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Dental Hygiene Students' Matching Accuracy When Comparing Antemortem Dental Radiographs and Oral Photographs to Simulated Postmortem WinID3® Odontograms

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ORIGINAL PAPER

Odontology

Dental hygiene students' matching accuracy when comparing antemortem dental radiographs and oral photographs to simulated postmortem WinID3® odontograms

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Abstract

Matching dental antemortem (AM) and postmortem (PM) data for human identification is especially challenging when the workforce is limited. Dental hygienists have served mass fatality incidents (MFIs) due to dental-related expertise. However, forensics within dental hygiene education and research on transferable skills is limited. This qualitative balance design study assessed senior dental hygiene students' match accuracy of simulated cases varying in dental identifiers based on AM full mouth series (FMS) radiographs and oral photographs to PM WinID3® odontograms to demonstrate possible disaster victim identification (DVI) transferable skills gained during formal education. A convenience sample of senior dental hygiene students ($n = 31$) was presented information on WinID3® interpretation, then presented with 5 mismatched cases and asked to visually interpret each to make 10 total matches; five based on AM FMS with simulated PM WinID3® odontograms and five based on AM photographs with PM WinID3® odontograms. Match accuracy scores ranged from 41.9% to 58.1% for cases with 1–10 identifiers, and 77.4% to 93.5% for cases with 11–40 identifiers. Accuracy when matching AM radiographs to PM odontograms versus AM photographs to PM odontograms was compared and revealed no statistical differences in match accuracy depending on image type ($p = 0.388$ to 1.000). Results of this pilot study suggests transferable match accuracy skills resulted from the participants' dental hygiene formal education. These baseline skills with additional specialized training support the rationale for dental hygienists serving on DVI teams. More research is needed in education and practice when preparing dental hygienists for forensic-based service.

KEYWORDS

antemortem and postmortem comparisons, dental hygiene students, dental odontograms, disaster victim identification, forensic odontology, identification match accuracy, mass fatality incidents

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Highlights

- This novel study assessed the transferability of dental hygiene formal education to DVI skills.
- Dental hygiene formal education provides foundational skills applicable to DVI.
- Specially trained dental hygienists are excellent supplemental personnel for DVI teams during MFI.

1 | INTRODUCTION

Comparison of antemortem (AM) and postmortem (PM) forensic dental evidence is heavily relied upon for establishment of human identification and is a multidisciplinary effort during mass fatality incidents (MFIs) [1–3]. Naturally, teeth and surrounding oral structures have characteristic features considered unique enough to be distinguishable from others, but human identification is not limited to naturally occurring features. Distinguishing features are greatly increased due to changes which occur during the lifespan and serve as clinically detectable dental identifiers (CDDI) classed as: restorative treatment, pathology, and morphology; unique features that are useful alone or in combination [4–7]. CDDI can be imaged and documented in AM and PM records via radiographs, photographs, and/or symbols on odontograms for comparative matching [4]. The visualization and presentation of dental evidence must be of good quality—characteristics driven by dental industry standards, radiographer/photographer techniques, and the end user's expectations for legal and scientific integrity [8]. AM dental images and record documentation are primarily produced by dental hygienists in private practice and are of great importance to human identifications. Specially trained dental hygienists may serve as personnel for disaster victim identification (DVI) to collect, organize, and transcribe AM and PM decedent data, and as consultants for the comparison team to support forensic odontologists.

Radiographs are considered the most objective and reliable source of information in an AM dental record for showcasing the diversity of missing, filled, and unrestored patterns among teeth and surrounding structures [6,9,10]. Diagnostic digital dental radiographs are regularly exposed and interpreted by dental hygienists for patients in accordance with the American Dental Association guidelines for patient selection criteria [11,12]. Therefore, many AM dental radiographs are products of dental hygienists' professional expertise regarding proper visualization and presentation, and much of the evidence-based diagnostic conclusions made by dentists are done in consultation with dental hygienists serving as the initial image interpreter. Dental hygienists complete Commission on Dental Accreditation (CODA) educational programs and are eligible for licensure as competent and self-directed in radiation scientific principles, use of radiography equipment, quality assurance, and interpretation of findings [11–13]. Radiography education and practice performed on mounted skulls and live patients are an integral part of laboratory and clinical hours for dental hygiene curriculum [11,14]. Additionally, dental hygiene education includes intensive coursework on head and neck anatomy and tooth morphology; coursework integrated with patient clinical examinations and radiographic interpretations that require recognition, description, and documentation of typical and atypical landmarks and structures for natural and man-made findings [14]. Dental hygienists' educational preparation makes them ideal for assisting PM examinations, exposing dental radiographs on decedents, and for visual discrimination and interpretation of imaged CDDI for the comparative phase when specially trained [2,15–18].

While dental radiographs are considered most critical for image comparisons, oral photographs can also provide visual information from varying views and are best when used in conjunction with other evidence [2,19–23]. Of particular importance, photographs can offer evidence of unique features of anterior teeth especially when patients are undergoing aesthetic improvements and photographed at various stages of cosmetic and orthodontic treatment [2,24–26]. Additionally, conditions such as early erosion, wear, and pathology may be pictorially represented even if not yet detectable on radiographs or difficult to adequately explain in written text [22]. Dental anomalies such as rotated teeth, talon cusp, and cusp of Carabelli can also be useful when pictorially captured, especially in cases with little to no dental restorations [20]. Interpol's guidance on AM collection states dental records should contain photographs of the dentition and of the patient when smiling as this can have a crucial role in cases when AM dental records are otherwise insufficient [27]. Additionally, Bollinger et al concluded human identification can be aided by comparisons of at least three or more teeth in AM and PM photographs, especially when AM images have captured multiple CDDI of both the maxillary and mandibular arches [23].

The "reconciliation" phase of DVI operations may include information from multifactorial assessments including a method known as comparative dental analysis where PM and AM data are objectively compared to determine identities of the decedents; a process often facilitated by the Microsoft Windows based WinID3® software program which can store thousands of cases of transcribed AM and PM dental data with collected images and odontograms [2,3,9,21,28]. DVI comparison teams perform WinID3® sorting and filtering functions to generate a list of possible matching cases for further scrutiny [1,21]. The examiner attempts to rule out unexplained discrepancies between AM and PM data; not to determine whether the two records are 100% identical but to determine whether they are sufficiently similar [28,29]. Comparative identification is informed by use of dental record documentation and software comparisons but is dependent on the ability of the analyzer to visually recognize and discriminate between AM and PM imaged patterns of CDDI within the dental record [4,5,18,21,30]. During DVI, a report regarding findings, recommendations, and conclusions is prepared by the forensic odontology section chief,

and it may be informed by data collection and organization, as well as quality assurance consultation with other DVI team members such as dental hygienists [2,21,31]. WinID3® codes are classed as "primary" or "secondary" to indicate surfaces of a tooth with a restoration [1,2]. For example, a tooth with an amalgam filling on the distal and occlusal, and a resin filling on the mesial and occlusal will have a primary code of "MOD" and shaded black on those surfaces regardless of the restorative material used for the separate restorations; "E" for resin and "S" for silver amalgam will serve as secondary codes noted adjacent to the tooth number. WinID3® primary and secondary coding is considered "midlevel granularity" requiring a moderate amount of time and skill [1]. More simplistic coding systems typically use one code to represent the existence of a restoration (low granularity), while complex, detailed coding systems utilize multiple codes to characterize restorations and the involved tooth surface (high granularity); as detail and granularity increases, the time, skill, and potential for inaccuracies is theorized to also increase [1,6]. For this reason, the simplicity of WinID3® is highly accepted for MFIs especially when varying expertise and experience exist among supplemental personnel [1,2,6]. In dental hygiene formal education and in clinical practice, detailed dental coding systems with complex "high granularity" are typically utilized for AM record keeping purposes [11,14,32]. Though not formally educated on WinID3®, dental hygienists are educated on varying dental charting codes and can receive WinID3® training through standard operation procedures (SOP) which includes terminology, abbreviations, and data entry procedures for the adopted software to familiarize novice personnel [2,21]. Additionally, WinID3® comes with sample cases complete with images for training novice operators [2,30]. It is likely dental hygienists' education and general experience with dental software would be transferrable to WinID3® utilization, especially when provided software training.

Dental hygienists are recognized for their dental expertise and considered "skilled personnel" for MFI DVI with background knowledge that can serve as transferrable skill when supplemented with training [2,17,33,34]. When MFIs occur, specially trained licensed dental hygienists may be tasked with AM and PM data management, as well as comparative phase consultation supervised by a forensic odontologist [2,3,16–18,21,34]. Dental hygiene formal education standards and guidelines encompass the skills of recognizing and discriminating between unique features of dental materials, anatomical features, and pathology during clinical examinations, dental record keeping, and radiographic interpretation [11, 14]. However, despite recommendations [13,15,35–38], forensic odontology is rarely included in dental hygiene formal education, and the scientific literature does not adequately address dental hygienists' ability to perform DVI tasks due to transferrable skills. Therefore, the aim of this study was to assess the ability of senior dental hygiene students to accurately match simulated cases based on AM radiographs and oral photographs to PM WinID3® odontograms as possible transferrable DVI skills gained during formal education. This study also compared participant accuracy when matching AM radiographs to PM odontograms versus AM oral photographs to PM odontograms.

2 | MATERIALS AND METHODS

This study was given exempt approval by Old Dominion University Institutional Review Board (#1716413-3). A qualitative balance design was used to evaluate match accuracy of simulated DVI cases among a convenience sample of 33 senior dental hygiene students from one baccalaureate degree granting institution. Students were recruited via email to view a PowerPoint presentation regarding general information on terminology, interpretation of primary and secondary WinID3® codes, and were provided an example of a correctly matched case which was not used for data collection. Examples of the PowerPoint learning content presented to participants can be found in Figure 1.

Participants signed informed consent then completed a Qualtrics survey with drag and drop features where they were provided a total of 10 cases: 5 mismatched sets of digital AM full mouth series (FMS) radiographs and corresponding WinID3® PM odontograms to indicate match sets, as well as 5 mismatched sets of digital AM intraoral photographs and corresponding WinID3® odontograms to indicate match sets. The AM radiographic and photographic images were collected retrospectively from an educational dental hygiene care clinic where patients sign a release form granting permission for clinical data to be used for research purposes. The AM FMS radiographs were exposed using Schick Elite digital sensors and the AM 5-view sets of intraoral photographs were imaged by a Canon EOS Rebel T6 digital single-lens reflex (SLR) camera with ring flash. Images used in this study were not considered to be of perfect diagnostic quality but were assessed by the researchers and deemed appropriate for research purposes. Selected radiographs and photographs included a variety of CDDI such as missing teeth and restorative treatments (amalgam fillings, resin fillings, crowns, implants, bridges, and root canal therapy); distinguishing features existed from AM images to PM WinID3® odontograms. Five patient records (labeled A-E), each including a FMS and set of five intraoral photographs were selected to serve as AM images for the simulated cases. Researchers created simulated WinID3® PM odontograms for comparison against the AM images. Examples of images and WinID3® odontograms used for the study can be seen in Figure 2. Cases varied in CDDI complexity and were categorized based on the number of restored and missing teeth as having 1–10 identifiers or 11–40 identifiers (Table 1). The presented cases did not include an odd number of "no match" samples. Participant match accuracy per image type was assessed for performance differences between radiographic and photographic matching abilities. A researcher-designed Qualtrics posttest asked Likert scale questions of perceived levels of difficulty, confidence in making matches, and demographics. SPSS software was utilized for statistical analyses, and statistical significance was set at $\alpha = 0.05$.

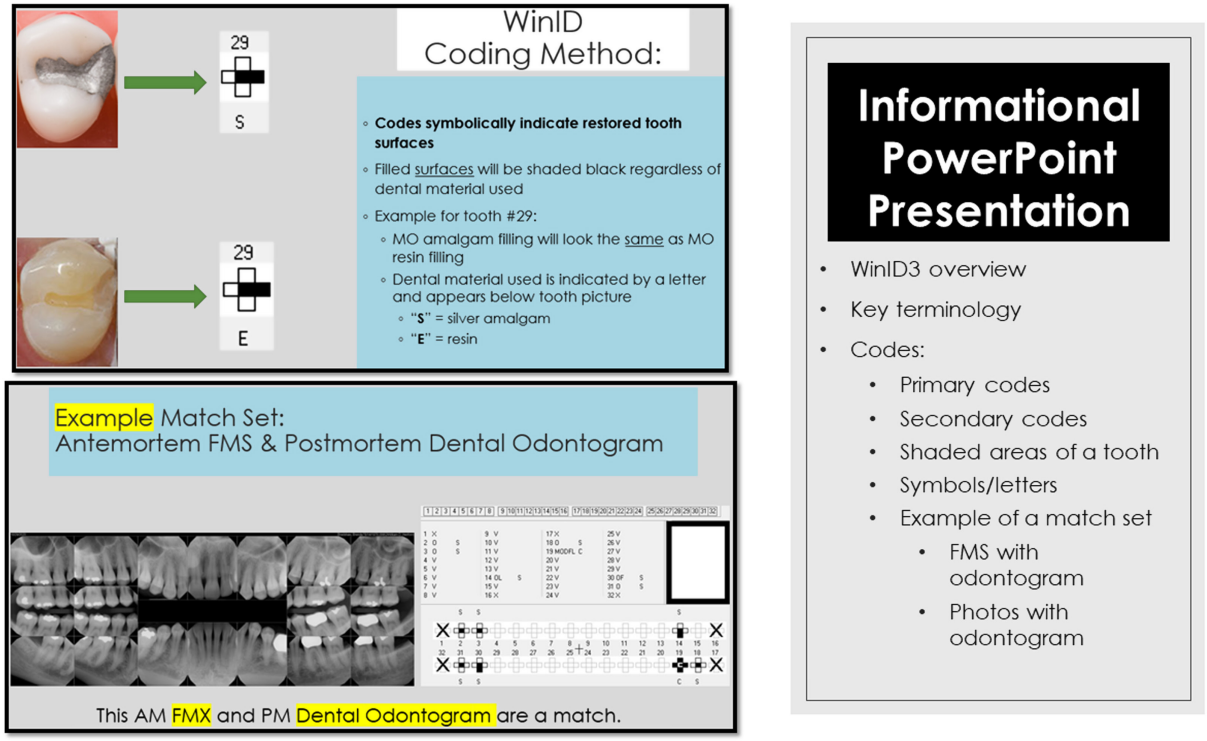

FIGURE 1 Sample learning content from the PowerPoint presented to research participants. [Color figure can be viewed at wileyonlinelibrary.com]

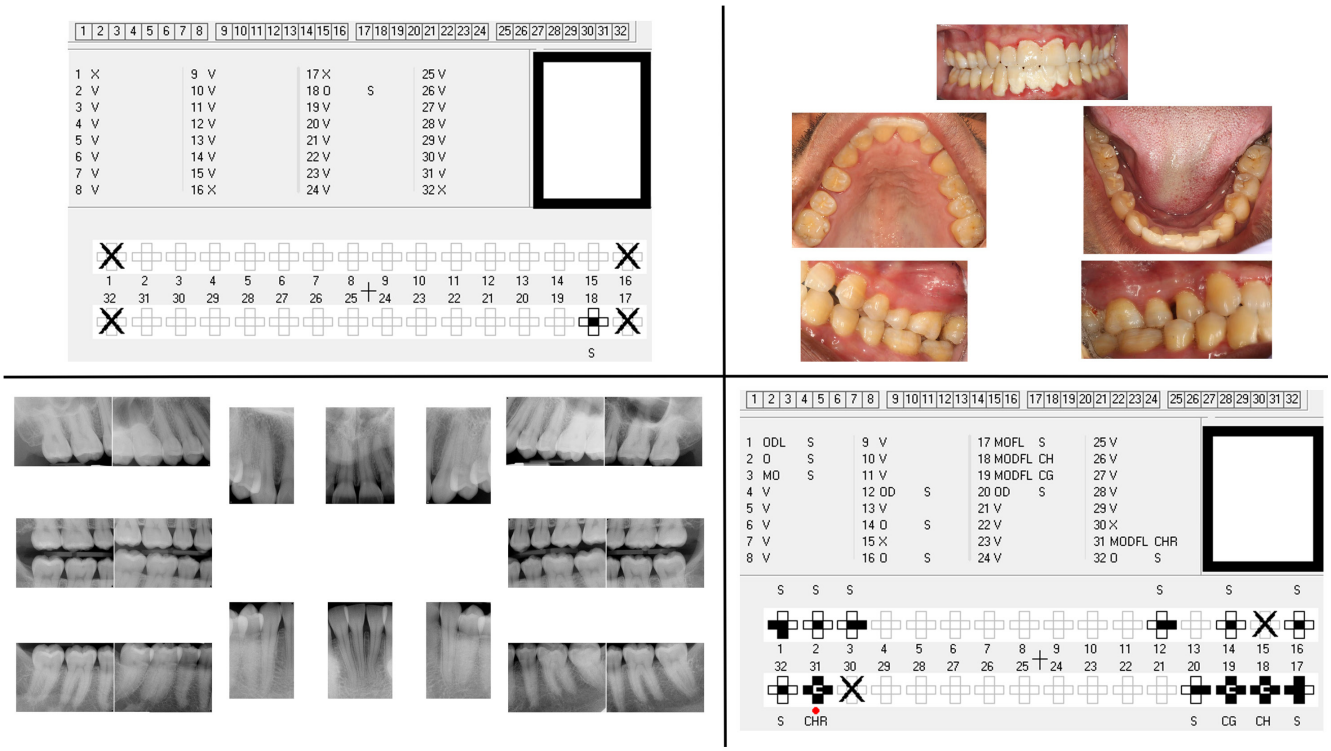

FIGURE 2 Samples of mismatched images and WinID3® odontograms used for the study. [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Quantity of visible CDDI (based on restored and missing teeth) for each case

	Amalgam and/or resin fillings	Crowns	Bridges	Implants	Root canal therapy	Missing teeth	Totals
CDDI in FMS radiographs							
Case A	10	3	0	0	0	2	15
Case B	1	0	0	0	0	2	3
Case C	9	0	0	0	1	1	11
Case D	14	7	2	2	5	10	40
Case E	6	0	0	0	0	4	10
CDDI in oral photographs							
Case A	9	3	0	0	0	[a]	12
Case B	1	0	0	0	0	[a]	1
Case C	9	3	0	0	0	1	13
Case D	10	7	2	0	[a]	[a]	19
Case E	6	0	0	0	0	3	9

[a]Denotes image type, or imaged field does not allow quantity to be determined.

3 | RESULTS

Thirty-one participants completed the research for a completion rate of 93.9%. All participants were female senior dental hygiene students, almost half were Caucasian (n = 15, 48.3%), and the majority were aged 18–29 years (n = 25, 80.6%). Table 2 summarizes research participant demographics. Participant match accuracy for cases A, C, and D with numerous dental identifiers (11–40 CDDI) ranged from M = 93.5 to M = 77.4. Match accuracy declined for cases B and E with fewer dental identifiers (1–10 CDDI) (M = 58.1 to 41.9). Figure 3 shows participant match accuracy trends according to the number of visible CDDI for cases based on the image type. McNemar's chi square revealed no statistical differences in participants' match abilities depending on image type (radiographs vs photographs): p = 0.687 (case A), p = 0.388 (case B), p = 0.625 (case C), p = 1.000 (case D), and p = 0.774 (case E). Most participants (74.2%) indicated photo matching as more challenging compared to radiograph matching despite quantitative findings showing that matching performance was not statistically different depending on image type. Figure 4 shows that most participants (70.9%) indicated experiencing none to slight difficulty when attempting to match radiographs to odontograms, and 87% indicated slight to moderate difficulty when matching photographs to odontograms. When asked about perceived confidence, 93.5% indicated they were moderately confident in correctly matching the cases.

TABLE 2 Research participant demographics

	n	%
Gender		
Female	31	100%
Male	0	0%
Age Range		
18–29	25	80.6%
30–44	5	16.1%
45–59	1	3.2%
Race/Ethnicity		
Caucasian	15	48.3%
African American	7	22.5%
Asian	7	22.5%
Native Hawaiian or Pacific Islander	1	3.2%
Hispanic, Latino, Spanish	1	3.2%

4 | DISCUSSION

In this novel study, senior dental hygiene students were provided a special training presentation to prepare them for use of WinID3® comparisons with AM radiographs and photographs to assess their ability to make identification matches; a task which dental hygienists assist during MFIs. These participants had no prior experience or education in forensics or exposure to WinID3®. However, they were in their final semester of the dental hygiene program, deemed competent with dental radiology including interpretation skills, and were well-versed with a dental record software and charting system of high granularity. Dental coding accuracy and interpretation is central to DVI so cases can be ranked for possible matches. However, the DVI comparison team must visually scrutinize the record against available images to provide consultation with forensic odontologists, so they may prepare a report of findings and recommendations regarding decedent cases. To date, scientific literature lacks research which assesses such DVI skills of licensed dental hygienists and the dental hygiene educational programs they attended. This study is unique in that it assessed senior dental hygiene students who were not yet licensed so their knowledge and skills resulting from formal education could be ascertained without the influence of work

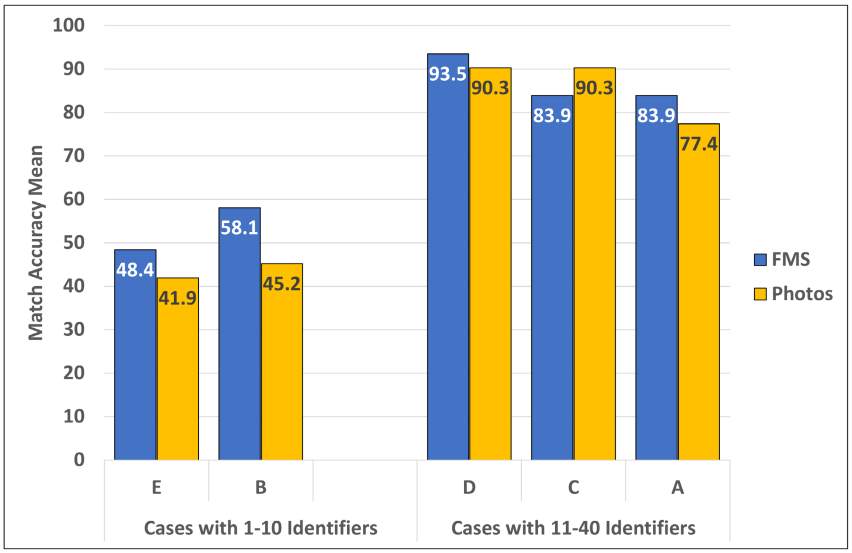

FIGURE 3 Participant match accuracy by visible CDDI per image type. [Color figure can be viewed at wileyonlinelibrary.com]

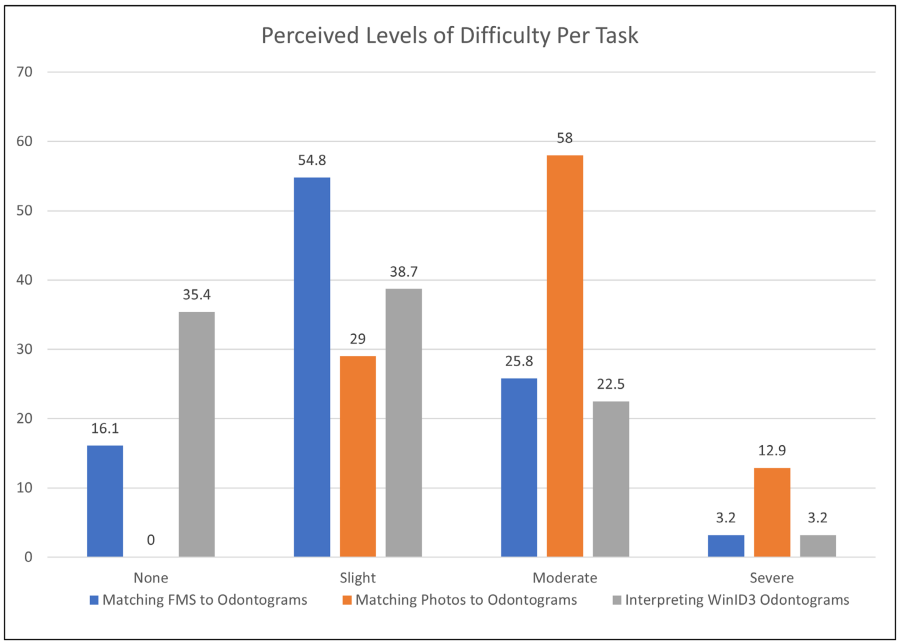

FIGURE 4 Participants' perceived difficulty when deciding on matches and interpreting WinID3® odontograms. [Color figure can be viewed at wileyonlinelibrary.com]

experience that may influence interpretation skills over time. Results of this study suggest dental hygiene graduates are well-positioned to further their education by learning more about forensic odontology to prepare themselves as supportive personnel for DVI teams if needed for such service in the future.

Results revealed the students' education did prepare them with transferrable knowledge and skills and allowed successful completion of the simulated DVI task. Participants collectively performed well with accuracy rates ranging from 93.5% to 83.9% for five matching tasks involving 11–40 CDDI, except one which yielded an accuracy rate of 77.4% based on AM photographs. These accuracy rates are similar to findings reported by Pinchi et al in a study inclusive of 20 senior dental students who matched AM and PM radiographs with accuracy rates ranging from 97% to 89% [39]. Pinchi also reported forensic odontologist participants outperformed the students and demonstrated less inter-operator variability, pointing to reliable expert opinion among the forensic odontologists [39]. Importantly, this research reinforces the need for forensic odontologists to be the ones who make reconciliation recommendations based on dental findings; however, during MFIs it is also important to know the abilities and limitations of supplemental personnel who may assist with DVI comparisons. Results of the current study support this need and suggest dental hygienists can apply competencies from their educational preparation to contribute expertise for visually comparing AM images against PM WinID3® search results to assist in narrowing down the list of possible matches. A similar suggestion

was made by Wenzel et al who assessed matching accuracy of AM and PM bitewing radiographs among 10 dental students and 3 forensic expert controls [30]. Wenzel reported half the students made 1 to 2 false-positive matches, except for one outlier which made 13 false-positive matches, and the 3 experts made no false positives [30]. However, among those same participants (3 DVI experienced experts and 10 novice students), all experts made false-negative matches and all but one student made a false-negative match [30]. Wenzel concluded half the students performed with accuracy comparable to the experts and novice dental experts should be considered for DVI assistance during MFIs due to their demonstrated abilities with pattern recognition while interpreting and comparing AM and PM data [30]. Bradshaw et al assessed dental hygiene students' dental charting of three human skull dentitions and comparisons with bitewing radiographs to determine match accuracy [35]. Participants' dental charting accuracy scores ranged from 91% to 99%, and their accuracy for matching skulls and radiographs was 100% [35].

It is important to note participant accuracy rates in the current study declined for more difficult cases with 1–10 CDDI and ranged from 41.9% to 58.1%. However, declined rates exist for other research studies of match accuracy with little to no CDDI among participants inclusive of dental students, dentists, and various types of forensic experts (odontologists, anthropologists, and radiologists with DVI experience). Gorza et al compared 19 forensic experienced experts and reported that match accuracy rates increased for cases which displayed higher numbers of visual similarities between AM and PM images [40]. Additionally, participants in Gorza's study self-reported their ability to decide on matches was negatively affected when there was insufficient visually distinguishing data in the images to facilitate comparisons [40]. Chaim et al conducted a balance design match accuracy study of dentists and forensic odontologists and reported case difficulty was ensured by reduced rates of accuracy and confidence among participants [10]. Pinchi et al reported case difficulty due to lacking visual identifiers resulted in reduced match accuracy for all participants, still forensic odontologists outperformed others and demonstrated the least amount of variability [39]. Pinchi concluded that only professionals with dental training should participate in radiographic comparisons since they outperformed non-dental trained participants [39]. Considering the need for DVI personnel to be specially trained with demonstrated competence, the current study helps meet this need and addresses a gap in the literature by assessing how well dental hygienists are prepared by their educational programs and identifies additional training needed for them to best serve DVI when MFIs occur. Due to variations of methodology and research participants among the studies mentioned above, it is difficult to synthesize the results and draw consistent conclusions regarding DVI supplemental personnel. However, the concerning need for research regarding DVI personnel qualifications and abilities is often cited in the literature and considering the service of dental hygienists in this role, the current research helps address this need. Additionally, this research supports the First International Forensic Radiology Summit recommendations which recognized the need for research inclusive of multidisciplinary teams and with individuals of minimal direct forensic experience [8].

Furthermore, the combined use of radiographs and photographs to support a forensic investigation is an example of multimodal imaging and was identified as a research priority for forensics [8]. The current study supports these research recommendations by assessing and comparing dental hygiene students' ability to utilize radiographs and photographs to decide on matches. In a study by Agelakopoulos et al., photographs were more effective in narrowing down matches when compared to radiographs [4]. Still, radiographs are critical and commonly part of retrieved AM dental records; when complemented by photographic images, the ability to narrow down matches may be increased considerably [4]. In fact, most DVI software like WinID3® only allows for coding entries of restorations and not morphologic or pathologic features [4]. Unique and naturally occurring morphologic dental identifiers are useful and increasingly more important due to the frequency of people maintaining their dentition with less need for restorative work as a result of preventative dental hygiene care. Therefore, it has been suggested more forensic research should investigate the utility of photographic images due to their ability to best capture dental crown morphology and soft tissue contours compared with radiographs—images which best capture root morphology, maxillofacial bone structures, and restoration contour lines [4]. Future match accuracy studies of licensed dental hygienists should assess their performance with actual DVI cases varying in CDDI presentation.

Interestingly, participants self-reported more perceived challenge (74.2%) and difficulty (87%) when matching cases based on the photographs despite no statistical difference in performance outcomes according to image type. There was also a high frequency (93.5%) of self-reported perceived moderate confidence for overall ability in correctly deciding on matches. This finding is similar to Page et al who reported confidence levels ranging from 90% to 93% in a study of dentists and forensic odontologists in a match accuracy study [41]. It is possible the findings of the current study occurred because the participants received more practice with radiographic interpretations in the education program compared to interpretation of photographs. Their perceptions and confidence may have been influenced by perceived comfort with radiographic interpretations they routinely perform in the educational program, as this has been cited as a type of cognitive bias in forensic odontology studies [42,43]. However, research shows the link between confidence and performance is weak [41,42], and it is uncertain that findings of the current study can be interpreted as being affected by overconfidence. Cognitive bias may not be completely avoidable but should be recognized and mitigation should be in place to minimize the effect during forensic practice and training. Therefore, future studies of practicing and student dental hygienists is needed to assess types of cognitive bias they may be susceptible to when serving as DVI personnel.

There were several limitations of the current study. It has been suggested that DVI match accuracy research results may be impacted by participant cognitive bias. It is possible participants of the current study were affected by the Hawthorne effect and/or observer effect which have been cited in other forensic studies [39,42]. The researchers attempted to control the Hawthorne effect by making it known to participants their responses were not graded and would not affect their position in the dental hygiene program. However, in order to orient participants to the experiment task to be performed, they were told interpreting the images and WinID3® charts may be similar to interpretation techniques they rely on when doing similar tasks for their educational program. This suggestion may have contributed to observer effect cognitive bias by unintendedly suggesting an expected behavior. However, this project did require participants to use prior knowledge to interpret visual symbols on WinID3® odontograms which is not part of their formal education. Research suggests undergraduate educational programs should address cognitive bias related to forensic purposes and mitigation strategies should be implemented to control the effects of potential biases [11,44,45]. Therefore, this research supports the 5th and 8th recommendations from the National Research Council that research is needed on biases of practitioners involved with forensic examinations so mitigation strategies can be devised and implemented as part of standard operating procedures [45]. Additionally, participants consisted of a small convenience sample from one educational institution and therefore the results cannot be generalized to other dental hygiene programs, students, or licensed dental hygienists. Students of any discipline should not be part of DVIs; however, the current study helps fill a gap in the literature to define transferable skills as a result of formal education. Finally, images provided to the research participants were limited and not totally representative of what they may encounter during actual DVI. For example, only screen shots of the WinID3® odontograms were provided which created a limited view and restricted access to functionality features built into the software. Additionally, the photographs and radiographs were presented in Qualtrics, an electronic survey data collection tool also utilized by Chaim et al. [31]. Qualtrics allowed images to be magnified; however, the magnification was limited and did not allow full screen magnification which can be achieved in most dental image software including the software these participants were accustomed to using in the dental hygiene educational program. Furthermore, this simulated study utilized FMS radiographs and comprehensive intraoral photographs which are not always available in AM dental records and is not necessarily representative of all DVIs.

Dental hygiene students demonstrated general success in matching AM images with simulated PM WinID3® odontograms, suggesting their educational program prepared them with transferrable DVI skills. However, forensic odontology educational opportunities are not readily available in dental hygiene formal education, and little is known about the transferability of their skills to assist forensic odontologists during actual DVI events. While much research has been performed to validate the uniqueness of dental radiographs, oral photographs, and charting for human identification purposes, this study is innovative due to its focus on assessing the ability of dental hygiene students to accurately match AM and PM data. More research is needed in education and practice when preparing dental hygienists for forensic-based service.

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