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Department of Oral Sciences
University of Otago
Dunedin
New Zealand
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EDITORIAL

> *"For example, forensic odontology might not be sufficiently grounded in science to be admissible under Daubert, but this discipline might be able to reliably exclude a suspect thereby enabling law enforcement to focus its efforts on other suspects"*
>
> *Strengthening Forensic Sciences in the United States: A Path Forward. National Academies of Science, 2009.*

With these words our profession is being sidelined.

The idea that forensic odontology is a useful and reliable forensic science has been around for a long time, and I suspect that most dental practitioners and academics would accept it as a fundamental method that truly defines how dental techniques and procedures may be employed to identify the dead, to analyse bitemarks and to evaluate non-accidental injury to the craniofacial region. There are now a number of scientists working in this field and, together with numerous published case reports, the literature supporting forensic odontology is maturing. However, as the quote above signals, our profession has come under severe scrutiny by no less a body of scientific research than the National Academy of Sciences (NAS).

The NAS document stresses that while some forensic techniques, such as DNA analysis, rest on solid bodies of research, others have been developed heuristically; in other words, rest on observation and experience rather than experiments designed to test reliability of such methods. Forensic odontology, they assert, is one of the latter. However, the testimony of forensic dental experts continues to provide the basis for conviction of accused parties in criminal cases. What this means is that in order for us to keep on providing reliable expert evidence, and in order for us to ensure that innocent persons are not convicted of crimes they did not commit, we need to return to the forensic odontological laboratory.

Typically, our experiments should be conducted over a large range of conditions, to ensure that the roles of confounding factors can be understood. Our studies need to be methodologically sound, so as to provide the statistical power needed to draw inferences at a high level of confidence. This will in turn allow for the clear description of limitations of current methods as well as the validation of new methods to determine their accuracy and reliability under different conditions.

So the NAS has asked us to think about the relevance of forensic odontology in the context of developing an understanding of our own strengths and weaknesses and what we have to achieve to ensure our position as a modern scientific method that meets the standards of admissible evidence. We are particularly challenged to think about measurement error rates, peer review and sources of bias. Whether we are sidelined or not, clearly rests upon our researchers and the continued publication of our results in peer reviewed journals such as the Journal of Forensic Odontostomatology.

Jules Kieser

DOES THE QUALITY OF DENTAL IMAGES DEPEND UPON PATIENT'S AGE AND SEX? – EXPLANATIONS FROM THE FORENSIC SCIENCES

B. Gelbrich[1,2], G. Gelbrich[2], R. Lessig[3]

[1]Department of Orthodontics, University of Leipzig, Leipzig, Germany
[2]Coordination Center for Clinical Trials, University of Leipzig, Leipzig, Germany
[3]Institute of Legal Medicine, University of Leipzig, Leipzig, Germany

ABSTRACT

The objective of this analysis was to investigate the dependency of image quality of dental panoramic radiographs on patient's age and sex, and to demonstrate that forensic science can explain these relationships. The image qualities of 100 dental panoramic radiographs obtained from 50 patients with two devices were assessed by ten independent observers of different specialisations. Image quality decreased with increasing age of the patients (P=0.003). One of the devices turned out to be superior to the other; however, this difference between the devices was present only in older patients but not in young ones (P=0.03). Image quality was higher in women than in men (P=0.01). The observed influences of age and sex are explained by results of forensic investigations concerning age-related changes of the dental pulp and sex differences of the skull geometry. Thus forensic science can elucidate effects relevant for everyday clinical practice. Studies on dental image quality must consider age and sex of the patients.

(J Forensic Odontostomatol 2009;27:1:2-11)

Keywords: forensic odontostomatology, age estimation, sex differences, dental panoramic radiography, image quality

INTRODUCTION

X-ray imaging became generally available to dental practitioners in the past few decades and is widely used. Numerous investigations on image quality in dental radiography have been carried out in order to compare, for example, several devices, different operational modes of devices, the effects caused by varying radiation doses, and various techniques of image processing. The possibility that dental image quality as a matter of principle might be related to age and sex of the patients was mentioned years ago.[1] However, a data based examination of this issue has never been presented so far.

The data we deal with were originally collected for a comparison of two imaging devices. However, the scope of the analysis presented herein is to demonstrate that the image quality of panoramic radiographs depends on age and sex of the patients by using empirical data. Results of forensic investigations concerning the estimation of age and sex provide plausible explanations for these phenomena. The consequences for forensic and radiological practice and investigations will be discussed.

According to the intention of this paper, a review of the image quality literature will not be presented here. The reader who is not familiar with the matter may refer, for example, to Dannewitz et al[2] in order to see a typical study on image quality and to get a link to further references.

MATERIALS AND METHODS

Radiography devices

Radiographic images were obtained by using Orthophos Plus Ceph®*, programme P1, with Lanex Regular Screens† for image output, and Veraviewepocs®‡, programme P1, with output on Grenex HR-12 Super HR-S 30 screens§. These two devices will

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* Sirona Dental Systems GmbH, Bensheim, Germany
† Kodak, Rochester, NY, USA
‡ J. Morita MFG Corp., Kyoto, Japan
§ Fuji, Kanagawa, Japan

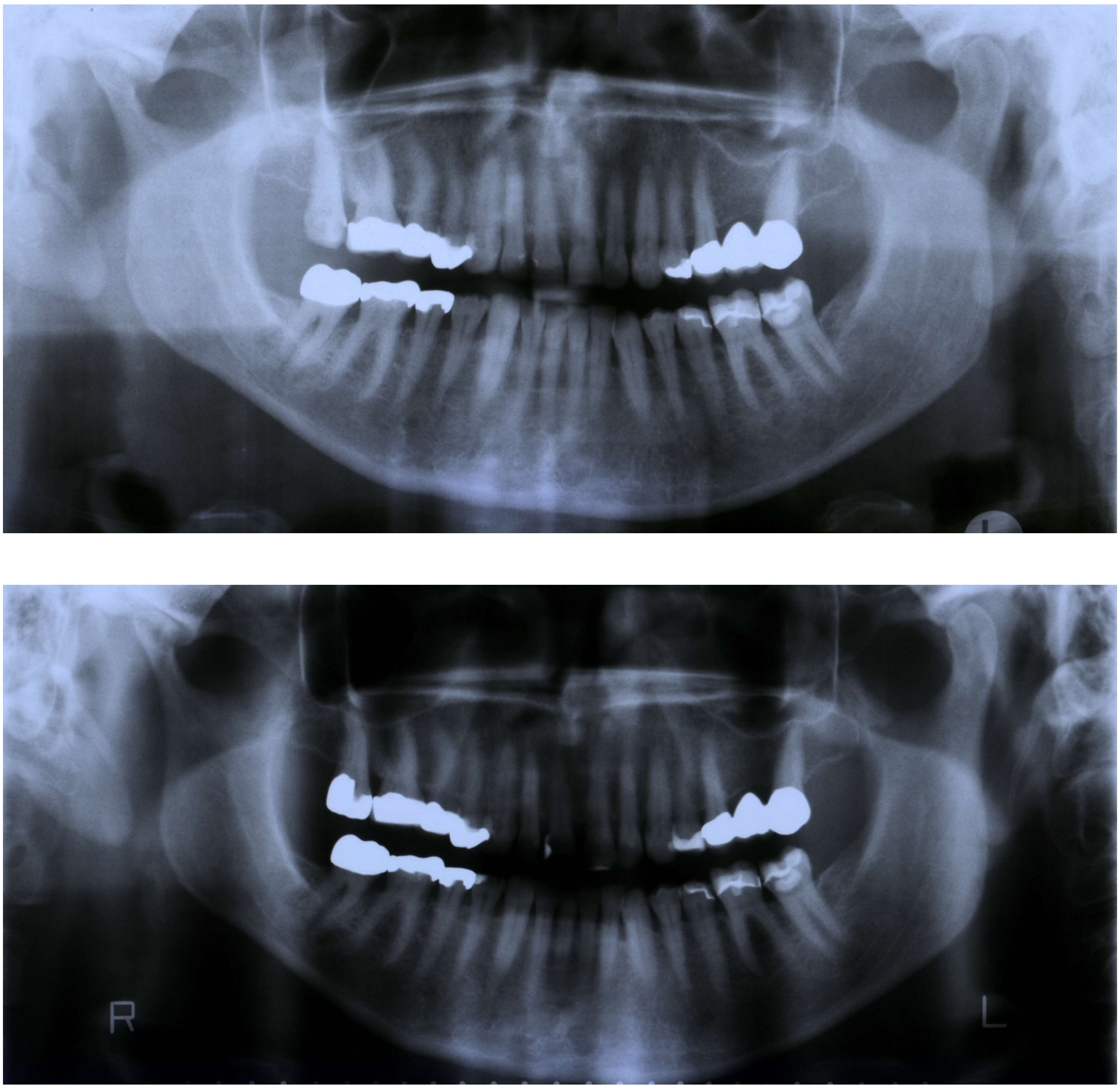

Fig.1: *Panoramic images of the same patient obtained with OPC (upper panel) and VVE (lower panel).*

be referred to as OPC and VVE, respectively, in the following. VVE was working with lower exposure to radiation than OPC (time 8.2 vs. 14.1 seconds, respectively, at similar tube current and voltage). For all radiographs taken with both techniques the same developer solution and device was used. Figure 1 shows panoramic images of the same patient obtained by both devices.

Subjects

Radiographs of 50 patients (27 male, 23 female) aged 17-75 years were included in the study by screening their files for the presence of two consecutive panoramic images, one obtained with OPC and one with VVE. Exclusion criteria were any missing teeth that were subject to assessment in this study, or major treatment of such teeth in the time between the dates of the two radiographs, as well as concomitant diseases associated with significantly impaired bone mineral density (e.g. osteoporosis). As the study was retrospective, and no clinical or identity data of the patients were processed, a vote of the ethics committee was not necessary according to German legal requirements.

Assessment of images

All 100 images were presented to ten observers of different specialisations (dental radiologists, oral and maxillofacial

Table 1: *Landmarks included in the assessment of image quality and their grouping into anatomical regions.*

Anatomical region	**Items subject to assessment**
Dentoalveolar region	Root canal
	Periodontal ligament space
	Periapical region
	Crown and Filling
	each assessed for first incisors, first premolars and first molars
Maxilla	Anterior nasal spine
	Nasal septum
	Maxillary sinus
	Floor of maxillary sinus
	Maxillary tuberosity
Mandible	Condylar process
	Coronoid process
	Mandibular canal
	Mental foramen
	Inferior cortex

surgeons, orthodontists, dental practitioners, students of dental medicine) in random order. Information regarding the radiographic device used and patients' data, in particular age and sex, were blinded. The Planilux LJS 75x44 AP/HER screen** was used for presentation. Each observer assessed the image quality by separate ratings of each of the anatomical details listed in Table 1. The possible ratings were the following five levels: 100 = excellent, 75 = good, 50 = moderate, 25 = poor but still usable, 0 = inadequate for clinical use.

Statistical analysis

Total image quality was computed as the average of all particular ratings across the ten observers and the 42 items assessed on each image. This overall score was computed for each patient and both OPC and VVE images. Furthermore, regional image qualities were computed for each of the dentoalveolar, maxillary and mandibulary regions by averaging only over ratings concerning items of the respective region (see Table 1). Because image quality scores were averages of multiple particular ratings, they could be treated as continuous variables, so parametric methods were used. Normality was examined using the Shapiro-Wilk test. Agreement of observers was described by the intra-class correlation coefficient (ICC). Repeated measurement analysis of covariance was applied to assess the dependency of image quality on age (covariate), sex (between-subject factor) and device (OPC or VVE, within-subject factor). The particular relationships of age and sex to the image qualities in the three anatomical regions were investigated using Pearson’s correlation coefficient. Parameter estimates are accompanied by 95% confidence intervals (CI) and P-values for the test of the null hypothesis that the respective parameter is zero. P-values less than 0.05 were considered significant. All

** F. Schulte GmbH, Germany

statistical analyses were carried out using SPSS 14††.

RESULTS

The overall image qualities on a scale from 0 to 100 were ranging from 47.9 to 70.7 (OPC, median 57.1, interquartile range 53.1 to 61.0) and from 41.6 to 67.3 (VVE, median 52.7, interquartile range 49.7 to 55.7). Normality of the image quality scores was accepted (P=0.60 for OPC, P=0.89 for VVE). Inter-observer agreement was high (ICC=0.92, 95% CI: 0.85 to 0.95, for OPC and ICC=0.85, 95% CI: 0.79 to 0.91, for VVE).

Relationship between image quality and age and sex

The relationships between image quality, age and sex of the patients, and imaging device are displayed in Figure 2.

There are two kinds of relationship between age and image quality. First, image quality decreased with higher age of the patient, regardless of patient's sex and of the imaging device. This is illustrated by the negative slopes of all regression lines. For each ten years of age, average image quality was reduced by 1.0 point (95% CI: 0.6 to 1.7, P=0.003). In terms of analysis of covariance, this is called the main effect of age.

Second, Figure 2 suggests that the scoring is better for OPC images than for VVE images, since the regression lines for OPC (dashed) are above the lines for VVE (solid) for both sexes. The magnitude of this superiority was depending on age, illustrated by the lines drifting apart from each other when seen from the left to the right. In statistical language, this is called the age-by-device interaction. The mean difference between the devices increased by 1.1 points per decade (95% CI: 0.1 to 2.1, P=0.03). Consequently, the superiority of OPC over VVE should be expressed as a linear function of age rather than by a single quantity. For example, the estimates for difference between the devices was 1.8 points (95% CI: –1.6 to 4.9, P=0.22) for patients aged 20 years, but 6.9 points (95% CI: 4.2 to 9.6, P<0.001) for patients aged 65 years.

Another observation is that women had higher ratings than men. This is illustrated by the fact that for each of the devices the regression lines for women (Fig.2, right panel) lie above the corresponding lines for men (left panel). The mean difference between sexes was 2.8 points (95% CI: 0.6 to 5.0, P=0.01). This influence of sex on image quality was present independently of age and device, as there was no significant interaction of sex with age (P=0.74) or device (P=0.65).

Age, sex and device explained 33% of the variance of overall image quality.

Differences between the anatomical regions

The results of pairwise correlation analysis of age and sex with image quality in the three anatomical regions are summarised in Figure 3. For comparison, correlations with total image quality are included. Note that the P-values of the latter differ slightly from those of the analysis of covariance results mentioned above, since they were computed from pairwise correlation.

From the upper panel (Fig.3) it can be seen that the main effect of age as described above is attributable to the dentoalveolar region since only the quality score for this region was significantly correlated with age. The correlation of age with the overall score was lower than with the dentoalveolar score alone. Thus, in terms of statistics, averaging over all three regions somewhat obliterates the essential information on age hidden in the dentoalveolar region.

In contrast, the detailed analysis of the age-by-device interaction effect shows another pattern (Fig.3, middle panel). The correlation of age with the difference between the devices (OPC minus VVE image quality) was not significant in all three anatomic regions. However, the correlation coefficients were similar (0.23, 0.21 and 0.26, respectively), and averaging over the regions resulted in a significant correlation of age with the total score. This pattern is typical for the statistical scenario that each of several components (scoring of the three regions) contains a small piece of the same type of information. Averaging over all components accumulates this information, leading to stronger correlation

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†† SPSS Inc., Chicago, IL, USA

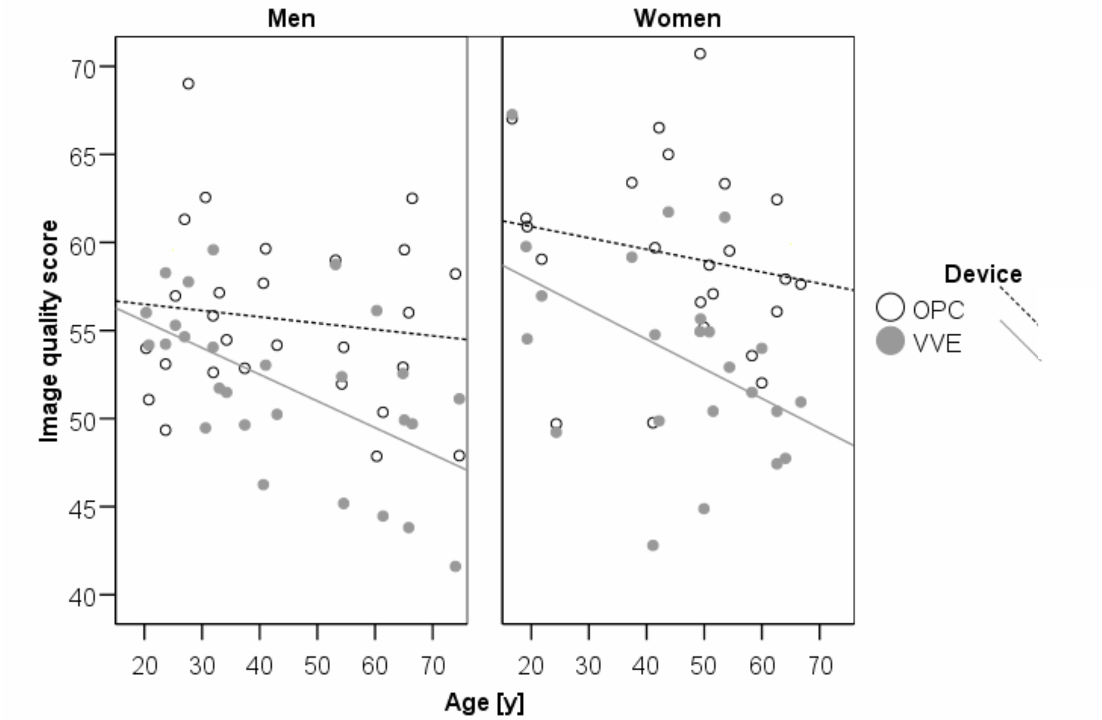

Fig.2: *Overall quality of the panoramic radiographic images depending on age, sex and device. Each circle corresponds to one image. Regression lines were computed separately for both images and both sexes.*

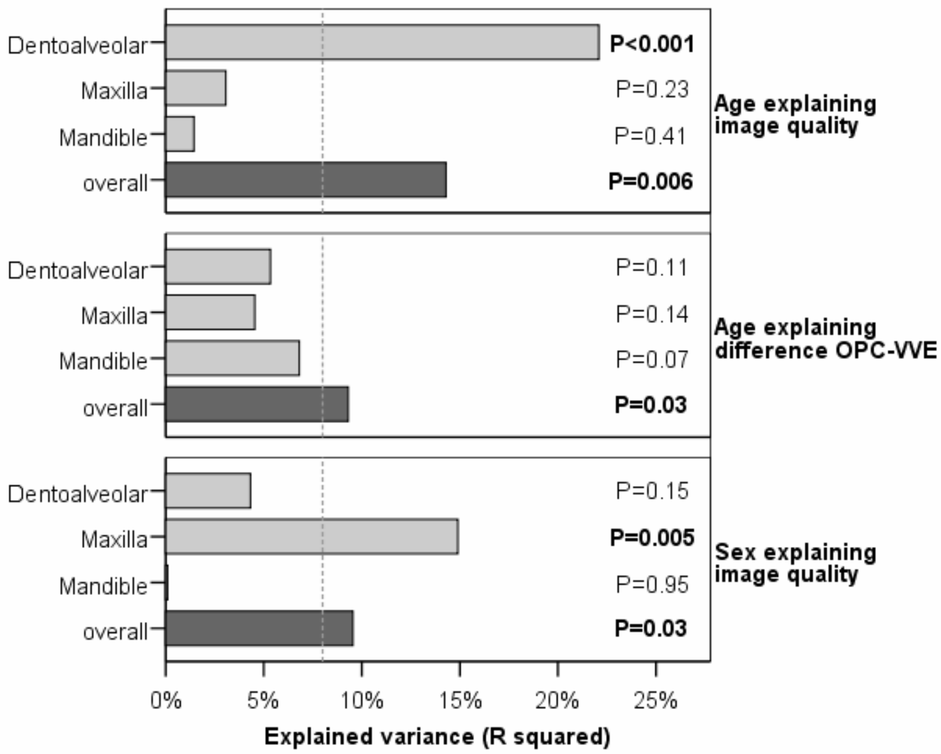

Fig.3: *Variances of image quality explained by age (upper panel), the age-by-device interaction (middle panel), and sex (lower panel) in the three anatomical regions and overall.*

and thereby, higher explained variance and higher statistical significance.

The situation for the effect of sex is similar like for the main effect of age, with the difference that the essential information is now contained in the maxillary region (Fig.3, lower panel). While the relationship of sex to the quality scoring of maxillary items was considerable, no meaningful correlation was found for the dentoalveolar and mandibular regions. Again, averaging over all regions resulted in lower explained variance and weaker significance for the overall image quality, compared to the scoring for the maxillary region alone.

DISCUSSION

We demonstrated that subjectively assessed image quality of dental panoramic radiographs depends upon age and sex of the patients. Such findings in empirical data are presented for the first time. We should therefore, first, exclude that findings were misled by significant bias in the data, and second, explain the results. According to the correlation pattern (Fig.3), these explanations should be based on facts solely related to dentoalveolar structures for the main age effect and to the maxilla for the effect of sex. On the other hand, the dependency of the difference between the devices upon age should be explained by arguments which are not associated with a specific region.

Discussion of potential bias

Due to the design of data collection, there was a time lapse between the two images obtained from each patient, ranging from few days to 4 years, on average 2 years. In regard of the loss of image quality with increasing age estimated to be 1.1 scale points per decade, the time lapse may be expected to be associated with an average change of image quality by 0.22 scale points. This quantity is small compared to the effects presented in the results section, hence the resulting bias is modest (if present at all). Indeed, when we performed our computations again with adjustment for the putative time lapse bias, the results were not altered. We conclude that the influence of the time lapse can be neglected.

Explanations of the results

We first look for an explanation why higher age is associated with lower image quality. It is known that secondary dentin causes a narrowing of the dental pulp.[3] This effect is stronger in the elderly[4] and so it has been used to establish formulas for forensic age estimation.[5-7] The same phenomenon which plays an important role in forensic science seems to be responsible for the correlation of age with image quality. Narrowing of the pulp lowers its recognisability, thus it is plausible why the corresponding ratings for image quality are worse. If this would be the right argument, only ratings for this particular item but not the ratings for other anatomical structures unrelated to the pulp should depend upon age. Indeed, the analysis illustrated in Figure 3 shows that a significant correlation with age is present only in the dentoalveolar region, but not in the maxillary and mandibular bone structures. Going more into detail, we found that the quality ratings related to all pulps under examination contributed the main part of this correlation, while the ratings for crowns and fillings were not at all correlated with age. In addition, regressive changes occuring along with ageing, e.g. microvascular calcification, may have caused that the periodontal ligament spaces and the periapical regions may appear somewhat blurred and cloudy on the images. This will, of course, contribute to lower quality ratings, but the correlations between age and the ratings for the respective structures were of minor extend. After all, narrowing of the pulps used in forensic age estimation turned out to be the key explanation for the relationship between age and subjective image quality. An illustration of the effects discussed here is given in Figure 4.

Now we deal with the age-by-device interaction, i.e. with the question why lowering of image quality in elderly was stronger with the VVE than with the OPC device. Decline of bone mineral content and density is a further phenomenon correlated with age,[8,9] and changes in bone tissue texture may affect image quality. It seems plausible that X-ray image quality is only marginally lowered by declining bone mineral content or density when using a sufficient dose of radiation

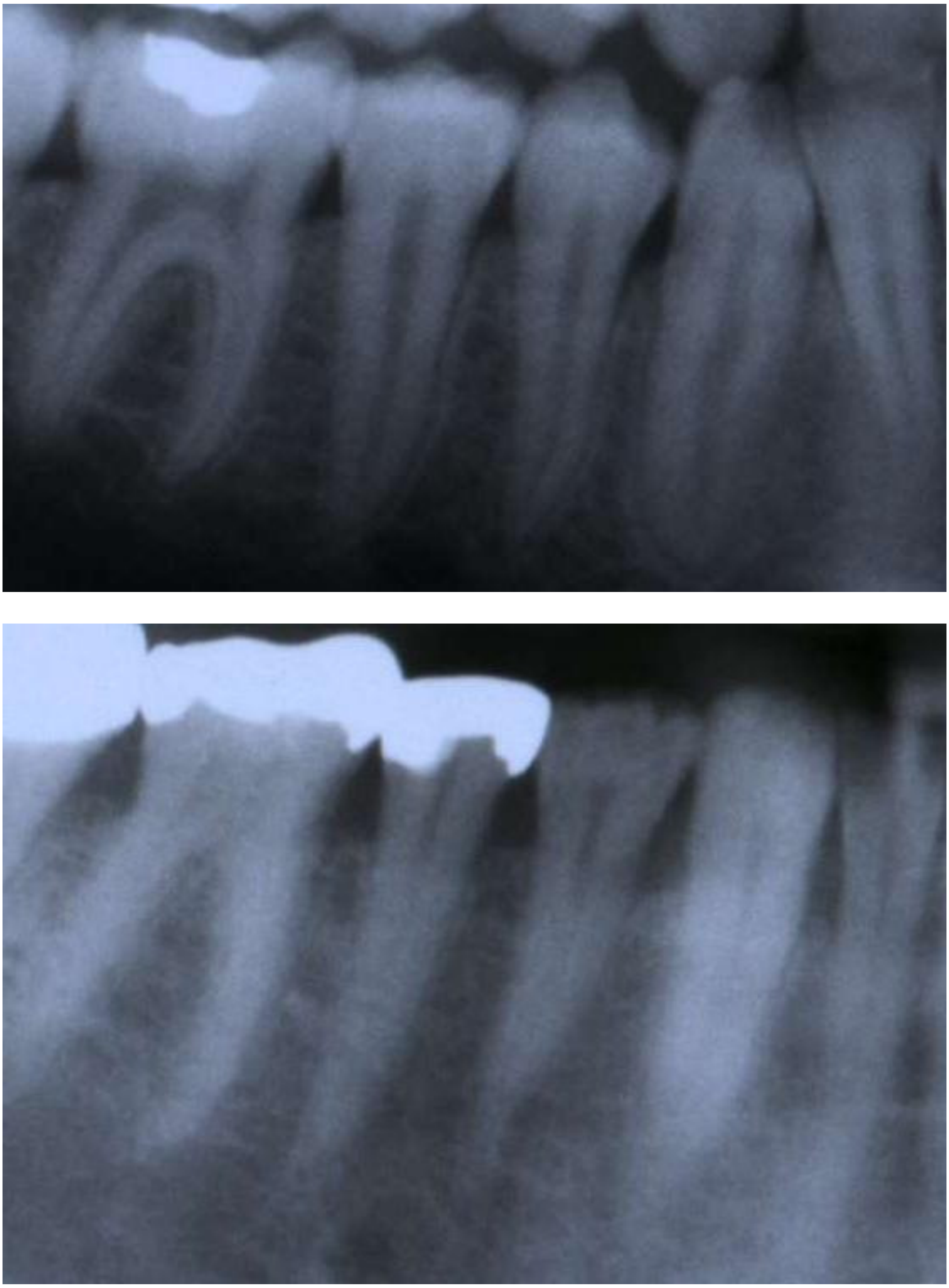

Fig.4: *Regio 42 through 46 in the panoramic images of two female patients of different ages: 18 years (upper panel) and 58 years (lower panel). Both images were obtained with OPC. Narrowing of the pulps and microvascular calcification in the older subject makes it more difficult to recognise the dentoalveolar structures.*

like done with OPC. By contrast, image quality may be more affected when a reduced radiation dose is applied like done with VVE. This is exactly what we observed in our data (Fig.2). Moreover, loss of bone mineral content concerns basically all, not particular, bone structures, thus its influence (if present at all) should be seen in all anatomical regions we considered. This matches our results as the age-by-device interaction was not a region-specific effect (Fig.3, middle panel). Note that decline of bone mineral density is not so closely correlated with age as are other age-related anatomical changes, so it does not provide reliable information in forensic age estimation. Again, this is consistent with our observation: the variance of image quality in the dentoalveolar region explained by the age was much higher than the variance of image quality explained by the age-by-device interaction (see Fig.3).

Finally, we should examine the possible reason why women and men differ in their panoramic image qualities. Recall that in a panoramic imaging device the X-ray tube and the screen are flexible parts which move around the patient's head fixed in the centre of the device (Fig.5A). The movement of a panoramic imaging device is adapted to a human "standard" skull such that the distance between the anatomic structures of interest and the screen is all the time kept optimal to obtain an image of high quality (Fig.5B). The standard is based on the averages of measures of the skull geometry in the population. Any individual departure from the standard my cause that the distance between skull and panoramic screen is no longer optimal at least in certain positions of the device (Fig.5C). This may obviously result in suboptimal image quality. The more individual a skull is (the more it departs from the "standard" geometry), the higher is the risk of suboptimal distances during panoramic imaging and hence the risk to obtain an image of low quality (Fig.5D). Now forensic knowledge comes into play. Some forensic methods to predict sex are based on geometric properties of the skull.[10] Studies which aimed to develop such methods found that the distances between certain landmarks have higher variance in men than in women.[11] More important, the correlations of such distances were found to be stronger in women than in men.[12] In other words, the variability of the individual shape of skulls is larger in men than in women. In combination with the considerations above, this implies that more men than women are at increased risk to provide panoramic images of low quality, and hence the average quality of panoramic images is better in women than in men. It is noteworthy that this effect occurs predominantly in particular anatomical structures. Among the three anatomical regions we considered, the variances of geometry were reported to be largest in the maxilla.[11,12] This is consistent with our data: the mainpart of the difference between sexes was found in this region (Fig.3, lower panel).

CONCLUSIONS

The immediate clinical implication of our findings, in particular of the age-by-device interaction, is that loss of image quality associated with reduced radiation dose does not occur in all age groups. It is possible for young subjects to use lower radiation doses without significant loss of image quality, which is especially interesting in regard to the risk of cumulative exposure to radiation over lifetime.

This may also have implications in the context of criminal proceedings. Here the question is often whether a subject under investigation, not possessing personal documents, has reached the age of criminal responsibility (i.e. 14 years in Germany). Assessment of the mineralisation of the third molars is then routinely performed. However, German radiation law and safety regulations require to justify any application of radiation in living individuals. In case the subject does not agree, the X-ray procedure must be ordered by a judge who may have concerns when that person is potentially a child. Thanks to our results we can state that panoramic imaging using a reduced (and hence much less harmfull) radiation dose is able to provide images of first class quality in young subjects. This argument may influence the judge's decision in favour of the diagnostic procedure.

Another implication arises in the context of the identification of dead bodies. Here dental films are used for imaging purposes.

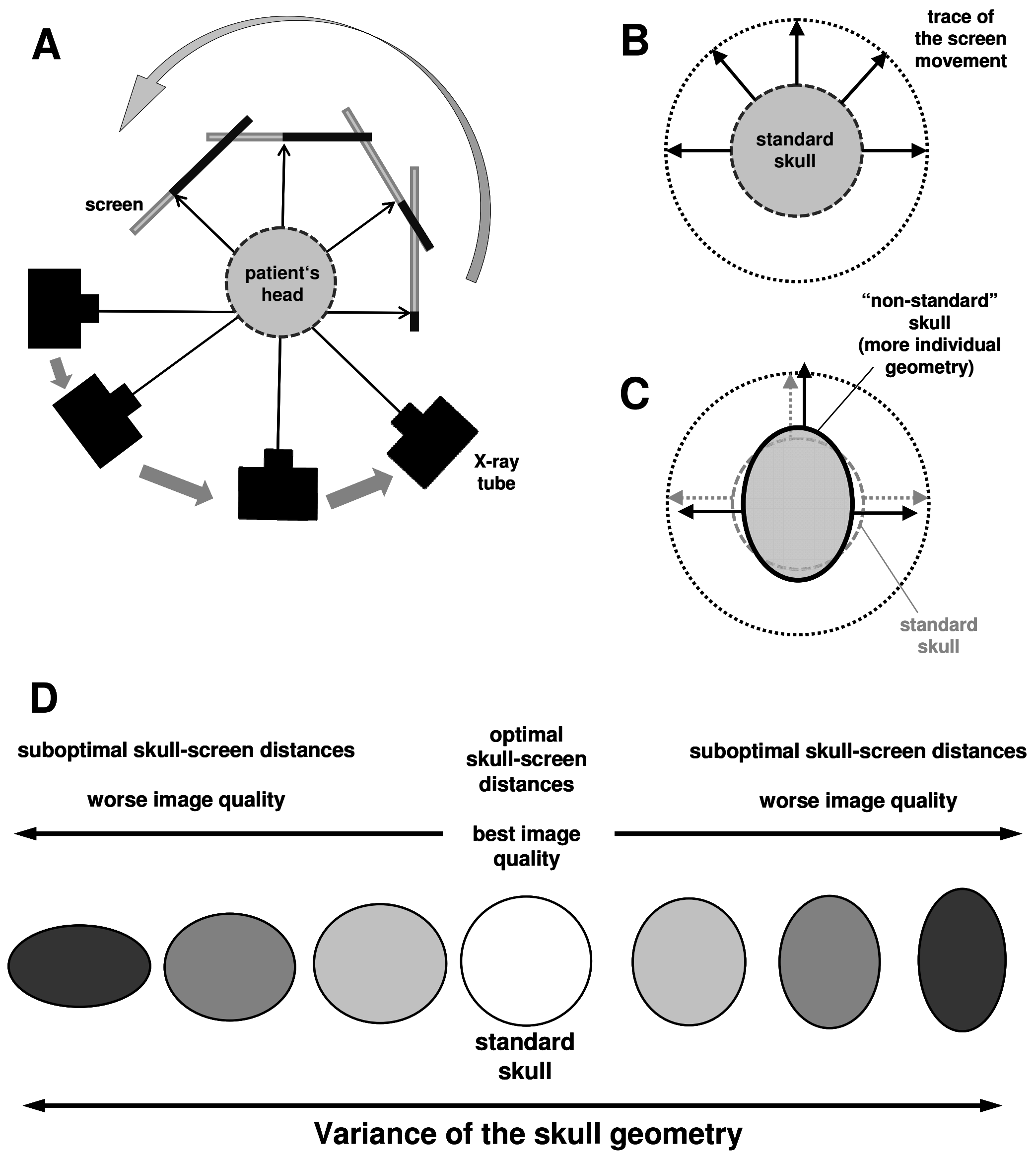

Fig.5: *Movement of a panoramic device during imaging (A). The distance between screen and target object is designed to be optimal for a standard skull to obtain high quality images (B). Distances may not be optimal for a more individual skull geometry departing from the standard (C). Higher variance in the skull geometry is associated with more suboptimal distances and hence with a higher risk of worse image quality (D).*

Our results about the associations between age and image quality should generalise to other X-ray imaging techniques if our explanations are valid. (By contrast, the effect of sex should not generalise as our arguments were largely based on the special properties of panoramic imaging devices.) If so, we should conclude that imaging with high radiation dose should be used throughout as dead bodies can not be harmed by radiation, but low image quality due to low radiation dose with subsequent requirement of another image can be avoided. In particular in the setting of a mass disaster the workflow of the identification team should be rapid and not be slowed down by the need for any repeat procedures.

A consequence outside forensic science is that research on image quality of dental radiographic devices should include age and sex into analysis. Demographic imbalances between patient groups subject to comparison or age selection may bias the outcome. Note for example that it follows from the age-by-device interaction that a comparison of OPC with VVE with a sample of students aged 20 years would have resulted in a marginal non-significant difference. In the same study carried out with elderly aged 65 years, the difference between devices would have been four times larger and highly significant.

Finally, as a more general conclusion, it's an example that forensic odontostomatology and anthropology are not simply sciences about dead bodies, but clinicians many benefit from knowledge of these domains. It was demonstrated that some clinical phenomena relevant to patients may be understood by applying well-established results of forensic research, while there is, at first glance, no straightforward explanation relying on daily clinical experience. It is therefore worthwhile to disseminate the results of forensic research more widely, not confining oneself to forensic applications.

Conflict of interest: None declared.

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Address for correspondence:
Dr. Bianca Gelbrich
University of Leipzig, Department of Orthodontics
Nürnberger Straße 57, 04103 Leipzig, Germany
Phone: +49-341-9721050
Fax: +49-341-9721059
E-mail: B.Gelbrich@medizin.uni-leipzig.de

INCIDENCE OF CLAVICULAR RHOMBOID FOSSA (*IMPRESSION FOR COSTOCLAVICULAR LIGAMENT*) IN THE BRAZILIAN POPULATION: FORENSIC APPLICATION

F.B. Prado[1], L.S. de Mello Santos[2], P.H.F. Caria[1], J.T. Kawaguchi[2], A.d'O.G. Preza[2], E. Daruge Jnr[2], R.F. da Silva[1], E. Daruge[2]

[1] Morphology Department, Piracicaba Dental School, State University of Campinas, UNICAMP, Brazil
[2] Forensic Dentistry Department, Piracicaba Dental School, State University of Campinas, UNICAMP, Brazil

ABSTRACT
In the last years, anthropology has been widely explored mainly when related to bones due to its morphologic characteristics, such as the rhomboid fossa of the clavicle. This study examined the incidence of the rhomboid fossa in paired clavicles of Brazilian subjects obtained from 209 adult bodies of known age and sex (107 males and 102 females) on which postmortem examinations had been performed by the senior author. The data were submitted to qualitative statistical analysis according to Fisher. There was a statistical difference ($p= 5.98 \times 10^{-23}$) between sexes related to the frequency of the rhomboid fossa. The fossa was absent in 97,1% of the female clavicles and the incidence of bilateral fossa was present in 2,9% of females. The incidence of bilateral fossa was 29% for male clavicles. The sexual or side differences in the incidence of the fossa could be found in this study, and qualitative analysis can corroborate sex determination of unidentified bodies in forensic medicine.
(J Forensic Odontostomatol 2009;27:1:12-16)

Keywords: forensic science, sex determination, rhomboid fossa, clavicle

INTRODUCTION
In the identification of humans, especially in the determination of the sex of whole skeletons, or isolated parts, the process of identification becomes progressively complex. The inexperienced observer can confuse particular anatomic characteristics such as the rhomboid fossa (*impression for the costoclavicular ligament*) with pathologic conditions varying from a simple fibrous displasia (benign) to a chronic osteomyelitis (malignant) as stated by the American College of Radiology (1992).

The costoclavicular ligament (*ligamentum costoclaviculare*) or rhomboid, on its insertion in the lower portion of a clavicle, can produce impressions, tuberosities, depressions, and even a fossa, known anthropologically and anatomically as the rhomboid fossa.[10]

Previous studies have evaluated the relationship between the presence of clavicular rhomboid fossa, and sex in skeletons of various populations worldwide, and found significant results related to incidence of the rhomboid fossa, being higher in males than females.[9,2]

Jit & Kaur (1986) did not find statistically significant differences between sex in relation to incidence of the rhomboid fossa in Indian individuals, where 59% of males and 54% of females showed this anatomic characteristic.[6]

A successful study conducted by Rogers et al (2000) examined the presence of the rhomboid fossa in relation to sex and to age of individuals in determining the sex of unidentified skeletons, since the rhomboid fossa was commonly associated with males more than females (36% for males left clavicles, 31% for male right clavicles, 3% for female left clavicles and 8% for female right clavicles) for 113 female and 231 male clavicles.[10]

Due to the scarcity of studies dedicated to this theme in the Brazilian population, the anthropologists in Brazil needs to refer to foreign research findings which do not always correspond to the national reality. Therefore, the aim of the present study was to determine the presence of the clavicular rhomboid fossa in the Brazilian population as a qualitative method for the determination of the sex in unidentified skeletons.

MATERIALS AND METHODS

The study included 209 pairs of clavicles from Brazilians (107 males and 102 females), all adult individuals and previously identified. They varied in age between 19 and 85 years and were from the ossuary of the Municipal Cemetery of São Gonçalo, Cuiabá – MT. All the bone pieces belonged to unclaimed bodies, whose families did not request the bones within the administrative time determined by the institution, and which had as final destination internment in a common grave or cremation.

The presence (Fig. 1) or absence (Fig. 2) of a rhomboid fossa in the clavicle was determined corresponding to the right and left of the human body. Recordings were taken for each clavicle, and the results were submitted to analysis of intra-examiner reliability, where all the observations were carried out by a single examiner on three different occasions, with an interval of two weeks between each observation, so that the observations could not be memorized.

Statistical analysis of the data.

The data collected were submitted to calculation of intraclass correlation coefficient (ICC), to descriptive statistics and to Fisher's exact test, utilizing Microsoft Excel and the program Bioestat 5.0.

This work was first submitted and approved by the Committee of Ethics in Research of the Piracicaba Dental School, State University of Campinas - UNICAMP.

Fig 1: *Clavicle with rhomboid fossa (Red Circle)*

Fig. 2: *Clavicle without rhomboid fossa*

Table 1*. Distribution of frequencies (absolute and relative) of rhomboid fossae according to sex.*

Clavicle	Males		Females	
	N	%	N	%
With rhomboid fossa bilateral	31	29,0	3	2,9
With rhomboid fossa only on right	20	18,7	0	0.0
With rhomboid fossa only on left	17	15,9	0	0.0
Without rhomboid fossa	39	36,4	99	97,1

p= 5.98 x 10-23 (Fisher's exact test)

RESULTS

The results obtained by the intraclass correlation coefficient (ICC) showed a correlation of r = 0.96, indicating a nearly perfect match among the three series of observations carried out on the clavicles.

Table 1 shows a highly significant difference (p= 5.98 x 10^{-23}) between sex related to the frequency of rhomboid fossae.

The table showed that 97.1% of the clavicles of female individuals did not have a rhomboid fossa and only 2.9% had a rhomboid fossa and bilaterally. However, 63.6% of males had a rhomboid fossa, 29% had bilateral fossae, 15.9% only on the left side and 18.7% only on the right side.

DISCUSSION

In the analysis of a body in which the sex is to be determined, observers should support their findings with the greatest number of existing tests, so that their conclusions become uncontested.

For the determination of the sexual dimorphism of a body, basically two types of data can be obtained, quantitative,[3,4] determined by measurements, such as weight, perimeter, length and others, and qualitative,[6,7] which examine the shape, presence/absence of a particular bone character by macroscopic means and which are often allowed to be documented in reports.

The results of this study demonstrate that the rhomboid fossa has a markedly greater incidence in males, occurring in 63.6% of male clavicles and only in 2.9% of female clavicles. Earlier studies found that the presence of a rhomboid fossa is more common in the left clavicle of men and in the right clavicle of women, and that the presence of this anatomic structure reflects a probability of 81.7% in the right clavicle and 92.2% in the left for males.[10] However, other authors have reported different values between sides and genders in relation to the incidence of a rhomboid fossa in different populations.[9,6]

Only 2.9% of the female clavicles examined showed a rhomboid fossa in this study, appearing on both sides (right and left), where there were no cases of an occurrence of a rhomboid fossa in only one of the clavicles on the same individual. However, in the present study, male individuals (107) showed a rhomboid fossa in 63.6% of the cases, where 29% were bilateral, 18.7% only on the right clavicle and 15.9% on the left. Cho & Kang (1998) reported an incidence of 58.70% in men and 54.14% in women.

One of the possible explanations for the results obtained in this study relies in the fact that female bones are generally more delicate and less voluminous with the extremities delicate, and that male skeletons are more robust, mainly due to musculoskeletal activity.[8]

Besides contributing to other information gathered that serve as the basis for the effective determination of sex, the findings of the present study can help in cases in the determination of sex when the body is in parts or reduced to bone fragments. In such situations, the simple presence of a rhomboid fossa would indicate with a relative degree of certainty for judicial authority, if the fragment comes from the body of male or female.[9] In addition to such an affirmation, molecular biology assays can be a handy ratification tool (e.g., amelogenin), verifying the result of physical anthropology.

The factors responsible for the morphologic alterations are still not completely elucidated, where comparative studies demonstrate that the differences in the shape and size of some human bones are determined basically by environmental factors and genetic influence, besides the pattern and rate of growth and development and the type of bone remodeling.[11,5]

CONCLUSIONS

The presence of a rhomboid fossa can be used as a qualitative criterion for the differentiation of sex in bodies of Brazilian individuals, because 97.1% of clavicles of the individuals of females did not posses a rhomboid fossa.

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Address for correspondence:
Department of Social Dentistry,
Forensic Dentistry Division
Piracicaba Dental School, P.O. BOX 52
University of Campinas -UNICAMP
13414-903, Piracicaba, SP, Brazil
Telephone: +55 (19) 3302- 9129.
Email: leonardosoriano@hotmail.com

THE DISCRIMINATION POTENTIAL OF AMALGAM RESTORATIONS FOR IDENTIFICATION: PART 1

V.M. Phillips, M. Stuhlinger

University of the Western Cape, Tygerberg South Africa

ABSTRACT
The dental identification of human remains utilizes the matching of dental restorations. The radiographic images of amalgam restorations are paramount in this process. The compound amalgam restoration has a unique radiographic morphology and can be readily identified in both antemortem and postmortem data. To test the radiographic morphology of compound amalgam restorations, 10 out of 40 Typodont teeth, restored by students, were tested for their discriminatory potential by 12 examiners. The results showed that the radiographic morphology of compound amalgam restorations can be accurately matched by dentally trained personnel. This suggests that in cases where accurate radiographic material is used for dental comparison, less than 12 concordant features are necessary for positive dental identification. If the antemortem and postmortem radiographic images of a compound amalgam restoration are exactly the same then this feature is unique and identification can be achieved by a single concordant feature.
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***Keywords**: dental amalgam, radiology, identification, forensic odontology*

INTRODUCTION
In the process of forensic dental identification the reason for collecting and correlating antemortem and postmortem data is to compare these data and thereby identify an individual. The aim of the comparison is to examine the features of the same jaw sector, single tooth or even a tooth surface for concordance between antemortem and postmortem data.[1] There is no way of knowing how correctly a given restoration is depicted in an antemortem odontogram that was sketched by a dentist or the assistant, and a comparison based on a drawing of a restoration contour or cavity outline is never safe. Keiser-Nielsen (1980) recommended that the restored tooth surface as depicted in the odontogram be regarded as the smallest 'unit' to consider in the comparison of dental restorations for identification purposes. Thus 12 concordant features are required for a positive dental identification. The comparison of the most recent antemortem radiographs with those taken postmortem is one of the safest methods of comparison of dental features. The concordance of both the written data and the radiographs are usually used to establish identification.

No physical or dental feature is unique; if it were it would only have occurred once throughout history. However, any physical feature does possess a certain discrimination potential according to its frequency of occurrence; the more frequently it occurs the less characteristic it is.[1] In an expansion of the study by Keiser-Nielsen[1], Fellingham & Kotze[2] indicated that at either end of the range where, on the one hand a mouth of almost entirely normal teeth or, at the other end, an almost edentulous mouth, there are few possible configurations. One is then unlikely to be able to identify the persons with any degree of certainty. In the central part of the range, however, where the subject may have an assortment of decayed, missing or filled teeth, a specific configuration is likely to be rare and should lead to identification in most cases. While 12 concordant features are considered the minimum requirement for dental identification by Keiser-Nielsen[1], it has generally been found that this number of features cannot always be established. One or more extraordinary features could be involved and these should be accorded their appropriate degree of importance.[3] Keiser-Nielsen considered an extraordinary feature as one that does not occur in more than 10% of the population. One extraordinary feature may be sufficient, in certain circumstances, to make a positive identification. Two cases were presented by de Villiers and Phillips[4] in which the identification of two individuals were made utilizing one extraordinary dental feature in each case.

The measure of uniqueness of the patterns of amalgam restorations in the upper and lower dentition was investigated by Phillips[5] in which he found that the patterns of amalgam restorations in the first molar were relatively common and therefore had a low measure of uniqueness. If however the pattern of the amalgam in the first molar was combined with the patterns in one or more other teeth, then the measure of uniqueness increased markedly and improved the likelihood of identification of that person.

The standard dental radiographic pictures of the teeth, however, provide a morphological view of amalgam restorations that is possible to duplicate and used for comparison purposes in identification procedures. In a study by Borrman and Gröndahl[6] in which the radiographic appearance of teeth and restorations of two sets of bitewing radiographs were compared by seven dentally trained observers, all observers were able to identify all the cases in which simple restorations were present. The question is whether the radiographic image of a single compound amalgam restoration in a posterior tooth is unique.

Aim

The aim of this study was to investigate the uniqueness of the radiographic image morphology of standardized compound amalgam restorations in molar teeth with regard to their discriminatory potential for dental identification purposes.

MATERIALS AND METHODS

The undergraduate conservative dentistry teaching program utilizes 'Typodont' acrylic teeth to train students to prepare cavities and to restore these teeth with silver amalgam. Forty of these 'Typodont' teeth were collected in which three surface amalgam restorations (mesio-occlusal-distal restoration) had been placed by fourth year dental students. The 'Typodont' teeth were numbered from 1 to 40 and placed in pairs into an acrylic mould to standardize their position for radiography. The cone of the X-ray machine was placed at right angles to the buccal aspect of the teeth and a radiograph taken to simulate a standard 'bitewing' dental radiograph. The images of the teeth from the twenty pairs of radiographs were labeled 1 to 40 (Figs.1a & 1b) and regarded as 'antemortem' images. A second set of radiographs, duplicates of the first set, was taken of each of these teeth and random alphabetic symbols were allocated to each radiograph for each tooth; these were considered as 'postmortem' radiographs. From this 'postmortem' group, 10 randomly selected radiographs Set 2 (Fig. 2) were chosen to compare with those of Set 1. These sets of radiographs were examined by 12 dentally trained personnel. The entire Set 1 and the ten radiographs from Set 2 were supplied to each of the examiners who were required to match the individual 'postmortem' radiographs (Set 2) with the 'antemortem' radiographs (Set 1). The examiners consisted of two Prosthodontists, two Maxillo-facial Radiologists, three Dentists, an Oral Pathology registrar, two Oral Hygienists, a Dental Radiographer and a Forensic Dentist. Their success rates of matching the radiographic images were recorded (Table 1).

RESULTS

The result of each of the observers was documented as the successful matching of all 10 'postmortem' radiographs (Set 2) within the 40 'antemortem' radiographs (Set 1).

Ten out of 12 examiners were able to match all 10 of the 'postmortem' radiographs, to the 'antemortem' set; two examiners obtained 9 out of 10 correct (Table 1). [To correctly match all 10 randomly selected radiographs successfully within a set of 40, was mathematically shown to be 1 possibility in 1,179 x 10_9 (1,179 billion)*]

* Consultant Statistician: T J van Wyk Kotze

DISCUSSION

Twelve concordant antemortem and postmortem dental features have been regarded as essential to obtain absolute certainty of identification from a written dental record. Each decayed, missing or filled tooth is regarded as a *concordant unit* when it appears in both records. If however one or more extraordinary features are involved these are accorded a greater degree of importance and less than 12 concordant features are required for identification. One unique feature has been shown to be sufficient to make a positive identification.[4] The comparison of dental radiographs has been considered a highly reliable method for identification purposes, but the success rate of matching antemortem and postmortem records is dependent on the skill of the observer.

Table1: *The results of matching 10 'postmortem' with 40 'antemortem' radiographs*

Observer	Score out of 10	Examiner
1 (VMP)	10	Forensic Odontologist
2 (PvZ)	9	Prosthodontist
3 (CN)	10	Maxillo-facial Radiologist
4 (GN)	10	Maxillo-facial Radiologist
5 (NP)	9	Prosthodontist
6 (AR)	10	Maxillo-facial Radiographer
7 (MS)	10	Dentist
8 (MC)	10	Registrar
9 (OH1)	10	Student Hygienist
10 (OH2)	10	Student Hygienist
11 (CdH)	10	Dentist
12 (JD)	10	Dentist

This table shows 10 examiners matched all the radiographs; two examiners matched 9 out of 10

Borrman et al[6] found that experienced examiners were all able to successfully match simple amalgam restorations from radiographic material. The results of the examiners in our study showed that the radiographic morphology of a compound amalgam restoration is easily identifiable within a group of radiographs when the 'antemortem' and 'postmortem' radiographic images are identical. In this study 10 out of 12 dentally trained examiners were able to match all the radiographic images correctly; two examiners scored 9 out of 10. This indicated that the radiographic morphology of the compound amalgam restoration is highly distinctive for identification purposes.

In a mass disaster where there is fragmentation of human remains, obtaining enough dental material to make an identification requiring 12 concordant points is often impossible. The radiographic morphology of dental restorations, roots and bony trabecular patterns are often used as identification criteria in these situations. After the removal of caries from a tooth and the repair of that tooth with a silver amalgam restoration, the radiographic shape of that restoration when viewed on a bitewing, periapical or Pantomographic radiograph has a very distinctive shape that can be matched in both the antemortem and postmortem radiographs. The placement of a lining material in the cavity prior to the amalgam filling will correct most of the irregularity of the floor of the cavity and produce a layer of material between the amalgam and the dentine that may also produce a distinctive radiographic image. It is most unlikely that two individual compound amalgam restorations can have exactly the same radiographic image; the thickness of the amalgam restoration together with the irregular occlusal surface morphology is highly distinctive in each restoration. This suggests that when undertaking identification using dental radiographs, if the postmortem radiographs are accurate duplicates of those taken antemortem, then the radiographic images of the amalgam restorations have a greater discriminatory potential than a single concordant unit as stated by Keiser-Nielsen.[1] If the two images are exactly similar then this image can be regarded as highly extraordinary, if not unique.

CONCLUSION

It is the opinion of the authors that a single compound silver amalgam restoration has a radiographic morphology that is so distinctive that it is possible for one restoration to be used for the identification of an individual.

ACKNOWLEDGEMENT

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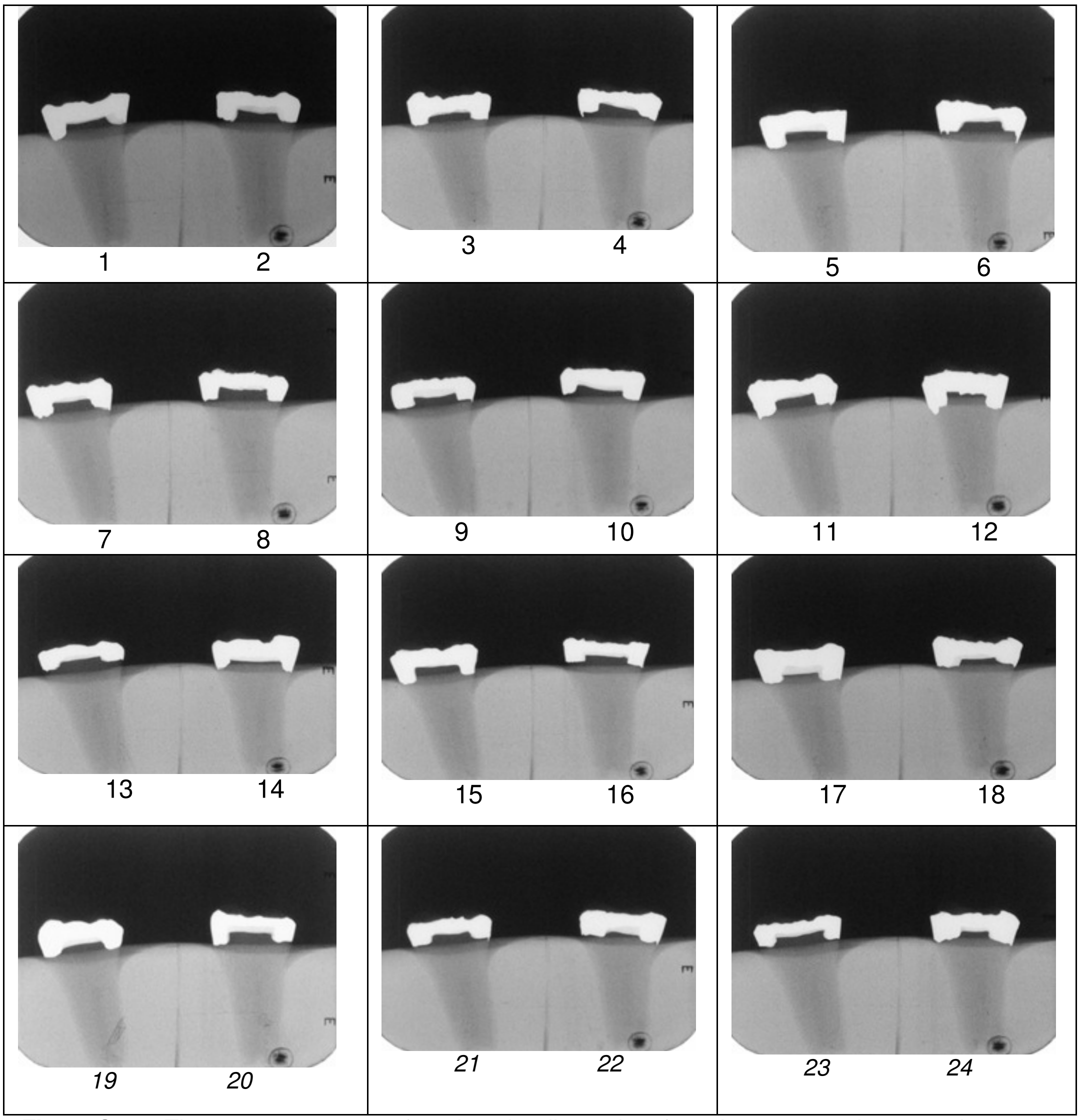

Fig1a: *Set 1. The 'antemortem' set of 40 dental radiographs of amalgam restorations - teeth 1 to 24*

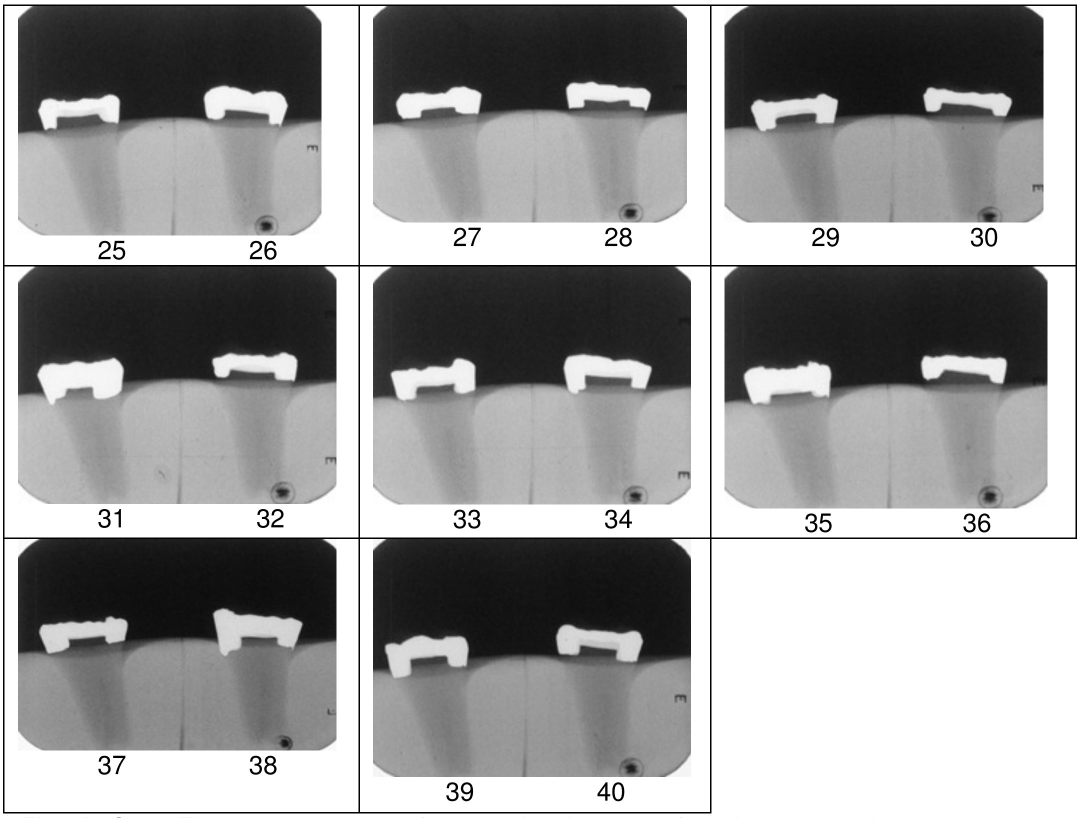

Fig. 1b: *Set 1. The 'antemortem' set of 40 dental radiographs of amalgam restorations - teeth 25 to 40*

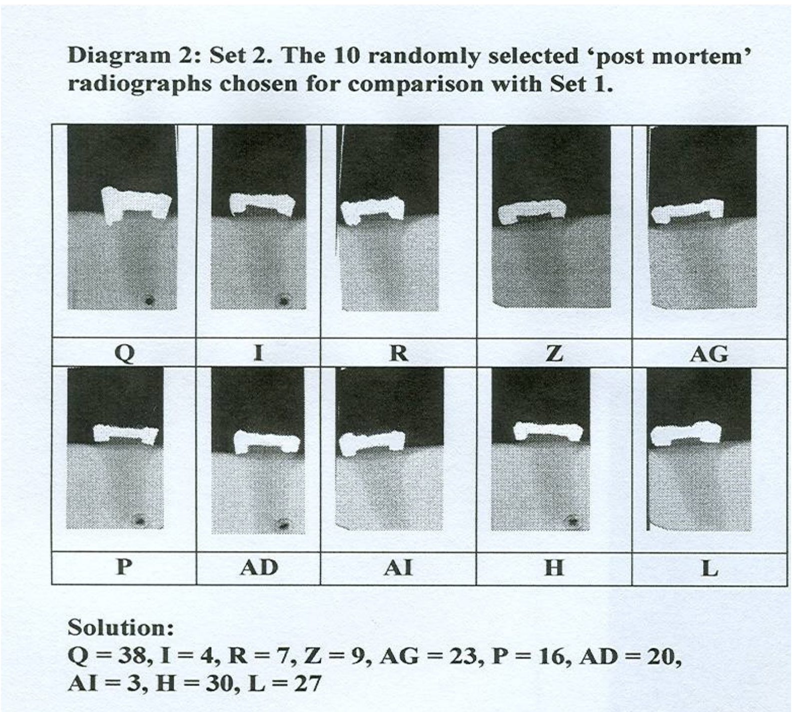

Fig. 2: Ten randomly selected 'postmortem' radiographs.

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Address for correspondence:
Prof. VM Phillips
University of the Western Cape
Private Bag X1
Tygerberg 7505
Email: vmphillips@uwc.ac.za

THE DISCRIMINATION POTENTIAL OF AMALGAM RESTORATIONS FOR IDENTIFICATION: PART 2

V.M. Phillips, M. Stuhlinger

University of the Western Cape, South Africa

ABSTRACT
The standard dental bitewing radiograph is used to detect interproximal caries but it also provides a specific view of the dental restorations that can be duplicated for identification purposes. The antemortem and postmortem bitewing radiographs are often not at the same angle and result in distorted images of the restorations. The aim of this study was to investigate the progressive increase in angulations of a bitewing radiograph of the same restoration and to determine at what angle the image is distorted sufficiently as not to be recognized. Bitewing radiographs were taken of the same two restorations at 5˚, 10˚, 15˚ and 20˚ superior, inferior, mesial and distal to the original 0˚bitewing radiograph. Twenty examiners were required to determine at what angle the distortion prevented matching of the image with the original bitewing radiograph. The results showed that the image distortion at 15˚became suspect but at 20˚none of the images could be matched to the original bitewing radiograph.
(J Forensic Odontostomatol 2009;27:1:23-26)

Keywords: forensic dentistry, identification, DVI

INTRODUCTION
Dental identification of human remains is dependant on accurate antemortem dental records that should include radiographic images of the teeth and the restorations. These radiographs are usually the so-called bitewing radiographs that are used to detect interproximal caries in the posterior teeth. The technique of taking bitewing radiographs is standardized and relatively easy and these images are intended to be at right angles to the long axis of the posterior teeth and parallel to the occlusal surfaces of the teeth thereby providing an uninterrupted view of the interproximal surfaces of the teeth, but also providing a specific image of the restorations that may be present in these teeth. These radiographic images of the restorations can be compared in antemortem and postmortem records for identification purposes. Borrman & Gröndahl[1] reported that dentally trained personnel were able to accurately match antemortem and postmortem bitewing radiographs; this was also shown in Part 1 of these articles where the two sets of radiographs were exact duplicates.

Most dentists are aware that their bitewing radiographs are not always at right angles to the long axis of the teeth and that the angulation of the cone of the x-ray machine can be either anterior or posterior to the right angle plane resulting in a degree of overlapping of the interproximal enamel surfaces of the posterior teeth; the cone may also be angulated superior or inferior to the occlusal plane. These images will then be distorted to a lesser or greater degree depending on the error in the cone angulation. The comparison of antemortem and postmortem dental radiographs depends on the matching of dental restoration morphology. If the antemortem and postmortem radiographs are taken at the same angle the restoration morphology will be identical. If, however, the angulation of the antemortem radiograph is significantly different to the postmortem radiograph there can be overlapping of two restorations and this can occur with occlusal and palatal restorations on a molar in a tooth, and thereby result in inaccurate interpretation of the dental records.

In Part 1 of this series it was shown that exact duplicates of radiographic images of compound amalgam restorations are easily matched and a single restoration may be used to identify an individual. If there is a significant difference between the angulations of the antemortem and postmortem radiographic images, at what angle is it not possible to accurately distinguish that two restorations are the same?

Aim

The aim of this study was to investigate the variations of the angulations of bitewing radiographic images of compound amalgam restorations in molar teeth and compare these images with a control bitewing radiograph to determine at what angle the image changed significantly to prevent matching of the radiographic images.

MATERIALS AND METHODS

A pair of molar teeth each with a three surface amalgam filling was radiographed at right angles to the long axis (equivalent to a bitewing radiograph) and this was designated as 0º. This pair of teeth was then radiographed at 5º, 10º, 15º and 20º superior, inferior, mesial and distal to the plane of the bitewing radiograph (Fig. 1). These angulated views were examined and compared to the 0º bitewing radiograph by twelve dentally trained personnel to determine at which angle the images of the restorations were no longer comparable with the 0˚bitewing radiographic image. The examiners were required to match the various angulated radiographs and indicate Y if the image was comparable to the 0˚image and N if unrecognizable. The result of the matching procedure by each examiner was recorded (Table1).

RESULTS

The examination of the angulated views of the radiographs showed that accurate matching of these radiographs with the 0˚ occurred at 5º and 10º, but at 15º the morphology of the amalgam restorations had changed sufficiently as to make confident matching doubtful; at 20º the images were not recognizable (Table 1). The mesial angulation showed that at 5˚ and 10˚ the images were comparable to the bitewing radiograph but at 15˚ six examiners indicated that the image was unrecognizable, at 20˚ the image was unrecognizable by all the examiners. Similarly the distal images were not comparable at 15˚ by seven of the examiners. The superior images showed that at 15˚ eight of the twelve examiners were not able to match the images to the bitewing image and amongst the inferior images six of the twelve examiners were not able to compare the image of 15˚ with that of the 0˚ bitewing radiograph.

Table 1: *The results of the comparison of the images of the mesial, distal, superior and inferior angle variations of the radiographic images.*

	MESIAL				**DISTAL**				**SUPERIOR**				**INFERIOR**			
Examiner	5º	10º	15º	20º	5º	10º	15º	20º	5º	10º	15º	20º	5º	10º	15º	20º
1 (VMP)	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	N	Y	Y	Y	N
2 (PvZ)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N
3 (CN)	Y	Y	Y	N	Y	Y	Y	N	Y	Y	N	N	Y	Y	Y	N
4 (GN)	Y	Y	Y	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
5 (NP)	Y	Y	N	N	Y	Y	N	N	Y	Y	Y	N	Y	Y	N	N
6 (AR)	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N
7 (MS)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
8 (MC)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
9 (OH1)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
10 (OH2)	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N	Y	Y	N	N
11 (CdH)	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N
12 (JD)	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	N

Y = yes recognizable, N = not recognizable

The table shows that the radiographic images of the amalgam restorations were comparable at 5º and at 10º. At 15º the images became inaccurate and not easily recognizable to some examiners; at 20º the images were unrecognizable by all examiners.

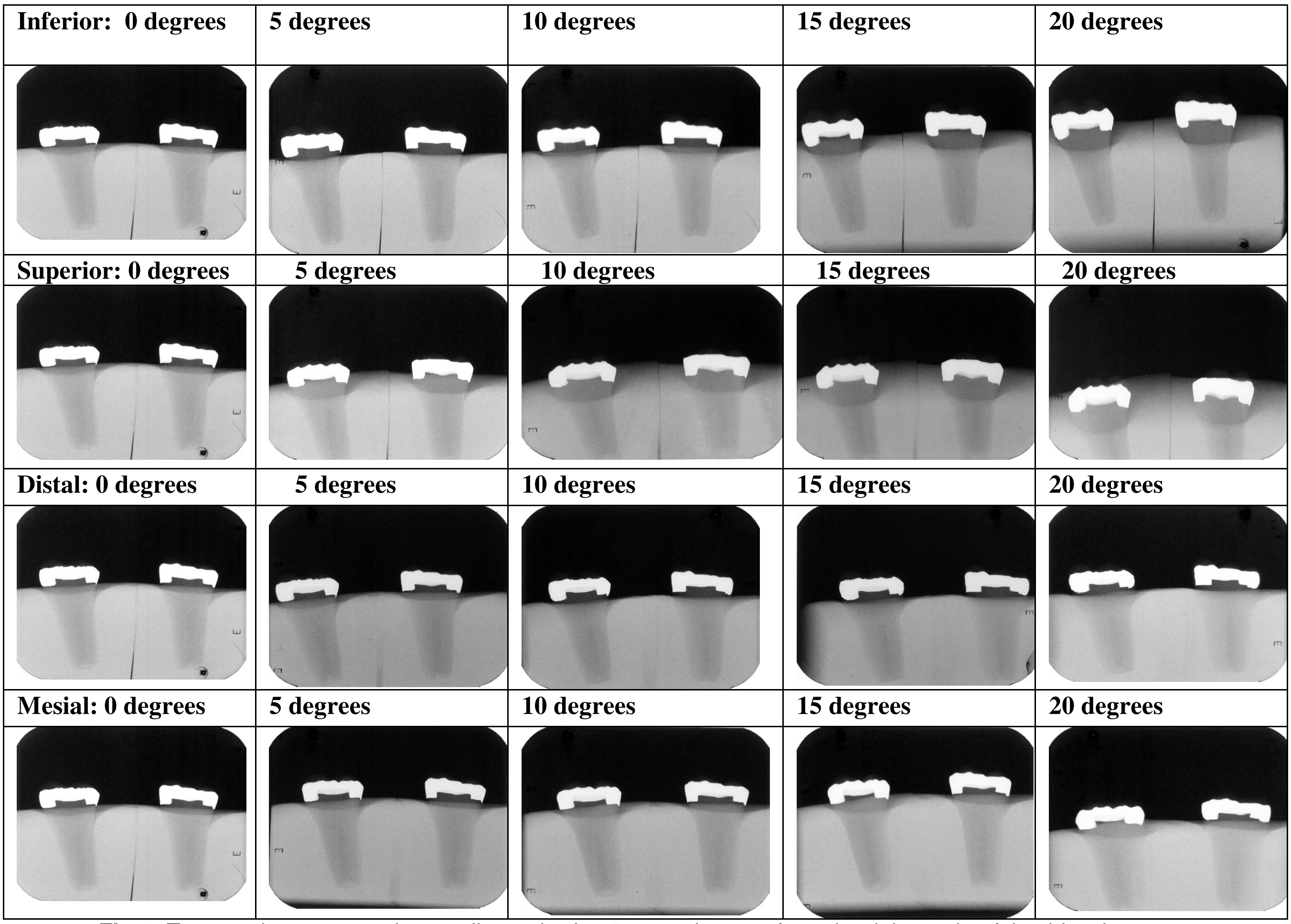

Fig.1: *Two amalgam restorations radiographed at 5 to 20 degrees from the right angle of the 'bitewing' radiograph 0-Degrees.*

DISCUSSION

The process of matching antemortem and postmortem dental radiographic images is a very accurate method of assessing identification of human remains especially if there are dental restorations present. The previous concept regarding dental identification was to obtain 12 concordant features between the antemortem and postmortem dental records to obtain positive identification.[2] If the antemortem and postmortem radiographic images are exactly the same then less than 12 concordant features are necessary for identification; in fact one unique feature can suffice. In Part 1 of this series of articles it was shown that one exact replica of a dental image of a compound amalgam restoration was extraordinary enough to be used for identification of an individual.

This study surmised that very few postmortem radiographic images are exact replicas of the antemortem radiographs and that the degree of distortion of the postmortem image when compared to the antemortem one needed to be tested to determine at what stage the images were no longer comparable. The results of this study showed that at 5˚ and 10˚ the distortion of the image was small enough to allow matching of the radiographic images of the amalgam restorations with the original 0˚ bitewing radiograph. However, at 15˚ and greater the image was sufficiently distorted to prevent positive matching by the examiners.

CONCLUSION

In the comparison of antemortem and postmortem bitewing dental radiographic images of compound amalgam restorations in posterior teeth, the dentally trained person is able to recognize and match images that are within a discrepancy of 15˚ of each other. This recognition of radiographic morphologies of amalgam restorations obviates the need for 12 concordant dental features for a positive identification.

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Address for correspondence:
Prof. VM Phillips
University of the Western Cape
Private Bag X1
Tygerberg 7505
Email: vmphillips@uwc.ac.za

THE DISCRIMINATION POTENTIAL OF RADIO-OPAQUE COMPOSITE RESTORATIONS FOR IDENTIFICATION: PART 3

H. Zondagh, V.M. Phillips

University of the Western Cape, South Africa

ABSTRACT
The methods used for disaster victim identification is comparative postmortem profiling of dental and fingerprint data. Twelve dental concordant features are normally required for dental identification. The radiographic image of dental amalgam restorations has been shown to be highly significant for identification purposes. The aim of this study was to investigate the radiological morphology of standardized radio-opaque composite fillings in premolar teeth with regard to their discriminatory potential for identification purposes. Thirty lower first premolar teeth ("Typodont" acrylic teeth) that were filled with 3-surface fillings (MOD) radio-opaque composite resin (Z100) by 4th year dental students were used for this study. Bitewing radiographs were taken of all thirty fillings and labeled Set 1. A second set (Set 2) consisted of 10 randomly selected duplicate radiographs of Set 1, plus 2 other radiographic images not from Set 1. Instructions were given to 20 dentally trained examiners to match the 12 radiographic images of Set 2 with the 30 images of Set 1. The results showed that 18 of the 20 examiners correctly matched the 12 radiographic images, one scored 11 out of 12 and one scored 10 out of 12.

This study shows that if the ante-mortem and post-mortem radiographs of a single composite filling have exactly the same morphology, this image is unique and 12 concordant features are not necessary for dental identification.
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Keywords: radiology, teeth, identification

INTRODUCTION
The recent increase in demand for esthetic restorations has resulted in the replacement of amalgam restorations with composite resins. The popularity of these materials is reflected in the quantity of resin brands currently on the market.[1] Early composite resins were not radio-opaque and their radiographic images were difficult to visualize. The radiopacity of a composite restorative material is an important constituent as it influences the opalescent properties that mimic enamel and also provides radiographic contrast to the tooth structure. Adequate radiopacity permits assessment of marginal overhangs, open gingival margins, interproximal contour as well as recurrent caries.[2]

According to Keiser-Nielsen (1980), no physical or dental feature is unique; if it were, it would only have occurred once throughout history.[4] However, any physical feature does possess a certain discriminatory potential according to its frequency of occurrence; the less frequently it occurs, the more characteristic it is.[4]

Forensic dentistry plays a major role in the identification of those individuals who cannot be identified visually or by other means. The most common methods used for disaster victim identification is comparative postmortem profiling of dental and fingerprint data[3]. Several studies have been documented regarding the successful use of dental restorations for identification purposes.[4,5,6,8]

In the process of identification, the collecting and correlating of antemortem and postmortem data is used to identify an individual. Keiser-Nielsen (1980) recommended that the restored tooth surface be regarded as the "smallest" unit to consider in the comparison of dental restorations for identification purposes. Buchner (1985) stated that recovery of only a single tooth or jaw fragment may be enough to confirm a positive identification.[6] Where a victim has an assortment of decayed, missing or filled teeth, a specific configuration is likely to be rare and should lead to identification in most cases. While 12 concordant features are considered the minimum requirement for dental identification by Keiser-Nielsen,[4] it has generally been found that this number of features need not always be necessary when using radiographic images of restorations. One or more extraordinary features could be involved and these should be accorded their appropriate degree of importance. An extraordinary feature is one that does not occur in more than 10% of the population. One extraordinary feature may be sufficient in certain circumstances, to make a positive identification.[7]

The measure of uniqueness of the patterns of amalgam restorations in the upper and lower dentition was investigated by Phillips (1983) in which he found the clinical patterns of amalgam fillings in the first molar were relatively common and therefore had a low degree of uniqueness for identification purposes.[9] Borrman and Grondahl (1990) showed in their study that the radiographic appearance of the teeth and restorations on two sets of bitewing radiographs, when compared by 7 observers, could be accurately identified in all the cases where simple restorations were present.[10]

It is therefore apparent that the clinical appearances of dental restorations together with an odontogram of recorded treatment required 12 concordant features to obtain a positive dental identification[10]. However, the radiographic images of dental restorations have a far greater value in the correlation between ante mortem and post- mortem dental records and a single image may be unique for identification (Phillips & Stuhlinger; 2007).[11]

AIM

The aim of this study was to investigate the radiological morphology of standardized radiopaque composite fillings in premolar teeth with regard to their discriminatory potential for identification purposes.

MATERIALS AND METHODS

The undergraduate conservative dentistry teaching program utilizes 'Typodont' acrylic teeth to train students to prepare cavities and to restore these teeth with silver amalgam and composite resins. Thirty of these 'restored' premolar teeth (Fig.1) were collected. Each tooth had been filled with a three - surface composite filling (mesio-occlusal-distal) using Z100 (3M ESPE); this is a radio-opaque micro-hybrid composite (60% zirconium filler with a 0.04 - 4.0µm particle size.

The 'Typodont' teeth selected were marked from 1 to 30 and individually placed into a mould to standardize their position for radiography. Two exact dental radiographs were taken from the buccal aspect of each tooth using the same distance form source to object (15cm), the same exposure time (1.8s), the same kV (70) and mA (10) thus simulating a standard "bitewing" dental radiograph (Figs.2 & 3). Thirty of these radiographs were used for Set 1 and labeled in numerical order from 1-30 (Fig.4).

Set 2 consisted of 10 randomly chosen exact duplicate radiographic images of Set 1. Each was given a random number and labeled accordingly. Two unmatched radiographic images were added to Set 2 (Fig 5). A record was kept of the accurate correlation between Set 1 and Set 2 that was not revealed to the examiners (Table 1).

Instructions were given to 20 dentally trained examiners to match the radiographic images from Set 2 with those of Set 1. Each examiner was requested to view the radiographs on their own without consulting a colleague. The success rate of each examiner was recorded. The examiners consisted of: one member of staff from the Dept of Pediatric Dentistry, two from the Dept of Orthodontics, six from the Dept of Conservative Dentistry, three from the Dept of Oral Medicine and Periodontology, three from the Department of Oral Pathology & Radiology, three from the Dept of Prosthodontics, one from Dept of Oral Surgery and one final year undergraduate dental student.

RESULTS

The results of each of the examiners were documented by recording the number of correct matches of the fillings of Set 2 with those of Set 1 (Table 2).

The results in Table 2 showed that 18 examiners scored 12/12, 1 scored 11/12 and 1 scored 10/12.

DISCUSSION

The removal of caries from a tooth and the restoration of that tooth with a radiopaque composite filling creates a highly recognizable radiographic image of that restoration. This study showed that 18 out of 20 dentally trained examiners were able to match the twelve fillings correctly despite there being 2 aberrant images (Table 1).

This is significant, taking into consideration that discrimination potential of the images of the restorations increases with the increase in number of images, eg:

To be able to correctly match:

- 5 out of 30, is one chance in 142, 506
- 10 out of 30, is one chance in 30,045,015
- 12 out of 30 is one chance in 86,493,225

This indicates that the discriminatory characteristic of a radiographic image of a compound restoration is so significant that it could be unique for identification purposes. The result of the examiners in this study shows that the radiographic morphology of a radiopaque composite filling is easily identifiable when the antemortem and postmortem radiographic images are identical. The radiological shape of that filling when viewed on a bitewing radiograph has a morphology that can be duplicated with a similar radiograph. This study has shown together with that of Phillips and Stuhlinger (2007) of amalgam restorations, that it impossible for two compound restorations to have exactly the same radiographic image.[11] This suggests that when undertaking an identification using dental radiographic images of radio-opaque restorations, if the post-mortem radiographs are accurate duplicates of those taken ante-mortem, then the shape of the composite fillings have a discrimination potential that is unique.

CONCLUSION

The radiographic images of radiopaque composite fillings in premolar teeth in this study were shown to have extraordinary morphological features. If the ante-mortem and post-mortem radiographs of a single composite filling in the same tooth show the same morphology, this is unique and the radiographic image of one restoration can be used for identification.

Fig.1: *Numbered Typodont acrylic teeth with MOD composite fillings*

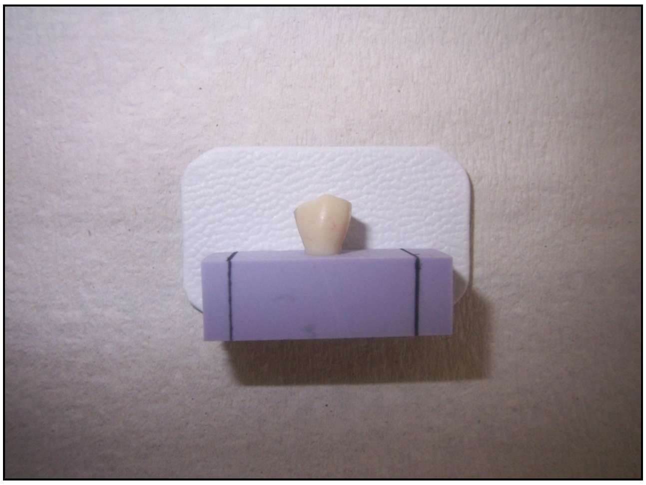

Fig.2: *Typodont tooth in the mould and placed on the radiographic film*

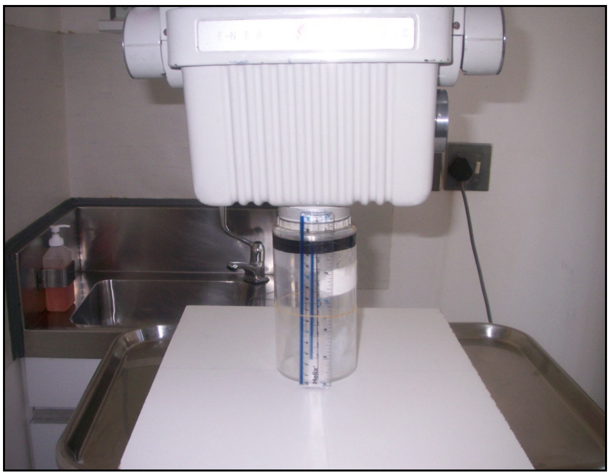

Fig.3: *The standardized method used to radiograph each restored premolar tooth*

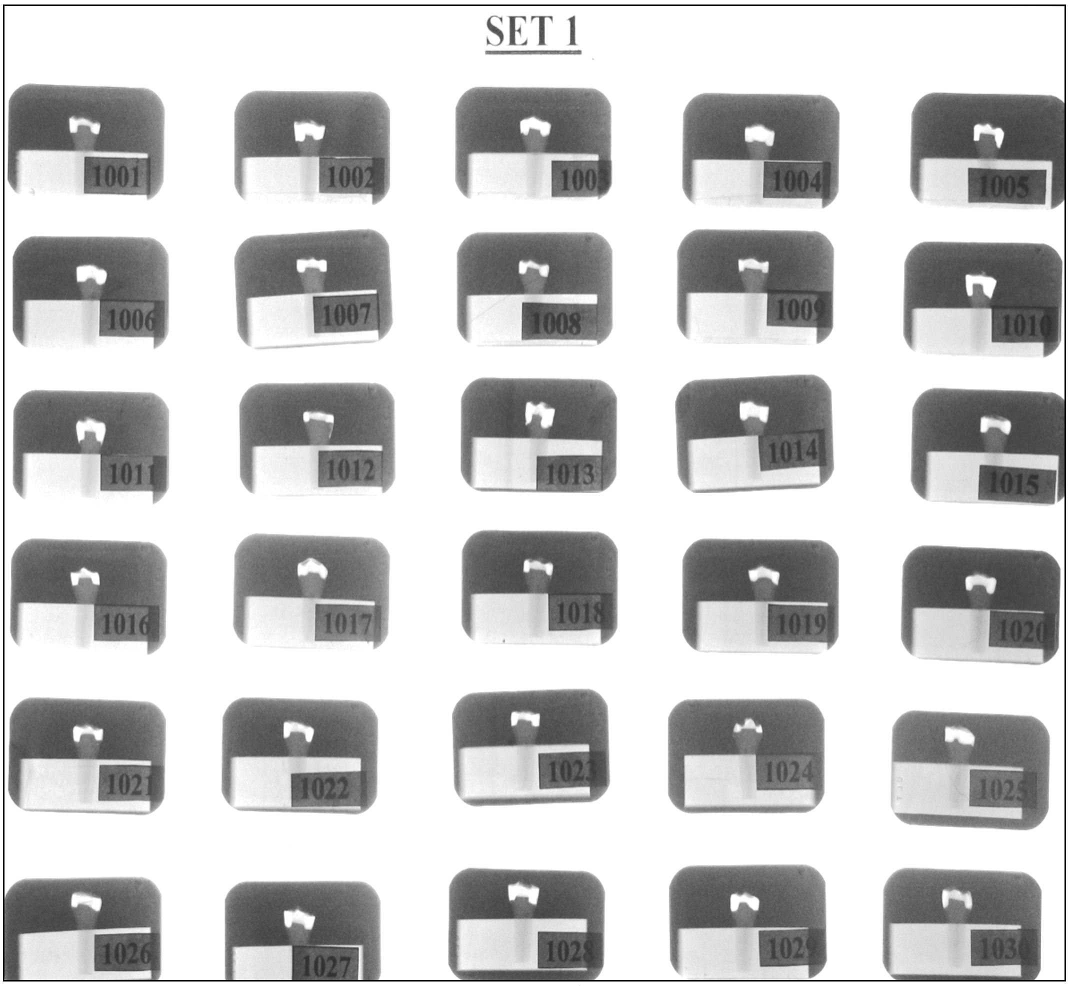

Fig.4: *Thirty numbered “ante-mortem” radiographs of the premolar teeth restored with composite resin Set1.*

Fig.5: *Twelve randomly chosen matching radiographs- forming the 'post-mortem' Set 2 (plus the two non-matching images 6491 & 8273).*

Table 1: *Matching radiographs between Set 1 and Set 2.*

Nr of random post-mortem radiographs picked from Set 2:	**Set 1**	**Set 2**
1.	1002	2400
2.	1007	0729
3.	1009	5102
4.	1012	4237
5.	1015	0965
6.	1016	7364
7.	1022	1543
8.	1023	6745
9.	1027	9826
10.	1030	6130
11.	Non matching	6491
12.	Non matching	8273

Table 2: *The result of examiners matching 12 radiographs of Set 2 with the 30 radiographs of Set 1.*

Examiner	Score
1.	10/12
2.	12/12
3.	12/12
4.	12/12
5.	12/12
6.	12/12
7.	12/12
8	12/12
9.	11/12
10.	11/12
11.	12/12
12.	12/12
13.	12/12
14.	12/12
15.	12/12
16.	12/12
17.	12/12
18.	12/12
19.	12/12
20.	12/12

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12. ®: Z100 Composite (3M ESPE)

Address for correspondence:
Prof. VM Phillips
University of the Western Cape
Private Bag X1
Tygerberg 7505
Email: vmphillips@uwc.ac.za

BIOMECHANICAL APPROACH TO HUMAN BITEMARK RECONSTRUCTION

G. Radford [1], J.A. Kieser[1], V. Bernal[2], J.N. Waddell[1], A. Forrest[3]

[1] *University of Otago, New Zealand*
[2] *Universidad Nacional de La Plata, Argentina*
[3] *Griffith University, Queensland, Australia*

ABSTRACT

This paper investigates the changes in upper and lower dental bite records that occur when the anterior teeth occlude into a three-dimensional rather than a flat object. Methods: anterior bite registrations were obtained from 20 volunteers with full and unrestored dentitions. As a three-dimensional, life-like bite target we cast a silicone replica from the impression of an actual arm, fitted with a rigid bony interior. Each participant was asked to bite into a single layer of softened bite registration wax wrapped around the same location on the fake arm, as well as into a flat wafer of the same material. Upper and lower bite registrations were then scanned in the same location on a flat bed scanner. We analysed the sizes of the different bite marks by means of landmark- and semi-landmark analysis to calculate Procrustes distances between tooth outlines. In order to analyse shape variation between the two types of bite registration we carried out principal components analyses on the partial warp scores. These were derived from partial Procrustes coordinates aligned by means of thin-plate spline decomposition based on a bending energy matrix.

Our results show that there are significant differences in the shape of the upper or lower teeth when they occlude into a flat or three-dimensional target.

We conclude that the use of a traditional flat bite registration in human bitemark reconstruction and analysis has to be seriously questioned.
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Keywords: tooth shape, bitemarks, odontology

INTRODUCTION

A bitemark is the physical end-product of a complex set of events that occur when human or animal teeth are applied to the skin or foodstuff. Odontologists have traditionally based their analyses of bitemarks on the subjective visual comparison of a purported injury on the skin or food with photographs and study models of the biter's teeth. This method relies heavily on two premises; firstly, that skin can faithfully capture details of the indenting occlusal surfaces of the teeth and secondly, that the anterior dentition is unique with respect to size, shape or arrangement of the teeth.[1,2,3] However, despite computational advances, bitemark analysis continues to rely on the two-dimensional analysis of three-dimensional events.[4,5] This paper investigates the differences in upper and lower dental bite records that occur when the anterior teeth occlude into a three-dimensional rather than into a flat object.

MATERIALS AND METHOD

Anterior bite registrations were obtained from 7 volunteers with full and unrestored dentitions. As a three-dimensional, life-like bite target we cast a silicone replica from the impression of an actual arm, fitted with a rigid bony interior (Fig.1). Each participant was asked to bite into a single layer of softened bite registration wax wrapped around the same location on the fake arm, as well as into a flat wafer of the same material (Fig.2). Upper and lower bite registrations, as well as the occlusal surfaces of upper and lower dental casts of each participant were then scanned in the same location on a flat bed scanner. We analysed the sizes of the different bite marks by means of landmark- and semi-landmark analysis to calculate Procrustes distances between tooth outlines. In order to analyse shape variation between the two types of bite registration we carried out principal components analyses on the partial warp scores. These were derived from partial Procrustes coordinates aligned by means of thin-plate spline decomposition based on a bending energy matrix.

Fig.1: A three-dimensional, life-like bite target cast as a silicone replica from the impression (top) of an actual arm (bottom), fitted with a rigid bony interior.

RESULTS AND DISCUSSION

Fig.3 shows the results of a relative warp analysis of the upper dentition. There is poor association between the three variables; occlusal surface, squash bite and arm bite (m_{12}= 0.6334; p = 0.1257, based on 10000 permutations). In contrast, lower teeth show a significant association between these variables (m_{12}= 0.8614; p = 0.0154, 10000 permutations).

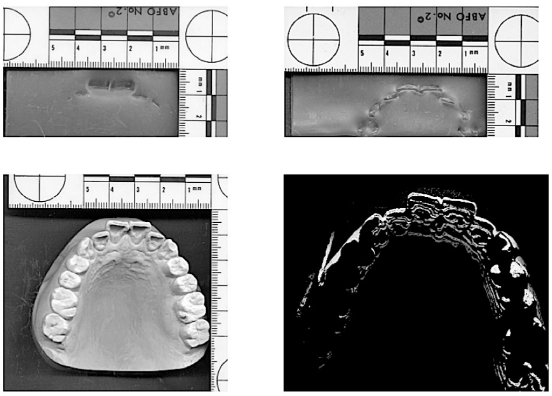

Fig.2: *Top left - arm bite in wax, right squash bite; Bottom left - biter's model, right - laser reconstruction of anterior teeth.*

Irrespective of the sophistication of the method used, bitemark analysis rests on two premises; firstly, that each individual's teeth are unique and secondly, that the material bitten can accurately convey an impression of the biting tooth surfaces.[2,3] This project tests the hypothesis that teeth leave the same impression on a surface, irrespective of its three dimensional shape of the object bitten. Our results show that while for each jaw, occlusal surfaces, squash-bites and arm-bites were highly co-ordinated there were notable differences in the shape imprinted by the upper teeth when they occluded into a flat or a three-dimensional target.

Jaw opening obviously varies with differences in size and consistency of the object bitten. Hence large, tough objects will require a large jaw opening.[6] Early studies have speculated that the extent of vertical separation of the teeth and jaws beyond the freeway space my have a marked effect on magnitude and path of biting force.[7,8] Recently, Haggman-Erikson and Eriksson[9] have shown that during biting and chewing, there was a degree of neck extension that was highly coordinated with jaw opening. Larger head movements were correlated with larger size and harder texture of the bolus. The implication for human bitemarks is clear; the larger the three dimensional object bitten and the tougher it is, the more the neck will flex as the jaw opens and consequently, the more the mandibular path will be altered during forceful closing. Clearly, this means that two joints are operational; the TMJ as well as the atlanto-occipital joint. By extension a squash bite registration only records a bite resultant from the mandible closing at the TMJ, and disregards the trajectory travelled by the teeth when both the jaw and the neck moves during hard biting on a large object. The small shift in head position seen before the start of a forceful bite on a large object implies that the upper teeth are repositioned in an anticipatory position, relative to the lower anterior teeth. This could correspond to our finding of a poor association between the three mandibular variables; occlusal surface, squash bite and arm bite. Taken together, we conclude that the use of a flat bite registration such as a squash-bite in human bitemark reconstruction and analysis may have to be questioned.

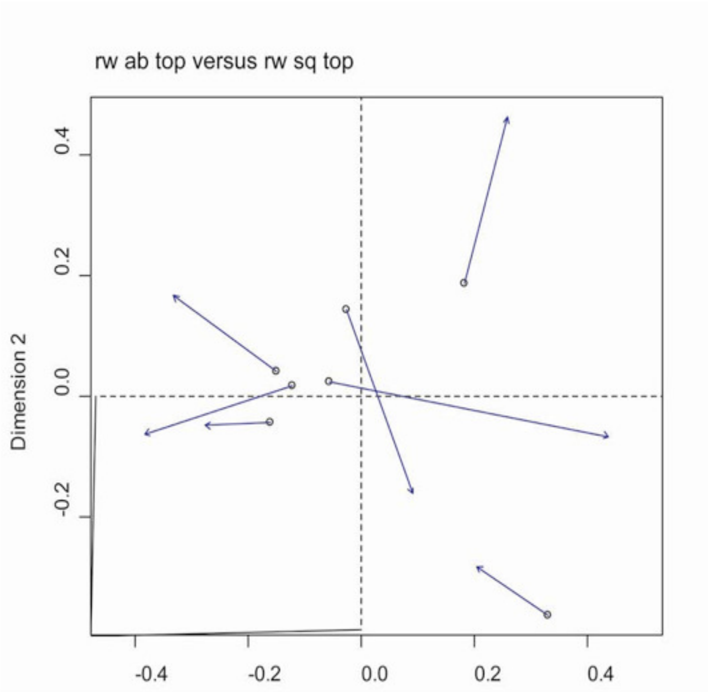

Fig.3: *Relative warp analysis of bites by upper teeth. ab: arm bite; m: model; sq: squash. Poor association (m_{12} = 0.6334; p = 0.1257, based on 10000 permutations).*

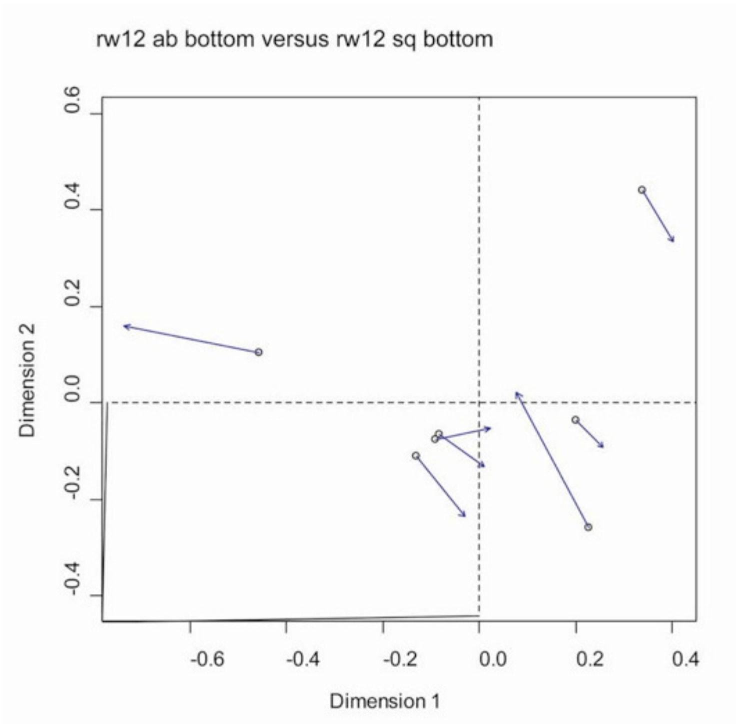

Fig.4: *Relative warp analysis of bottom bite. ab: arm bite; m: model; sq: squash. Significant association (m_{12} = 0.8614; p = 0.0154, 10000 permutations).*

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Address for Correspondence:
Prof. JA Kieser
Sir John Walsh Research Institute
Faculty of Dentistry
University of Otago
Dunedin
New Zealand
Fax: +64 03 479-7070
Email: jules.kieser@stonebow.otago.ac.nz