

Each cadaver was examined in turn, as follows. To facilitate optimal conditions for a traditional post-mortem dental examination, a lamp was positioned to illuminate the mouth. The mandible was opened as far as possible and held in position with a dental prop. The teeth were then cleaned using surgical gauze. Following which, an experienced forensic odontologist (AH) undertook a traditional post-mortem dental examination and dictated the findings to a scribe.

A hard-copy dental chart (odontogram), based on the Fédération Dentaire Internationale (FDI) notation, was used to record the findings. These odontograms charts subsequently served as the ante-mortem records for this study. No radiographs were taken, as protocols in CAHID did not permit this.

After the ante-mortem chart for each cadaver was completed and re-checked by the forensic odontologist (AH), videos of the dentition were recorded a medical student (SM). An IOVC connected via USB to a laptop was used to capture the videos. The medical student handled the IOVC whilst the forensic odontologist handled the laptop. As the IOVC had its own light source, the dental lamp used for the traditional post-mortem dental examination was not required for the intra-oral filming. Seven views were recorded per subject in the following manner:

1. An overall view of the dentition;
2. Upper buccal surfaces (cheek surfaces of teeth);

3. Upper occlusal surfaces (biting surfaces of teeth);
4. Upper palatal surfaces (surfaces of teeth facing the tongue);
5. Lower buccal surfaces;
6. Lower occlusal surfaces; and lastly
7. Lower lingual surfaces (surfaces of teeth facing the tongue)

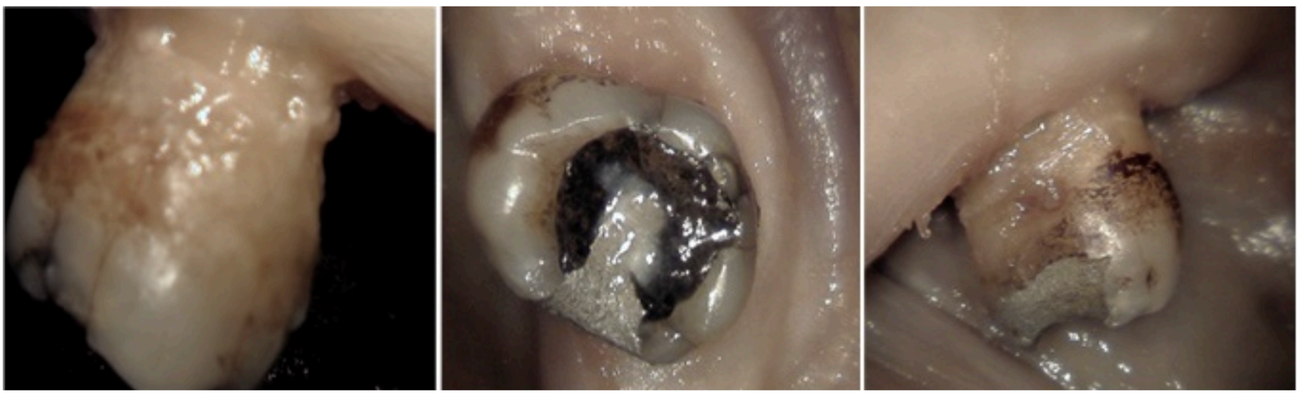
This particular IOVC had three zoom settings; the lowest zoom setting was used for the overall view, whilst the remaining six videos of the buccal, occlusal, and palatal surfaces were recorded at the highest zoom setting (Fig. 1) to optimise the details captured. For the overall view, the lips were reflected with the primary aim of capturing the number and position of teeth present (Fig. 2). Each tooth was thus visible from three viewpoints (i.e. buccal, occlusal and palatal) after a composite viewing of the videos of these three viewpoints (Fig. 3). In select cases, a second take of a surface was recorded where the first take was deemed insufficient (i.e. blurred, jerky, or incomplete); this decision was at the discretion of the forensic odontologist (AH). The videos were then saved to an external hard drive.

The external hard drive was passed to a second forensic odontologist (GC) who was not present at the traditional intra-oral examination and virtual dental autopsy of the subjects. Using only the information provided in the videos, a set of post-mortem records was constructed for each subject (i.e. teeth present, condition of the teeth, type of restorations present and tooth surfaces involved). No limit was set on the time spent nor number of video plays required to produce a post-mortem record.

Once the eight post-mortem records were completed, the authors compared the ante-mortem and post-mortem records. Using the American Board of Forensic Odontology (ABFO) standards, the identifications were subsequently classified as positively established, excluded, or possible.[25] Where discrepancies were found between the ante-mortem and post-mortem records, the videos were re-examined by all the authors and a consensus reached where possible.

Figure 2. Still image from Video 1, Subject 4 to give a general overview of teeth present and treatment present

Figure 3. Three views of a mesio-occlusal restoration on tooth #17 (FDI notation) of Subject 6. From L-R: buccal view; occlusal view; palatal view



RESULTS

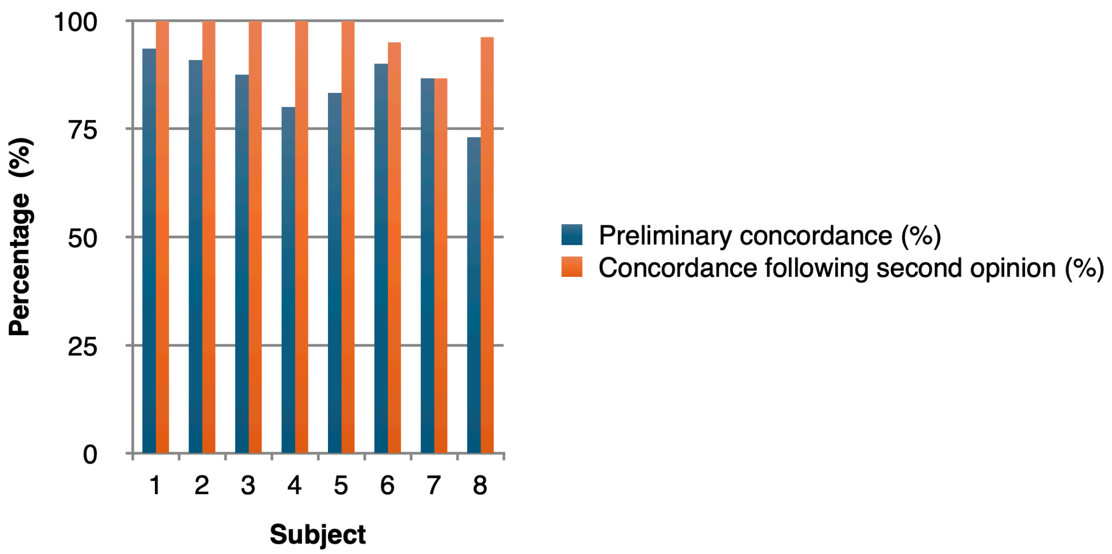
All the post-mortem records were positively matched to the ante-mortem records such that, if required, a definitive dental identification of each cadaver could be established. A perfect match was observed in five out of the eight subjects. In the remaining three, the discrepancies were insufficient to alter the identification decision.

The percentage of teeth charted consistently in the ante-mortem and post-mortem records is shown in Figure 4. Before the second opinion, 85.6% of the teeth per study subject were charted consistently. After the second opinion, the percentage of consistency increased to 97.2%. When comparing the antemortem and post-mortem records, there were initially a total of 23 discrepancies (Table 1), notably the presence or extent of a tooth-coloured restoration. Following re-examination of the videos by the authors, these points of discrepancy were addressed and a consensus reached for 19 out of the 23 discrepancies (82.6%) (Fig. 4).

Table 1. Cumulative frequency of charting inconsistencies, total N= 32

Charting Inconsistencies	Frequency (n)
Presence/absence of amalgam restoration	2
Surface extent of amalgam restoration	2
Presence/absence of composite resin	8
Surface extent of composite resin	7
Presence/absence of veneer	1
Surface involvement/extent of caries	2
Surface involvement of fracture	1

Figure 4. Graph illustrating the accuracy (*i.e.* concordance) of post-mortem charting when compared against ante-mortem records, before and after a second opinion



In total there were four charting differences that could not be resolved with re-examination of the videos, and would require radiograph analysis to arrive at a definitive conclusion (two differences regarding the extent of caries, and two differences regarding the presence or absence of tooth coloured restorations). However, these differences were not significant enough (i.e. irreconcilable) to affect positive identification of the subjects.

Each video on average was about 4.13 minutes in duration (Figure 5) and the average time taken to interpret and chart the post-mortem dental examination at the first attempt was 11.63 minutes (Figure 5). It can be seen from Figure 6 that the combined process was completed in less than 25 minutes per subject (average of 15.76 minutes). When a second opinion was required the length of time taken increased but was not recorded.

Figure 5. Total duration of IOVC videos per subject and the time taken to construct individual post-mortem charts

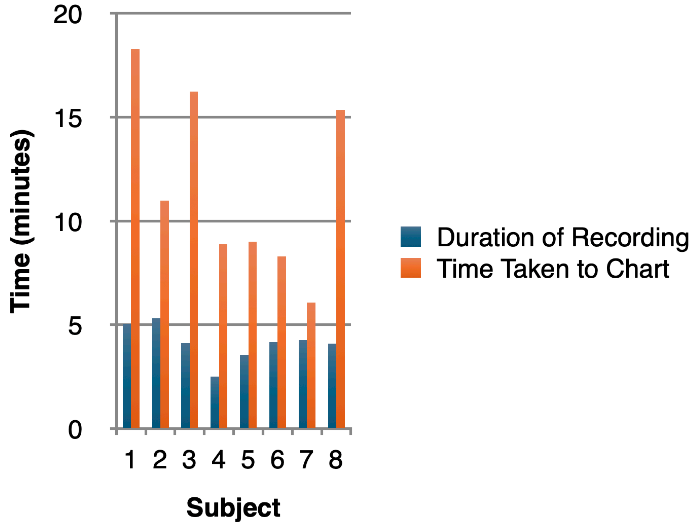
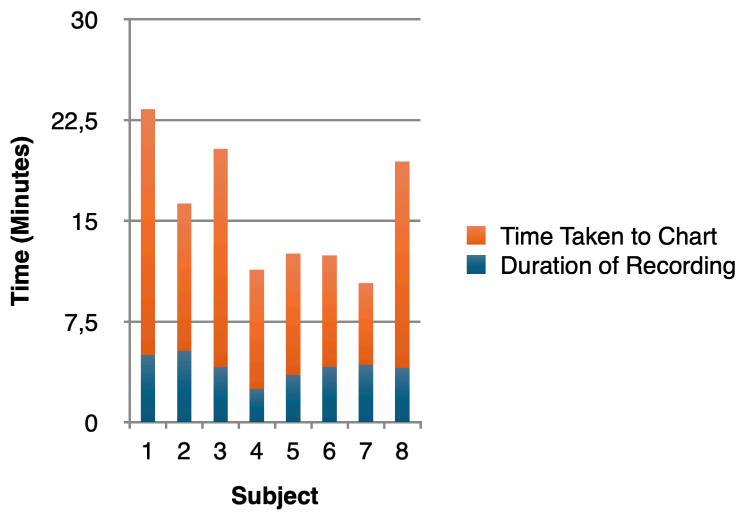


Figure 6. Stacked column representation of Fig 7. to illustrate the total time invested per subject



DISCUSSION

This study shows that (i) a non-dental forensic staff can be trained to competently operate an IOVC to capture intra-oral videos, and furthermore (ii) a forensic odontologist working remotely can rely on these videos to accurately undertake forensic dental identifications with a high degree of certainty. Established identities were positively made in all eight study subjects because of matching ante-mortem and post-mortem records. It is important to highlight that the post-mortem records were charted from the intra-oral videos without any attempt to first calibrate between the non-dental staff (SM) and forensic odontologists (AH and GC),

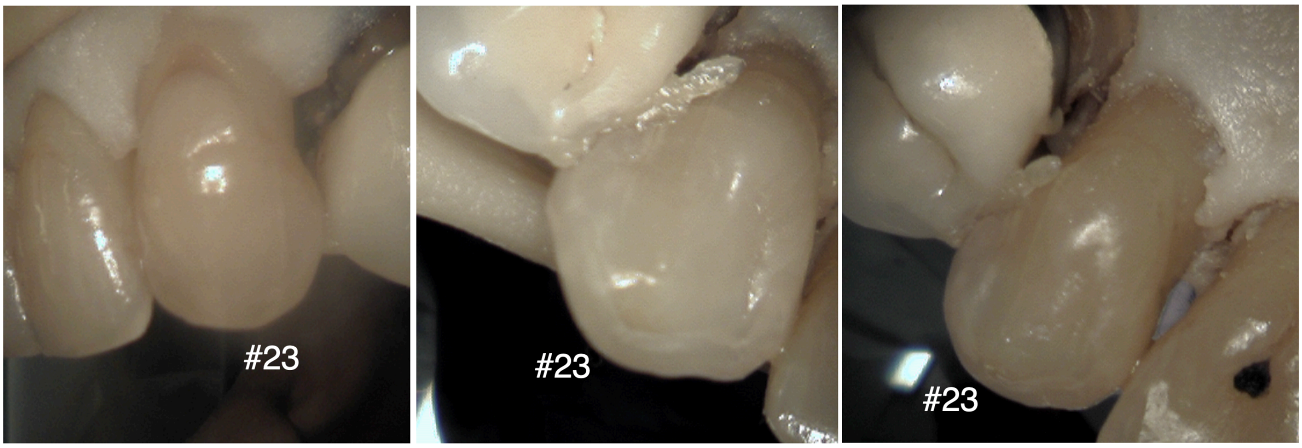
The decision to record seven separate videos per subject was to provide maximum information with minimum disorientation. After some trial and error prior to commencing the study proper, it was found that it was easier to individually record by teeth surfaces rather than by each quadrant (the latter of which proved disorienting and more challenging to interpret). Effective use of the IOVC is a skill that requires development and the early videos were at times jerky, blurry, and of poor quality. This resulted in difficulty interpreting the initial videos. However, as the operator (SM) became more familiar with operating and manipulating the IOVC, the quality of the videos increased. This highlights the importance of appropriate training prior to implementing a new technology.[6,7]

The model of IOVC used for this study was a basic model which lacked specifications that may have enhanced the produced videos, including: an autofocus feature; a dedicated button to capture photographs; an adjustable light source; a microphone; and wireless connectivity. Many of these features are available on newer models of IOVCs; therefore when selecting a particular IOVC brand and model for virtual dental autopsy, consideration should be given as to which specifications will produce the optimum results at the most reasonable cost.

In this study, the videos were asynchronously transferred, in a store-and-forwarded manner, from the non-dental forensic staff to the remotely based forensic odontologist. A case study during the COVID-19 showed the feasibility of using clinical photos taken by physicians, using smartphones which were synchronously transmitted via a general-purpose messaging application, for the purposes of a remote dentist undertaking teledental consultations.[13] When extrapolated to virtual dental autopsies, the assumption is that the real-time synchronous transfer of videos (and images) should also achieve the outcome of undertaking forensic dental identifications remotely. Theoretically, remote dental identification via teledentistry should be possible from any location that is equipped with a computer connected to the internet.

The difficulties associated with charting from the video produced by the IOVC included the difficulty in identifying the presence and extent of tooth-coloured restorations (Fig 7); however, this is also a common experience during traditional visual only post-mortem examinations (i.e. sans radiographs). An additional consideration for this finding is that dentists may chart the same multi-surface restoration differently depending on their perception of the extent of surface involvement (e.g. involving the mesial-occlusal surfaces as opposed to mesial-occlusal-distal surfaces). Variations in the surface involvement of restorations was one of the most commonly encountered inconsistencies between the ante-mortem and post-mortem records (n=9) (Table 1).

Figure 7. A tooth-coloured restoration on tooth #23 (FDI notation) (labelled) of Subject 2 that was initially omitted from the post-mortem record. From L-R: buccal view; incisal view; palatal view



The lack of tactile feedback when viewing the videos compared to performing a traditional post-mortem examination was an obvious disadvantage, as the videos offered a 2-dimensional representation of 3-dimensional structures. Radiographs could have assisted to resolve some of these challenges with charting. However, in this study the lack of radiographs did not hinder positive identifications from being established. Intra-oral videos have an advantage over intra-oral photographs (that are typically taken using mouth mirrors) in that the latter results in reversed images.[10] Therefore, with intra-oral photographs there is the danger that the dentist charting the post-mortem findings may confuse between the upper and lower jaws, and/or the right- and left-hand sides of the mouth.[10]

At this stage, it is not an aim for the authors to prove the superiority of this novel virtual dental autopsy approach (note: another group of researchers have coined the term "forensic tele-odontology"[6]) over a traditional post-mortem examination. However, this teledental approach has proved to be accurate and time-efficient (which were the aims of this study). The video of each individual surface (of which there were six per subject) lasted on average one minute or less and this was sufficient duration to capture the necessary information without inducing motion blur in the video. The average amount of time taken to create the intra-oral videos for each subject by a non-dental staff in this study was comparable with that of an earlier study (which took a dentist who was inexperienced with using that particular model of IOVC 4 minutes).[7] Although the time to interpret the video may be longer than the time taken to perform a visual only post-mortem dental examination, time is significantly saved in other ways, notably travel to the site and/or for the forensic odontologist to take time off his/her clinical schedule.

These are very encouraging results from a pilot study, and offers the promise of: (i) manpower savings, especially during disaster victim identification efforts,[7,12] in jurisdictions with limited number of forensic odontologists to allow them to work remotely, (ii) time savings without the need for the forensic odontologist to travel[7] to the mortuary or disaster site (particularly in remote areas), (iii) the ability to do a second independent examination remotely,[8,12] and (iv) the ability to undertake the dental identification in a relatively sterile environment without exposure to the typical sights, smells, and tactile sensations associated with traditional dental post-mortem examinations.[19] This last point is important because the dentist on the receiving end of these videos and images may not be forensically trained (for example, in jurisdictions without any forensic odontologists), and/or emotionally adept at handling the trauma of mass fatalities. In addition, such a virtual dental autopsy may be less invasive than a traditional post-mortem dental examination,[7] which is especially important for examining friable or fragile remains.[19] Another potential further development from this study, is the printing out of 3D printed models from IOVC images which can later be used, for example, to present in the courts to spare the lawyers, judges, and juries the trauma of viewing photos/videos of deceased persons.

Virtual dental autopsies can also be undertaken using computed tomography (CT) scans[12,26] where the DICOM (Digital Imaging and Communications in Medicine) files obtained from the scans can be shared with forensic odontologists. However, as a means of undertaking virtual dental autopsies, IOVCs possess some significant advantages over CT machines, which include but are not limited to: (i) From a cost-benefit analysis, intra-oral cameras and their associated software typically costs 8.5x to 16x less than a CT scan ecosystem such that resource constrained jurisdictions/settings may not be able to afford a single CT machine. (ii) There is often significant scatter arising from metallic objects (such as amalgam restorations and prostheses) in CT scans (i.e. "metallic artifacts"). (iii) Training is required to interpret and manipulate CT scans. For instance, some skill is required to "convert" CT scans (3-D) to an orthopantomogram (OPG) / dental panoramic tomography (DPT) (which are 2-D). (vi) Intra-oral cameras are safer from an occupational health perspective since they do not produce ionising radiation. (vii) intra-oral cameras are more accessible and familiar for dental staff to operate compared to CT machines; and (vii) intra-oral cameras are much more portable than CT machines, and this would matter in situations where virtual dental autopsies are called for. The main disadvantage of using intra-oral cameras compared to CT scans for undertaking virtual dental autopsy, is that the former is unable to produce radiographs. However, the lack of radiographs in this study did not hinder positive identifications from being established amongst the study population. Therefore, from the perspective of undertaking virtual dental autopsies, intra-oral cameras have considerably more advantages compared to CT scans. However, if a mortuary is able to afford both IOVC and CT machines, then intra-oral cameras and CT scans could be seen as complementary methods for undertaking virtual dental autopsies.

For this proposed virtual dental autopsy method to be functional and operational on a larger scale, the approach must prove itself to be cost-effective, efficient, and accurate. As such, further larger-scale studies involving, for example, multiple dentists and non-dental forensic staff and other IOVC brands and models are required before widespread application of this teledental approach to undertaking remote forensic dental identification. Should this teledental application of virtual dental autopsy be implemented, time and money would need to be invested in training the non-dental staff to gain experience and familiarity with operating IOVCs, and to a certain extent to make an independent assessment of whether the videos and images they had created would be acceptable for forensic dental identification or not. Dentists who are unfamiliar with the principals behind operating IOVCs and manipulating the videos/images would also require some training, but presumably the time to train dentists would be shorter than to train non-dental staff. It is envisioned that man-hour costs incurred in the training would be the main start-up cost for this virtual dental autopsy approach, as intra-oral cameras and their accompanying software are relatively inexpensive and readily available (compared to other digital dental technology) in developed countries.

The strength of this study lies in the novelty in undertaking remote forensic dental identification using intra-oral videos produced by a non-dental staff. The limitations of the study were (i) the inability to take radiographs which would have allowed the authors to resolve four charting differences, and (ii) the relatively small number of subjects, which were sufficient for the purposes of a pilot study but more subjects would be required for further larger-scale testing of this virtual dental autopsy approach.

CONCLUSION

This pilot study has demonstrated that (i) non-dental staff can be trained to operate an IOVC and (ii) this virtual dental autopsy approach holds potential for accurately identifying bodies by forensic odontologists in a location remote from the mortuary. As such, this virtual dental autopsy poses a viable alternative to a traditional post-mortem dental examination when there are time sensitivities and pressures for the reconciliation to be concluded, no or limited number of forensic odontologists available locally, and to minimize exposure to handling human remains for religious[5] and/or mental health reasons. In answer to the research question and pending verification of these findings by larger-scale studies: forensic dentists can undertake dental identifications remotely.

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REFERENCES

1. Thali MJ, Yen K, Schweitzer W, Vock P, Boesch C, Ozdoba C, Schroth G, Ith M, Sonnenschein M, Doernhoefer T, Scheurer E, Plattner T, Dirnhofer R. *Virtopsy, a new imaging horizon in forensic pathology: virtual autopsy by postmortem multislice computed tomography (MSCT) and magnetic resonance imaging (MRI)--a feasibility study. ASTM Journal of Forensic Sciences* 2003;48(2):386-403. https://doi.org/10.1520/JFS2002166
2. Thali MJ, Jackowski C, Oesterhelweg L, Ross SG, Dirnhofer R. *VIRTOPSY - the Swiss virtual autopsy approach. Legal Medicine (Tokyo)* 2007;9(2):100-4. https://doi.org/10.1016/j.legalmed.2006.11.011
3. Matsuda S, Yoshida H, Ebata K, Shimada I, Yoshimura H. *Forensic odontology with digital technologies: A systematic review. Journal of Forensic and Legal Medicine* 2020;74:102004. https://doi.org/10.1016/j.jflm.2020.102004
4. Franco A, Thevissen P, Coudyzer W, Develter W, Van de Voorde W, Oyen R, Vandermeulen D, Jacobs R, Willems G. *Feasibility and validation of virtual autopsy for dental identification using the Interpol dental codes. Journal of Forensic and Legal Medicine* 2013;20(4):248-54. https://doi.org/10.1016/j.jflm.2012.09.021
5. Franco A, Souza PHC, Coudyzer W, Thevissen P, Willems G, Jacobs R. *Virtual autopsy in forensic sciences and its applications in the forensic odontology. Revista Odonto Ciência* 2012;27:5-9. https://doi.org/10.1590/S1980-65232012000100001
6. Sabourin C, Giraudeau N, Baccino E, Camarasa F, Martrille L, Inquimbert C. *Teledentistry and Forensic Odontology: Qualitative Study on the Capacity of Implementation. International Journal of Environmental Research and Public Health* 2023;20(19):6807. https://doi.org/10.3390/ijerph20196807
7. Giraudeau N, Duflos C, Moncayo C, Marin G, Baccino E, Martrille L, Inquimbert C. *Teledentistry and forensic odontology: Cross-sectional observational comparative pilot study. Forensic Science International* 2021;326:110932. https://doi.org/10.1016/j.forsciint.2021.110932
8. Pentapati KC, Siddiq H. *Clinical applications of intraoral camera to increase patient compliance - current perspectives. Clinical, Cosmetic and Investigative Dentistry*. 2019 Aug 23;11:267-278. https://doi.org/10.2147/CCIDE.S192847
9. Hanaoka Y, Tsuzuki T, Yoshida M, Iwahara K, Suyama Y, Matsukubo T, Sato Y, Minaguchi K. *New device for collecting intra-oral findings of unknown body. Bulletin of Tokyo Dental College* 2011;52(3):149-53. http://dx.doi.org/10.2209/tdcpublication.52.149
10. Yoshida M, Hanaoka Y, Tsuzuki T, Ueno A, Takagi T, Iwahara K, Yasuda M, Sato Y, Minaguchi K. *Collection of intraoral findings in corpse with small-scale color dental scanner system. Forensic Science International* 2009;185(1-3):e25-8. https://doi.org/10.1016/j.forsciint.2009.01.004
11. Tsuzuki T, Ueno A, Kajiwara M, Hanaoka Y, Uchiyama H, Agawa Y, Takagi T, Sato Y. *Evaluation of intraoral CCD camera for dental examination in forensic inspection. Legal*

Medicine (Tokyo). 2002;4(1):40-6. https://doi.org/10.1016/S1344-6223(01)00049-9
12. Nuzzolese E. VIRDENTOPSY*: Virtual Dental Autopsy and Remote Forensic Odontology Evaluation. Dentistry Journal (Basel)* 2021;9(9):102. https://doi.org/10.3390/dj9090102
13. Chong GTF. *Teledental Consultations Using a Messaging Application during the COVID-19 Pandemic: Experience from a Singapore COVID-19 Community Care Facility. Proceedings of Singapore Healthcare* 2021;31:20101058211041411. https://doi.org/10.1177/20101058211041411
14. Koonin LM, Hoots B, Tsang CA, Leroy Z, Farris K, Jolly BT, Antall P, McCabe B, Zelis CBR, Tong I, Haris AM. *Trends in the Use of Telehealth During the Emergence of the COVID-19 Pandemic — United States, January–March 2020. Morbidity and Mortality Weekly Report* 2020;69:1595–1599. http://dx.doi.org/10.15585/mmwr.mm6943a3
15. Karande S*, Chong GTF*, Megally H, Parmar D, Taylor GW, Obadan-Udoh EM, Agaku IT. *Changes in dental and medical visits before and during the COVID-19 pandemic among U.S. children aged 1-17 years. Community Dentistry and Oral Epidemiology* 2023;51(3):483-493. https://doi.org/10.1111/cdoe.12806
16. Spivack E. *Teledentistry: remote observation of patients with special needs. General Dentistry* 2020; 68:66-70. PMID: 32348247
17. Estai M, Kruger E, Tennant M, Bunt S, Kanagasignam Y. *Challenges in the uptake of telemedicine in dentistry. Rural and Remote Health* 2016; 16:3915. PMID: 27893947
18. Matsuda S, Yoshimura H. *Possibilities and challenges in digital personal identification using teledentistry based on integration of telecommunication and dental information: a narrative review. Journal of International Medical Research* 2022;50(4):3000605221097370. https://doi.org/10.1177/03000605221097370
19. Vadivel JK. *Virtual autopsy. International Journal of Forensic Odontology* 2016;1:14-6. https://doi.org/10.4103/2542-5013.185694
20. Chong GTF. *Forensic Dental Education and Training in Singapore - An Evolution Over the Past Two Decades. Journal of Forensic Science Education* 2024;6(1).
21. Forgie AH, Pine CM, Pitts NB. *The assessment of an intra-oral video camera as an aid to occlusal caries detection. International Dental Journal* 2003;53(1):3-6. https://doi.org/10.1111/j.1875-595X.2003.tb00648.x
22. Willershausen B, Schlösser E, Ernst C-P. *The intra-oral camera, dental health communication and oral hygiene. International Dental Journal* 1999;49(2):95-100. https://doi.org/10.1111/j.1875-595X.1999.tb00515.x
23. Brüllmann DD, Weichert CID, Daubländer M. *Intraoral cameras as a computer-aided diagnosis tool for root canal orifices. Journal of Dental Education* 2011;75(11):1452-1457. https://doi.org/10.1002/j.0022-0337.2011.75.11.tb05202.x
24. Erten H, Üçtasli MB, Akarslan ZZ, Uzun Ö, Semiz M. *Restorative treatment decision making with unaided visual examination, intraoral camera and operating microscope. Operative Dentistry* 2006;31(1):55-59. https://doi.org/10.2341/04-173
25. American Board of Forensic Odontology (ABFO). *Body Identification Information and Guidelines*. February 2017.
26. Azizah WN, Oscandar F, Damayanti MA. *Systematic review: oral and maxillofacial radiology as fundamental methods of virtual autopsy. Forensic Sciences Research* 2023;8(3):185-197. https://doi.org/10.1093/fsr/owad028