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Validation of Dental Radiographs for Human Identification

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ABSTRACT: Visual comparison of dental bitewing radiographs in simulated forensic identification, using observers of varying degrees of experience and radiographs with a range of time intervals from one to fifteen years showed an accuracy of 93%.

KEYWORDS: odontology, forensic dentistry, human identification, bitewing radiography, validation

Forensic use of radiography soon followed the announcement of the discovery of X-rays and general approval of the method was well established by the 1940s. A court challenge initiated a validation study of visual comparison of chest radiographs in 1977 [*1*], although a validation study of matching skull radiographs was reported in 1953 [*2*]. A similar test of the bitewing radiograph (BW) was published in 1990 [*3*].

The comparison of antemortem and postmortem radiographs is widely accepted as a fundamental method in forensic dental identification. Since intraoral dental radiographs are an essential diagnostic and treatment aid in dental practice, they are a component of most patients' dental records. The BW, a non-screen film used to detect interproximal dental caries, is the most commonly taken radiograph. The object to film distance is negligible and repeated films display minimal distortion. Fine details of anatomy, disease and dental treatments can be recorded accurately over time.

Dental identification relies heavily on the disclosure of antemortem treatment in the comparison process. Until recently, most dental restorative materials were metallic and appeared radiodense. The location, shape and unique characteristics of each restoration could be compared with great accuracy when one examines antemortem and postmortem films. Metallic restorations and other intracoronal techniques such as retentive pins, endodontic posts, cements and obturation materials contribute a wealth of fine discriminatory features which supports the use of dental radiographs in dental identification.

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During the past two decades, there has been a significant decrease in the caries rate in most countries [*4,5*]. The obvious result of this improvement in oral health will be an increase in the number of intact, unrestored dentitions in children and young adults. When forensic dentists are called upon to identify members of this age group, they are often confronted with antemortem and postmortem dental radiographs, which lack the unique metallic restorations that were often the significant feature used to establish identity. In addition, during this period there has been an increase in the use of less durable, relatively radiolucent materials. While these were commonplace in anterior dental restorations, they are now becoming more frequent in posterior restorative dentistry where they appear on the BW. Therefore, the problem of fewer carious lesions is compounded by the decreased use of metallic restorative materials.

For a variety of reasons, police and dentists may be unable to locate the most recent radiographs. Therefore, comparisons often are attempted on pairs of films where a substantial amount of time has elapsed between the time when the antemortem film was made and the time of death. During this period, teeth may have been lost due to normal development, disease or trauma. New restorations may have been placed and other degenerative changes may have occurred. The value of dental radiographs in these situations has not been tested scientifically.

Only one study has attempted to validate the accuracy of BW in making forensic identifications. Borrman and Gröndahl [*3*] reported that in some cases, positive identifications were unable to be made in BW without dental restorations. The sample size was small and the results were not subjected to statistical analysis.

Forensic dentists have traditionally relied heavily on the points of agreement between antemortem and postmortem intraoral radiographs. This confidence has been based on empirical observations and historical precedence. Although there is little doubt that the continued use of these films in forensic identification is appropriate, it is fitting that a scientific foundation is laid to support not only the use of this technique but also to help define its limitations. This comparison study evaluated a large sample of BW pairs separated over a range of fifteen years of patients with minimal dental disease and limited treatment. Sensitivity and specificity statistics were obtained to assist in assessing the accuracy of the test.

Materials and Methods

The sample consisted of 560 BW selected from a large number exposed by the same dentist over a thirty year period. Initially, radiographs of intact, unrestored dentitions were selected. The yield was minimal in the adult population but there was a substantial number from teenage patients who had grown up during the years when the local water supply was fluoridated. Radiographs of restored teeth were accepted only if the presence of the restorations did not help the identification process.

BW examinations of the same patient over varying time spans were used to construct the matched pairs of simulated antemortem/postmortem radiographs. In total, 83 individuals made up the 140 matched pairs of BW. The unmatched group was selected with similar criteria but with radiographs from different patients, forming 140 unmatched pairs of BW. In the matched pairs, 60% of the radiographs were of unrestored permanent dentitions in both the antemortem and the simulated postmortem radiograph; in the unmatched, this figure was 46%.

The matched sample consisted of radiographs taken at intervals of one to fifteen years. Other than obvious discrepancies in dental age, no attempt was made to correctly match the antemortem and postmortem chronological ages of the unmatched group. As would be the case in a real forensic identification, radiographs which were not technically perfect

were allowed in the sample; severe beam angulation errors were also permitted if the faults were similar in both radiographs.

The pairs of radiographs were mounted in modified opaque paperboard mounts (Rinn Corporation #10-0156). Each antemortem radiograph was placed in the upper window and labelled with the patient's initials and the date it was exposed. Each postmortem radiograph was placed in the lower window and labelled with the date it was exposed. Both the matched and unmatched pairs of radiographs were randomly mixed in a box in preparation for the observers.

Three observers were used in the BW comparison; two experienced dentists and a senior year dental student. One of the dentists had considerable experience in forensic dentistry. Throughout the comparison phase, the observers were blinded to the identity of the two groups. Each observer worked independently, visually comparing and physically separating the mixed sample into two groups.

Viewing was not to be done if the observer was overtired and all comparisons were done using a radiographic viewer in a darkened room with extraneous light masked out. A 4× magnifying glass was available for use. Before beginning the task, both verbal and written instructions were given to the observers. The following features were suggested to assist identification; shape and size of crowns, outline of cusp and fossa anatomy, shape of pulp chambers, divergence or proximity of the roots of multi-rooted teeth, patterns of alveolar bone trabeculae, embrasure shapes and the alignment of adjacent roots, crests of alveolar bone, and the occlusal relationship of the maxillary and mandibular teeth.

Two sealed boxes were provided as receptacles for the paired radiographs. One was labelled MATCHED, the other was labelled UNMATCHED. A slot in the top of each box allowed the film mounts to be entered but not retrieved. The observers were forced to make only two choices: either the antemortem and postmortem radiographs were of the same person, that is, a matched pair; or they were not of the same person, an unmatched pair. If unsure, they were to return that pair to the mixed sample and continue with other randomly selected cases but eventually separating all 280 pairs into two groups.

Statistical Methods

The calculation of the sample size was based on the estimated proportion of incorrect matches to be 10%. Borrman and Gröndahl reported this error rate (2/20) in the matching of pairs of BW of teeth having no restorations [*3*]. For a 95% confidence interval, the sample size was calculated to be 140 for each group.

Sensitivity and specificity were used to analyze the data generated by the observers [*6*]. Sensitivity, also known as the true positive rate, is a measure of the observer's ability to correctly choose the matched radiographs. The correct choice in the matched radiographs is a true positive (TP). An incorrect decision, rejecting a match, in the matched group is a false negative (FN). Specificity, also known as the true negative rate, is a measure of the observer's ability to correctly detect unmatched radiographs. The correct choice in the unmatched category is a true negative (TN). An incorrect choice in the unmatched group is a false positive (FP). Sensitivity = TP / (TP + FN). Specificity = TN / (FP + TN). Accuracy is the proportion of all test results that are correct. Accuracy = (TP + TN) / (TP + TN + FN + FP).

Results

The sensitivity, specificity and overall accuracy of the observers is recorded in Table 1. Observer number three is the dentist with experience in forensic odontology. Although his true positive rate was lower than the other observers, his specificity was the highest; he had two false positive errors compared to four and eight false positive errors by the other

TABLE 1—*Accuracy of comparison of matched and non-matched BW radiographs.*

Observer	Sensitivity	Specificity	Accuracy
1	.97	.97	
2	.99	.94	.93
3	.71	.99	

observers. None of the false positive errors were common to any observer and there was only minimal repeat of the false negative errors (4/46).

The validity of BW comparisons of matched pairs over time is shown in Fig. 1. It is not feasible to show a similar graph for the unmatched group since the time lapse would be artificially constructed.

Discussion

The extensive availability of BW radiographs and the detail that they convey have established this dental record as one of the most valuable aids to postmortem antemortem comparison. These films are taken at all ages and are often repeated at regular intervals. Although there appears to be no published data, BW are very likely the most frequently used radiograph in dental identification. Their value in dental identification has neither been questioned nor supported by scientific validation.

A recent study by Borrman and Gröndahl used a relatively small number of antemortem and postmortem BW radiographs drawn from groups where the treatment complexity varied from no dental restorations to extensive restorations such as bridges and endodontic treatment. Although the authors present no statistical analysis, it is apparent that some of the examiners had difficulty making correct matches in two of the groups.

Using a somewhat different method, our results indicate that examiners with a range of clinical and radiologic experience can make matches of antemortem and postmortem BW of non-restored or minimally restored teeth with a high degree of sensitivity, specificity and accuracy. Our artificial test differs from an actual forensic experience where often some clues to identity are available and examiners usually make identifications from a

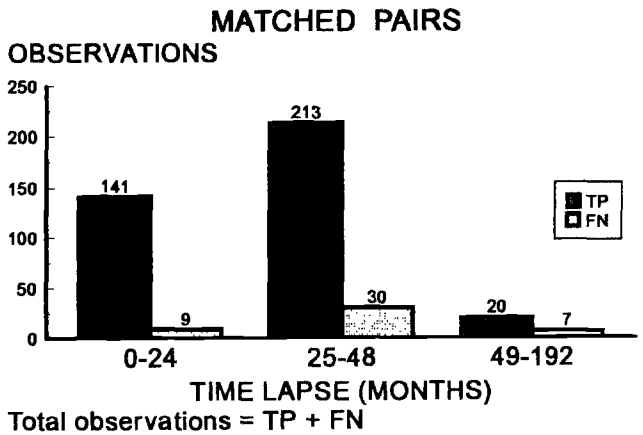

FIG. 1—*True positive (TP) and false negative (FN) results at various time intervals.*

limited pool. The chief problem in deriving statistical data from real forensic identifications is that the truth may not be known. In this test, the truth was known and each of the observer's decisions were made devoid of any hints of identity other than the radiographic features. However, even in a mass disaster, where comparisons of multiple antemortem and postmortem radiographs are required, for each comparison the decision for primary dental identification is match or non-match. The observers in our study did not have an opportunity to arrive at a consensus. Since the false negative and false positive errors were not generally consistent, it seems likely that if a consensus or consultative method was employed, as would happen in the field, the sensitivity, specificity and accuracy might be higher.

Although it is a fundamental requirement of forensic identification that a test yield extremely high true positive and true negative decisions, it is also important that the test does not produce a high proportion of false positive identifications. False negatives are the less critical error since there is an opportunity to retest or use alternative methods to lead to a correct identification. It is apparent that the observer, who had extensive experience in forensic odontology, took this factor into consideration. Some common features in the erroneous decisions were: restorations not helpful to the identification but obscuring normal anatomy; deviation from ideal beam angulation; time between radiographs greater than 10 years; and the presence of deciduous dentition in the antemortem radiograph, which resulted in few common teeth to compare.

The presence of deciduous teeth in a majority of the antemortem radiographs in the false negative decisions, raises the possibility that deciduous teeth compound the errors of identification by their physical changes and early loss. The changing positions of erupting permanent teeth makes positive identification of these cases difficult. When confronting these, the experienced forensic dentist took a more conservative position by protecting against false positive results.

BW are often made at intervals between 6 months and a few years, but radiographs available for identification may be separated by many years. In some cases, normal development has resulted in the loss of deciduous teeth, perhaps with characteristic restorations. The permanent successors may not have been visible on the antemortem radiograph or may not have obvious anatomic characteristics that could be used to support a firm opinion. Our results appear to indicate that there is a very high rate of true positive observations even when there has been a substantial time lapse between the antemortem and the postmortem radiographs.

This study demonstrates that BW are a valid tool for forensic identification. Although the prevalence of unique metallic restorations is decreasing, this radiograph often contains enough anatomic characteristics to be a highly useful comparative tool. It is of some interest that even a relatively inexperienced observer was able to make matches and non-matches with a high degree of accuracy. This study made no attempt to distinguish which feature or groups of features was most significant in decision making. As well, the number of radiographs in the sample at time intervals greater than four years was insufficient to comment on the effect of long time lapses on accurate identification.

Conclusion

Using a stringent test, observers of varying experience were able to identify matched and unmatched bitewing radiographs in a simulated forensic identification with an accuracy of 93%. The observer with forensic experience made the fewest critical errors. Considering the improvement in dental health observed over the last two decades, BW of individuals with no or few restorations will become more commonplace and the continued use of these radiographs for identification can be supported.

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