

Evaluation of dental expertise with intra-oral peri-apical view radiographs for forensic identification

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Abstract


Background: Identification of a dead person is important in starting the investigation into the circumstances of death. In the absence of forensic odontologist, it is vital that general dentists are able to compare the ante mortem-post mortem (AM-PM) records and with their ability, correctly interpret the individuality of the person. **Aims:** This study was carried out to find out the accuracy with which undergraduate, graduate and post-graduate dentists can do this comparison, using the simulated AM-PM intra-oral peri-apical (IOPA) view radiographs. **Setting and Design:** A total of 60 investigators of which 20 undergraduate students, 20 general dentists, 20 post-graduate dentists viewed 10 pairs of simulated AM and PM radiographs and recorded their findings. **Materials and Methods:** Ten pairs of simulated AM-PM IOPA view radiographs were given to 60 dentists to investigate their discriminatory potential for dental identification purposes. The results were statistically analyzed. **Statistical Analysis:** χ^2 -test and Mann-Whitney *U*-test were carried out to compare the sensitivity, specificity and accuracy of the three types of examiners (UG, G, PG). **Results:** The results showed sensitivity of 59.8%, specificity of 62.6%, accuracy of 61% for undergraduate students, sensitivity of 86.6%, specificity of 87.5%, accuracy of 87% for graduate doctors, sensitivity of 89.3%, specificity of 92.3% and accuracy of 90.5% for post-graduate doctors respectively. **Conclusion:** Inexperienced investigators in forensic identification showed fairly acceptable results, therefore, introduction of forensic odontology in an undergraduate course may help general dentists to provide better service, if required, in the absence of a forensic odontologist.

Key words: Concordant points, dental identification, forensic odontology, forensic science, intra-oral peri-apical view radiographs

Introduction

The positive identification of a living or deceased person using unique traits and characteristics of teeth and jaws

is a corner stone of forensic science.^[1] Forensic science refers to areas of endeavor that can be used in a judicial setting and accepted by the court and the general scientific community to separate truth from untruth.^[2] Forensic odontology is one of the specialties of forensic science in which forensic identification has become one of the most successful means of identifying a person. There are various methods of identification of a person such as visual, personal effects, finger print analysis, deoxyribonucleic acid (DNA) analysis, etc., however, most of these methods fail when the body is highly decomposed. Forensic odontologists are employed in cases of severe head and neck trauma, gross decomposition, burning and other peri-mortem assaults and despite the

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advent of biomolecular identification techniques they continue to be called upon by medical examiners, coroners and investigative agencies to provide valuable services.^[3]

Dental radiographs are considered the most important data because they are widely available, objective and reveal details not visible to the naked eye, such as hidden fillings, root shape, endodontic instruments and alveolar bone morphology. Their utility in identification has been well-established.^[4] The aim of comparison of dental radiographs is to examine features of the same jaw section, single tooth or even a tooth surface for concordance between ante mortem (AM) and post mortem (PM) data.^[3] The comparison of AM and PM radiographs is widely accepted as a fundamental method in forensic identification. It can produce results with a high degree of reliability with relative simplicity. Intra-oral radiographs comprise of a very solid basis for the identification of an individual. They are not only taken to record primary findings, but also to check therapeutic procedures and to document the final outcome. Keiser-Nielsen (1980) recommended that the restored tooth surface as depicted in the odontogram be regarded as the smallest “unit” to consider in the dental restorations for identification purposes.^[5] They are constantly and also often abundantly present in the dental records. The most common radiograph retained in the dental record is the intra-oral peri-apical (IOPA) view.

At present, there are three types of personnel identification circumstances that use the teeth, jaws and or facial characteristics for identification. They are: Comparative dental identification, reconstructive PM dental profiling and DNA profiling.^[1] Comparative dental identification is one of the most commonly employed method. Studies have attempted to validate radiographic dental identification. However, these studies had a critical limitation: They had not examined whether dentists experience and training level affect their diagnostic accuracy. Instead they had focused on the effects of various case attributes, such as extended time elapsed between AM and PM radiographs or the presence of subsequent restorations not present on AM films. While this focus is also important, the variability in human judgments is a critical factor that had not been adequately studied.^[4]

One report states that forensic odontology cannot be carried out by dentists without proper training, but in disaster of a large scale where there are thousands of fatalities, non-specialists also participate in the identification process.^[6] Therefore, the question of whether differences in dentists training or experience (e.g. forensic fellowship, number of actual cases, years of practice) affect their subsequent accuracy on dental identifications remains largely unanswered.

Aim

This study assessed the expertise of undergraduate, graduate and post-graduate dentists for comparative dental identification using IOPA view radiographs.

Materials and Methods

A total of 60 examiners consisting of 20 undergraduate dental students, 20 graduate dentists and 20 post-graduate dentists were made to examine 10 sets of non-standardized simulated AM and PM IOPA view radiographs. The undergraduate dentists were interns of a dental school, the graduate dentists had worked in various departments of a dental school for 10 years and the specialists consisted of two periodontists, three endodontists, two prosthodontists, two pedodontists, four oral- and maxilla-facial surgeons, two oral pathologists, two orthodontists and three oral- and maxillo-facial radiologists.

Out of the 10 pairs of radiographs, 6 pairs were from the same individuals, which were taken during treatment or during the follow-up period for various dental treatments. These constituted the true positive (TP). The other four pairs of radiographs were from different individuals from matching sites in the jaw. These constituted the true negative (TN). The interval between the first radiograph (labeled as AM) and the last radiograph (labeled as PM) ranged between 10 and 20 months. All the radiographs were of adult patients with some dental treatment done. The radiographs were non-standardized and had been taken using E-speed dental radiographic film (Eastman Kodak Company, Rochester, NY, USA) in the various departments of dental school. The dental X-ray machine operated at 65 Kvp and 10 mAmp. The investigators were asked to report in a tabular column whether the given sets match or do not match. The reports were subjected to 4-way contingency table as previously studied by Maclean *et al.*^[7] in 1994 as:

- The correct choice reported by the investigators in the matched radiographs was marked as TP
- An incorrect decision by the investigators rejecting a match was marked as false negative (FN)
- The correct choice reported by the investigators in the unmatched radiograph was marked as TN
- An incorrect choice by the investigators of unmatched pair was marked as FN.

Statistical methods

The following were calculated:

Sensitivity of the test or TP rate is determined as the measure of the observer’s ability to correctly choose the matched pair. This was calculated as:

$$\text{Sensitivity} = \text{TP} / (\text{TP} + \text{FN})$$

Specificity of the test or TN rate is determined as a measure of the observer’s ability to correctly detect non-matched pairs or unmatched pairs. This was calculated as:

$$\text{Specificity} = \text{TN} / (\text{TN} + \text{FP})$$

Accuracy of the test combines the sensitivity and the specificity and gives an overall success of the test. This was calculated as:

$$\text{Accuracy} = \frac{TP + TN}{TP + FN + TP + FP}$$

Results

All the 60 examiners completed the identification test, which consisted of 10 pairs of simulated AM-PM IOPA view radiographs. As shown in Table 1, the results support the hypothesis: Less clinical experience in dental practice predicts poor performance in undergraduate group.

The results showed sensitivity of 59.8%, specificity of 62.6%, accuracy of 61% for undergraduate students, sensitivity of 86.6%, specificity of 87.5%, accuracy of 87% for graduate doctors, sensitivity of 89.3%, specificity of 92.3% and accuracy of 90.5% for post-graduate doctors.

The results were statistically analyzed and tabulated. Table 2 shows the sensitivity, specificity and accuracy for the three groups and it clearly shows that post-graduate dentists outperformed other groups.

The performance of undergraduate students was inferior to graduate and post-graduate dentists whereas magnitude between graduate and post-graduate was quite small. The expected gradual improvement in accuracy, sensitivity and specificity, from undergraduate dental students to experienced post-graduate dentists was confirmed [Table 3].

Table 4 reports the co-relation between clinical experience and rates of TP, TN, FP, FN for each operator groups. Tables 5a and b show pairwise comparison to test the significance of difference in mean scores for sensitivity, specificity and accuracy using *t*-test.

Discussion

In this study, for comparative dental identification, the radiographs were taken using no extra precaution but routine radiographs of a dental clinic, which were non-standardized radiographs because in countries like India, dental visits are made only when there is a problem and these appointments may be separated by considerable time lapses. IOPA view radiographs are taken using non-standardized techniques by the dentist. Sometimes the dentist is not traceable or does not have the record or the record may be misfiled, or degraded due to poor processing. In PM situations, the same site may have been destroyed beyond recognition and radiograph may be of no help then.

The present study results provide clear evidence that different levels of training, experience and practice affiliation among dentists correlate significantly with

Table 1: The sensitivity, specificity and accuracy of the three groups

Measure	Undergraduate	Graduate	Post-graduate
Sensitivity	59.8	86.6	89.3
Specificity	62.6	87.5	92.3
Accuracy	61	87	90.5

Table 2: Mean ± standard deviation and range for sensitivity, specificity and accuracy in different types of students (undergraduate, graduate, post-graduate)

Measure	Undergraduate	Graduate	Post-graduate
Sensitivity	59.83 ± 19.60	86.67 ± 13.89	89.52 ± 13.12
	33.33-100.00	66.67-100.00	66.67-100
Specificity	63.75 ± 24.97	87.50-15.17	92.08 ± 12.53
	0.00-100.00	50.00-100.00	66.67-100
Accuracy	61.00 ± 15.18	87.00 ± 12.61	90.5 ± 9.45
	30.00-90.00	60.00-100.00	70.00-100.00

Mean scores and the range for sensitivity, specificity and accuracy values given in Table 2 show that the performance of undergraduate students was inferior to graduate and post-graduate students whereas magnitude of difference between graduate and post-graduate was quite small

their identification accuracy. The participants with a high level of training were significantly more accurate in their identification diagnosis when compared with participants with low training levels. Some examples of the previous research include MacLean^[7] and subsequently Kogon,^[8] who both studied the effect of variable elapsed time between AM and PM radiographs upon identification accuracy. Each study included only three participants, ranging in expertise from a dental student to a trained forensic dentist. Because there was only one participant at each experience level, these studies were unable to statistically assess the effects of differential training and experience upon the identification results. Borrman^[9] tested the accuracy of seven participants (six oral radiologists and one forensic dentist) upon both simple and more complex dental identifications. She found that some participants performed more poorly on the complicated cases, but she did not identify or analyze her data upon participants' experience levels. Ekstrom^[10] in a study had 17 forensic odontologists who analyzed 31 simulated forensic cases. However, the authors did not analyze the performance of the poor and good performing odontologists in relation to measures of their experience or training.

It is important that these tests yield high TP and TN decisions and low false positive decisions. FN is less critical since these would be subjected to further analysis by other means that can lead to correct identification. The most critical observation is probably the false positive record as this gives certainty to the evidence that mislead to the wrong conclusion. It is very unfortunate since in the real situation this means that the deceased is identified and returned to the bereaved family. Specialist training may secure a low number of matching errors. Previous studies have shown

Table 3: The mean and standard deviation of sensitivity, specificity and accuracy for the three groups

	Sensitivity			Specificity			Accuracy		
	V11 (undergraduate)	V21 (graduate)	V31 (post-graduate)	V12 (undergraduate)	V22 (graduate)	V32 (post-graduate)	V13 (undergraduate)	V23 (graduate)	V33 (post-graduate)
1	66.67	66.67	100	75	100	100	70	80	100
2	50	66.67	83.33	50	75	100	50	70	90
3	50	66.67	100	100	75	75	70	70	90
4	83.333	83.33	83.33	75	75	75	80	80	80
5	50	100	83.33	100	100	100	70	100	90
6	100	66.67	66.67	50	100	75	80	80	70
7	33.33	83.33	83.33	75	75	100	50	80	90
8	66.67	83.33	66.67	75	75	100	70	80	80
9	50	83.33	66.67	50	100	100	50	90	80
10	33.33	83.33	100	25	75	100	30	80	100
11	50	83.33	100	75	75	100	60	80	100
12	33.33	100	100	50	100	100	40	100	100
13	50	66.67	100	100	50	75	70	60	90
14	66.67	100	100	50	100	75	60	100	90
15	80	100	71.43	0	100	100	40	100	80
16	50	100	100	75	100	100	60	100	100
17	100	100	100	75	75	100	90	90	100
18	50	100	100	50	100	100	50	100	100
19	66.67	100	100	50	100	100	60	100	100
20	66.67	100	85.71	75	100	66.6667	70	100	80
Mean	59.83333	86.6667	89.5238	63.75	87.5	92.0833	61	87	90.5
Standard deviation	19.60054302	13.8918	13.1186	24.96708359	15.1744	12.5292	15.18309309	12.6074	9.44513
P (1, 2)	1.34831E-05			0.000819287			8.0122E-07		
t (1, 2)	4.995053027			3.635354125			5.891817505		
P (1, 3)	1.83365E-06			5.59093E-05			7.61801E-09		
t (1, 3)	5.629711536			4.535986733			7.378034355		
P (2, 3)	0.507707668			0.304175682			0.326694632		
t (2, 3)	0.668733855			1.041607282			0.993616956		

Table 4: Distribution of testing results (TP, TN, FP, FN) amongst different types of students (undergraduate, graduate, post-graduate)

Testing of result	Type of student		
	Undergraduate	Graduate	Post-graduate
TP	70 (35.00)	104 (52.00)	109 (54.50)
TN	52 (26.00)	70 (35.00)	72 (36.00)
FP	31 (15.50)	10 (5.00)	6 (3.00)
FN	47 (23.50)	16 (8.00)	13 (6.50)

Figures in brackets are percentages. χ^2 (6 df)=64.28; $P<0.001$, χ^2 -test was applied to test if the distribution was similar in different types of students (examiners undergraduate/graduate/post-graduate). The calculated value of χ^2 was 64.28 with six degrees of freedom ($P<0.001$); which indicated highly significant difference in distribution of test results in different types of examiners. A perusal of percentage values given in the above table shows that for undergraduate the percentage for TP and TN was less as compared to graduate and post-graduate examiners whereas reverse was the trend for FP and FN which were having higher percentage for undergraduate examiners as compared with graduate or post-graduate examiners. TP: True positive; TN: True negative; FN: False negative; FP: False positive

that a forensic specialist made fewer false positive matches than a general dentist and a dental student.^[7,8] In this study, it was 15.5% for undergraduate students, 5% for graduate

Table 5a: Pairwise comparison to test the significance of difference in mean scores for sensitivity, specificity and accuracy using t-test

Measure	Comparison between		
	Undergraduate and graduate	Undergraduate and post-graduate	Graduate and post-graduate
Sensitivity	t=4.995 P=0.00001348	t=5.630 P=0.00000183	t=0.669 P=0.50770767
Specificity	t=3.635 P=0.00081929	t=4.536 P=0.00005591	t=0.994 P=0.32669463

Highly significant difference in mean scores for sensitivity, specificity and accuracy were observed between undergraduate and graduate and still higher difference between undergraduate and post-graduate. Undergraduate students scored significantly less as compared to graduate and post-graduate. Though post-graduate students scored higher than graduate students for all the measures, i.e., sensitivity, specificity and accuracy but the difference in mean scores was statistically non-significant between graduate and post-graduate. Similar results were obtained when differences were tested using Mann-Whitney U-test (a non-parametric test) and are summarized in the following table

doctors and 3% for post-graduate doctors in a record of 200 comparisons. This is partially due to the fact that a choice to make "Not sure" was not given to the evaluators due to

Table 5b: Pairwise comparisons to test the significance of difference for sensitivity, specificity and accuracy, using Mann-Whitney U-test

Measure	Comparison between		
	Undergraduate and graduate (%)	Undergraduate and post-graduate (%)	Graduate and post-graduate
Sensitivity	Significant at 5	Significant at 5	Non-significant
Specificity	Significant at 5	Significant at 5	Non-significant
Accuracy	Significant at 5	Significant at 5	Non-significant

Combining the results of *t*-test and Mann-Whitney *U*-test, it can be concluded that undergraduate students performed significantly inferior as compared to graduate and post-graduate examiners for all the measures, i.e., sensitivity, specificity and accuracy whereas difference between graduate and post-graduate doctors was non-significant for these measures

insufficient and ambiguous points, to simplify calculation and to arrive at the sensitivity, specificity and accuracy. Moreover, the dentists who examined the radiographs did not have any exposure to forensic training. Hence, their knowledge in the criticality of false positive was limited. These are the reasons for elevated False Positive choices in this study, especially for the undergraduate students. A study by Pinchi *et al.* (2012) found that undergraduate students gave a false positive result of 5%, dentists 1% and dentists with formal training in forensic odontology without any experience 3% and forensic odontologists 0% respectively.

Early studies by MacLean *et al.*^[7] and Balagopal^[11] showed accuracy of 81.6% and 93% respectively. Borrman and Grondahl in the year 1990 found that 83.3% of examiners successfully matched the radiographs, in which simple amalgam restorations were done.^[9] Sholl attempted to relate the training and experience of odontologists to their accuracy in forensic identification. He examined the relative identification performance of nine dental hygienists, nine dental students and nine forensic odontologists. He stated that the odontologists group performed best and the subgroup of odontologists with the most forensic experience performed even better. However, he did not support the conclusion with any numerical analysis.^[12] In this preliminary study conducted before arranging training in forensic odontology for a group of practicing dentists, the accuracy was 61% for undergraduate students, 87% for graduate doctors and 90.5% for post-graduate doctors. In this study, the investigators were made to give their observations independently. They were not allowed to interact and discuss their observations, which could have produced better results. It was also observed that the false observations that were made by the different investigators were not always constant for any set of radiographs. Thus, considering the inexperience of the investigators in forensic examination, not given the choice to select "Not Sure," the observation that the false choices were not always constant and not allowed to discuss their observations, the value appears to be acceptable. In real life, all these which were prohibited, are permissible. Further collaboration

and consultation between investigators can improve the accuracy in identification as inconsistent false choices were observed by different investigators.

Dentists are respected as a source of valuable data that can be used to answer questions that arise during a death investigation.^[13] It has been shown that operators with dental training are considerably more accurate than those with a medical degree, despite the latter's experience in radiodiagnosis or forensic sciences.^[14] By imparting training of general dentists in forensic examination and reporting, they can substantiate the work of coroners, medical examiners and detectives, all for a great societal cause.

Conclusion

This study provides evidence that identification of individuals by comparison of AM-PM radiographs requires a high degree of ability. Within the constraints of this study, the results of IOPA view radiograph comparison appears fairly useful. The results presented that the specialists performed better than the undergraduates students. The low accuracy rates of undergraduate students suggests that they should be taught to compare and report simulated AM-PM radiographs so that their knowledge of dental materials and oro-facial anatomy can be used to interpret correctly various points and features. With the introduction of such a subject, general dentists may be able to provide valuable evidences for identification from even a single IOPA radiograph, especially in mass disasters. Further studies have to be conducted with longer simulated AM-PM interval, more volume of data and radiographs from different kinds of insults and injuries to the sites, etc., for more reliability and to strengthen the information from this study.

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