The use of panoramic images for identification of edentulous persons

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ABSTRACT

The aim of this study was to determine if edentulous persons could be identified using panoramic images by: I) investigating the possibility of matching two panoramic radiographs of the same person obtained on two different occasions, II) determining what anatomical features are used as the base for matching, III) investigating if oral and maxillofacial radiologists (OMR) and dentists who were not oral and maxillofacial radiologists (NOMR) differed in their ability to match the images, and IV) determining if the time elapsed between the images affected the results or the confidence of the match. Panoramic image pairs from 19 patients obtained on two different occasions were included, plus 10 images from other edentulous patients. The time elapsed between the image pairs varied between 4 months and 6 years. Four OMR and four NOMR were asked to match the image pairs depicting the same patient. The participants marked each match as "certain", "likely", or "possible" and what anatomical structure they used for matching. The OMR group correctly matched 100% of the images and the NOMR group correctly matched 96%. The anatomy of the mandible was most often used for matching. The OMR group was more certain in their decisions than the NOMR group. The time elapsed between the examinations did not affect the result. In conclusion, panoramic images can be used to identify edentulous patients. Both OMR and NOMR could identify edentulous individuals when only panoramic radiographic images were available and the OMR were especially confident in the identification process.

INTRODUCTION

Several studies have demonstrated the possibilities and importance of forensic odontology in human identification.[1-3] Intra-oral radiographic images including teeth are particularly helpful in the identification process due to large variations in the number of teeth, teeth anatomy and dental treatment. After the tsunami disaster in Asia in 2004, 79% of the deceased were identified using forensic odontology based on intra-oral radiography alone and 87% were identified when it was used in combination with other methods.[4] Also, panoramic radiographs have been used as a base for identification.[5-7] In this single image, a large number of characteristic features can appear.[8] Computer programs have been developed for automatic matching of panoramic images. However, this

automatic matching is highly dependent on sufficient dental characteristics in the images.[9]
The 2010 global prevalence of edentulism was 2.3% (158 million people). This is a large group of individuals; thus, studies of the possibilities to identify deceased edentulous people are of importance.[10] Panoramic radiographic examinations are often performed on edentulous patients. These images often disclose retained roots and/or pathological lesions. In a study by Serman and Nortje, pathological lesions were seen in 47% of the 539 studied panoramic radiographs. In the same material, 412 retained roots were found. The authors concluded that the combination of pathology and the varying anatomy have important forensic implications.[11] The study also showed that a large number of edentulous people do not have retained roots and/or pathological lesions.
The bone resorption that occurs after tooth loss can impede the ability to identify edentulous people by means of radiographs. In a study of a group of patients wearing dentures, the use of panoramic images > 3 years old in the identification process was questioned. The reason for this was that changes in bony anatomy over time can affect the ability to make a correct match between ante-mortem and post-mortem images taken > 3 years apart.[12]
The panoramic technique is sensitive to misalignments of the patient and this can lead to image distortion. However, it has been shown that the inner bony structures in the study, represented by mathematical anatomical models, can be recognised in panoramic images in spite of the distortion due to different patient positioning.[13]
It is known that dentists' qualifications, with respect to experience and training, affect the accuracy of radiographic identification.[14,15] It has also been shown that oral and maxillofacial radiologists (OMR) have better accuracy than dentists who are not oral and maxillofacial radiologists (NOMR) when studying radiographs in cases with reduced dental characteristics. This was seen in a study that aimed to match bitewing examinations performed within 1-3 years on 6-13 year-old children with un-restored dentitions.[16] The OMR have also shown higher success rates than NOMR when using intra-oral radiographs to identify edentulous individuals[17] and edentulous individuals treated with implants.[18] However, it is unclear if it is possible to match panoramic examinations obtained on different occasions of edentulous individuals without distinctive pathological lesions or retained teeth and/or roots and if there is a difference between OMR and NOMR in the success rate when performing such matches.
The aims of this study were: I) investigate the possibility of matching two panoramic radiographs of the same person obtained on two different occasions, where the patient was edentulous on at least at one occasion, II) determine what anatomical features are important when identifying edentulous individuals using panoramic images, III) investigate if there is a difference between OMR and NOMR in their abilities to match these types of images, and IV) determine if the time elapsed between the images affected the results or the confidence of the match.

MATERIAL AND METHODS:

The study materials were collected from the archives at the Department of Oral Prosthodontics, University Hospital in Umeå (Norrlands Universitetssjukhus, NUS), Sweden. Inclusion criteria were two panoramic images obtained on different occasions of the same patient, where on at least one occasion the patient was edentulous and without implants, impacted teeth, pathological lesions, or foreign bodies. There were 217 patient records screened with 19 presenting two panoramic images that fulfilled the inclusion criteria. The panoramic examinations had been performed by different examiners. This resembles a realistic scenario where the ante-mortem panoramic images are compared with panoramic images taken as part of the post-mortem examination. The elapsed time between the two images from the same patient ranged from 4 months to 6 years. Fourteen cases had images taken with 3 years or less between the images and five cases had an elapsed time >3 years.
Ten extra panoramic images of edentulous patients were added to complicate the task so that not all images had a match. All images were anonymised. In the ante-mortem images, the patients had teeth (8 cases) or were edentulous (11 cases). In the post-mortem images, the patients were either edentulous (20 cases) or edentulous and treated with implants (9 cases). The images were placed in two PowerPoint presentations. One presentation represented ante-mortem images marked with the numbers from 1-19 and the patient's gender and age. The other

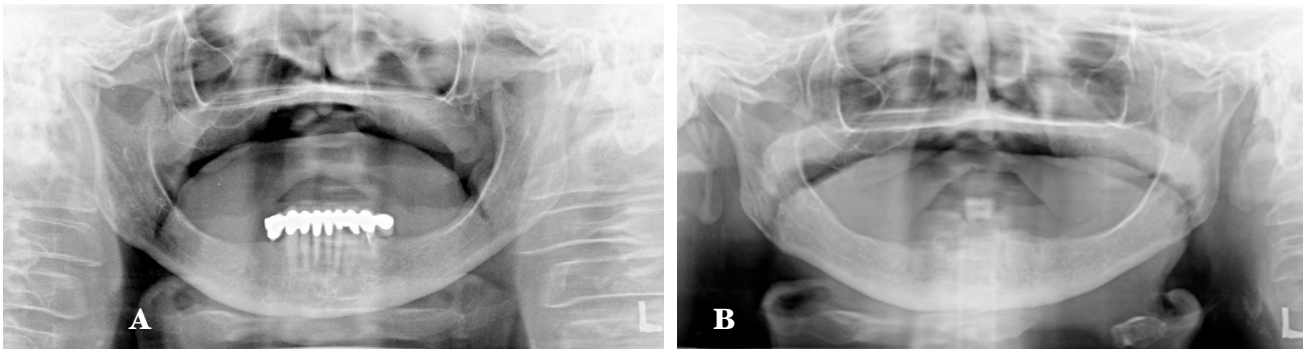
presentation (29 images) represented post-mortem images that were marked with letters and the patient's gender. It was possible to look at the two PowerPoint presentations at the same time and independently of which presentation, to scroll among the images and to zoom in and out. The presentations were installed on a computer assigned for the test. The task was performed by four OMR and four NOMR all working at the University Hospital of Umeå, Sweden. There were three general practitioners and one oral and maxillofacial surgeon in the NOMR group. The material was available for one month on the assigned computer at the department of Oral and Maxillofacial Radiology, Umeå University and the participants were free to choose when, during this period, to complete the task. Two participants were not able to use the assigned computer. They were given the material on an USB-drive to use on their own computers.

All participants received a form in which to fill in their assessments. They were asked to evaluate each match with respect to their confidence in their decision using one of the following words: "certain", "likely", or "possible". In each case, they also filled in which anatomical structures or other features they used to match the images. Other features could be, e.g. deviant anatomy or any other feature they noticed in the images. The forms were anonymous except for their declaration of being an OMR or NOMR. All assessors provided their informed consent to participate in the study. The study was performed in accordance with the principles of the Helsinki Declaration. Fisher's exact test and Pearson Chi-square test were used for statistical analyses.

RESULTS

All participants completed the study. The OMR group had 100% correct matches, while the NOMR group had a mean of 96% correct matches (min: 16, max: 19). This difference was not statistically significant, (p=0.1). In total, three cases were not correctly matched by one participant in the NOMR group. Figure 1 shows one of these cases.

Figure 1. "Ante-mortem" (a) and "post-mortem" (b) image of one of the cases that was not correctly matched by all of the dentists who were not oral and maxillofacial radiologists (NOMR).



The mandible information was most often used (95% of matches) in the matching for all participants (Fig. 2). The OMR used the mandible in 100% of their matches, and the NOMR group used it in 89% of their matches. The maxilla was used by the OMR group in 76% and the maxillary sinus in 88% of the matches compared with 59% and 53% respectively in the NOMR group. A variety of other anatomical features, such as soft tissue; bone patterns in the nasal region, orbit, and ears; and carotid calcification, were also used in the matching process predominantly in the OMR group. (Fig. 2).

The participants in the OMR group were "certain" in 92% of the matches; while, in 7% of matches they considered it "likely" that the images depicted the same person and in 1% they considered it "possible". All their matches were correct. The NOMR group was "certain" in 42% of the matches and all were correct. In 46%, they considered it "likely" that the images depicted the same person and 94% were correct. They considered it "possible" in 12% of the matches and 89% were correct. There was a statistically significant difference between the groups regarding the confidence in their matches, ($p \leq 0.008$) (Table 1). In 74% of the cases, the time between the images to be matched was ≤ 3 years. In the remaining 26%, the time was > 3 years. This time limit was used because of an earlier study questioning post-mortem panoramic images older than 3 years.[12]

Figure 2. Proportion of cases (%) in which various anatomical structures or other details were used by oral and maxillofacial radiologists (OMR) and dentists who were not oral and maxillofacial radiologists (NOMR) when matching panoramic images of edentulous individuals obtained on different occasions

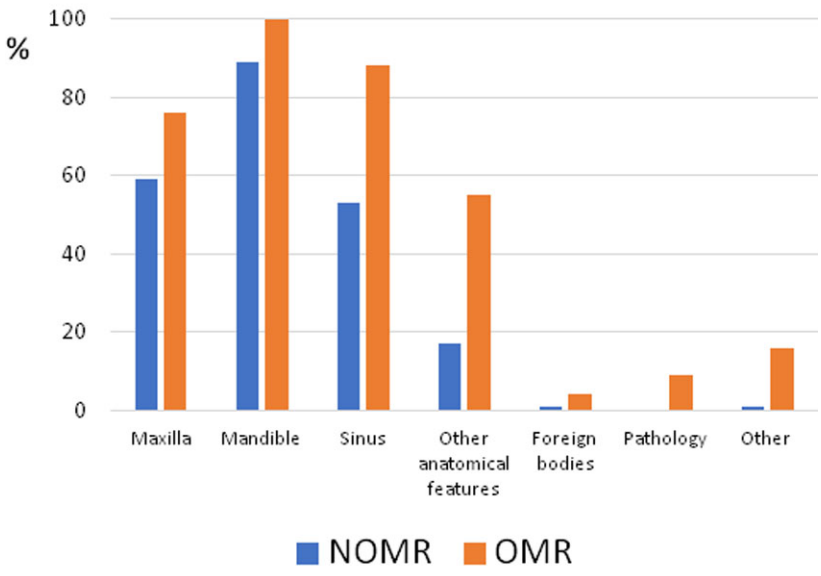


Table 1. Proportion of matches evaluated as "certain" by the oral and maxillofacial radiologists (OMR) and the dentists who were not oral and maxillofacial radiologists (NOMR) for all cases and separated by the time elapsed: ≤3 years and >3 years.

Time elapse between panoramic examinations	Proportion of matches evaluated as "certain"		P-value*
	by OMR	by NOMR	
0-6 years (n=19)	92%	42%	0.001
≤3 years (n=14)	91%	38%	0.001
>3 years (n=5)	95%	55%	0.008

*Pearson Chi Square

The participants in the OMR group were "certain" in 92% of the matches; while, in 7% of matches they considered it "likely" that the images depicted the same person and in 1% they considered it "possible". All their matches were correct. The NOMR group was "certain" in 42% of the matches and all were correct. In 46%, they considered it "likely" that the images depicted the same person and 94% were correct. They considered it "possible" in 12% of the matches and 89% were correct. There was a statistically significant difference between the groups regarding the confidence in their matches, ($p \leq 0.008$) (Table 1). In 74% of the cases, the time between the images to be matched was ≤ 3 years. In the remaining 26%, the time was > 3 years. This time limit was used because of an earlier study questioning post-mortem panoramic images older than 3 years.[12]

When assessing image pairs obtained within a short time period (≤ 3 years), the OMR group thought the match was "certain" in 91% of the

cases, "likely" in 7%, and "possible" in 2%. These answers were all 100% correct. For the NOMR group, the match was "certain" in 38% of cases and all were correct, "likely" in 48% (93% correct), and "possible" in 14% (90% correct). When assessing cases with a long time-period (>3 years) between the images, the OMR group thought the match was "certain" in 95%, "likely" in 5%, and "possible" in 0%. The NOMR group thought the match was "certain" in 55%, "likely" in 40%, and "possible" in 5%. All of the matches of these cases were correct in both groups. The OMR group was statistically significantly more often certain than the NOMR group, irrespective of the time elapsed between the examinations (Table 1).

DISCUSSION

The results of this study show that it is possible to use panoramic radiographic images to identify edentulous individuals. There were four OMR and four NOMR who conducted the matching. The OMR group had more correct answers and was more certain than the NOMR group in their matches. The difference between the groups could indicate that the OMR group, based on their experience, has an advantage in analysing panoramic images. This is in accordance with earlier studies in which OMR had a higher success rate and greater certainty than NOMR when radiographs were compared.[16-18] There were three different scenarios in this study and correct matching was possible in all of them. In the ante-mortem images, the patients had teeth or were edentulous. In the post-mortem images, the patients were edentulous or edentulous and treated with implants. At least one of the two images in a correct match was edentulous. Most of the post-mortem images contained implants, which is now a common treatment.

It has already been shown that it is possible to use intra-oral radiographic examinations when identifying edentulous patients treated with implants.[8] The findings in this study show that it is also possible to use panoramic images to identify patients treated with implants or a full removable denture (FDR), irrespective of whether the ante-mortem and/or the post-mortem panoramic image shows an edentulous patient without pathological lesions and/or retained teeth or roots. In some countries, FDRs are marked with an ID number that can be used to identify the patient. This could be of value in an identification process of edentulous patients with a FDR.[19] Although, since this method is not yet applied in every country, panoramic examinations can be of great value for identifying edentulous individuals. When using panoramic images in the identification processes, one has to consider many aspects of the technique used to obtain the images. For example, the person should be positioned correctly in the machine and stay still during the exposure. These factors may vary in the ante-mortem images. In post-mortem images, the risk for movement artifacts is negligible. The positioning of the head can, however, be different in the ante-mortem image. It has been shown that two panoramic images taken with different alignments of the examined object present inner structures that are recognisable in spite of the distortion.[13] Therefore, a correct match can be made using two panoramic images with different distortions.

In most cases, both OMR and NOMR used the mandible to make correct matches. This may be explained by the fact that the middle face is more difficult to depict because of the complex anatomy combined with the relatively complicated technique that is the basis for creating panoramic radiographic images. The mandible does not have the same complex anatomy and is not surrounded by other bony details that can be superimposed on the image of the mandible. Therefore, the mandible appears more clear in the images.[20] In a few cases, minor foreign bodies or a pathology, not noticed when selecting the cases, was detected and used by the OMR. An advantage of panoramic images is that they depict anatomical structures outside the tooth bearing areas, revealing e.g. bone patterns in the nasal region, orbit, ears and the region for carotid arteries with possible calcifications, all of which would not appear in intra-oral radiographs. Another advantage is that many anatomical structures are visible in one image and this can facilitate the identification process.

The usefulness of ante-mortem panoramic images older than 3 years in the identification process has been questioned.[12] In the present study, there were five ante-mortem panoramic images that were at least 3 years older than the matching post-mortem image. In one case, the elapsed time between the matched images was 6 years. The OMR group was more certain than the NOMR group when matching images irrespective of the time elapsed between the images and this could

probably be explained by their experience in analysing panoramic images. On the other hand, in both the OMR and NOMR groups, neither the confidence nor the correct matches were affected by the time elapsed between the ante-mortem and post-mortem images in this study. This means that in the cases containing panoramic images taken > 3 years apart, the remodeling of the bone and other changes that could have occurred over time did not affect the ability to correctly match. Based on these results, there is no reason to exclude panoramic images taken more than 3 years before the post-mortem image. However, the low number of cases with ante-mortem images older than 3 years in this study may affect the reliability of this result. However, the current results do contradict the conclusions drawn in the study by Richmond et al. in 2007 about not using ante-mortem and post-mortem images taken > 3 years apart.[12]

This study indicates that the identification of edentulous patients with panoramic images is reliable. However, panoramic examinations are normally performed with the person sitting or in a standing position. Since the production of the Zonarc® (Palomex Oy, Helsinki, Finland) and LPX7007 (ASAHI ROENTGEN, Japan) ceased, to our knowledge no panoramic equipment allows examinations with the patient in the supine position. This may be a practical problem when performing post-mortem panoramic examinations. In cases with loose body parts, e.g. the mandible and/or cranium, post-mortem panoramic examinations can be performed in conventional panoramic machines using suitable stands, support and if necessary, tissue equivalent material compensating for missing tissue, such as the cervical spine.[21] In cases with intact bodies, an alternative method for radiographic examination could be the use of cone beam computed tomography (CBCT) or conventional computed tomography (CT). In conventional CT and in some CBCT machines, patients are examined in a supine position. Some software allows the creation of images similar to panoramic examinations based on the three-dimensional data sets created in CT.[22-25] When examining edentulous patients, the problem with metal artifacts appearing in CT images is generally not a problem. However, it is unclear to what extent the reformatted images created from CT data are comparable to panoramic images created using conventional panoramic equipment with an entirely different technique.

CONCLUSION

Panoramic images can be used to identify edentulous persons. Both OMR and NOMR could successfully identify edentulous individuals in cases where only panoramic radiographic images were available. As the OMR were 100% correct in their matches and were more confident in their decisions, their knowledge could be especially valuable in the reconciliation process.

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