EFFICACY OF DIGITAL IMAGE PROCESSING TECHNIQUES IN INTRA ORAL DENTISTRY

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***Abstract*— Medical image processing is essential in many fields of medical research and clinical practices because it greatly facilitates early detection and diagnosis of diseases. This paper surveys an add-on approach in the area of medical image analysis for diagnosis of diseases in oral radiology using dental Xrays in dentistry. In case of medical images human involvement and perception is of prime importance. It is indeed a difficult task to interpret fine features in various contrast situations. The raw data obtained directly from X-ray acquisition device may yield a comparatively poor image quality representation. Because of the role of a human (dentist) interpretation based on his knowledge, experience and perception which may differ from doctor to doctor; there are chances of error in deciding the right medical treatment. Software developers along with domain experts have designed various standardized and scientific tools to minimize the human error in the case of deciding the right treatment on the basis of visual perception. One of the aims of this paper is to focus on the extracted part of the tooth from digital dental X-ray, finding the required information in the form of features and helping the dentist in the form of pre-diagnosis suggestions at an early stage.**

Keywords- Dental radiograph (X-ray), dentistry, image enhancement, segmentation, feature extraction, software's for dentistry.

1. INTRODUCTION

The importance of the medical imaging in healthcare is constantly growing, making health care more effective and patient friendly. With innovative imaging technologies diseases can be detected at an early stage and with more accuracy. They can be treated more specifically and are less invasive hence the therapeutic result can be closely monitored. Image post-processing of digital dental radiographs are used commonly in dental practices. Digital radiography has been available in dentistry for more than 25 years and its use by dental practitioners is steadily increasing. Digital acquisition of radiographs enables computer-based image post-processing to enhance image quality and increase the accuracy of interpretation. Image post-processing applications can easily be practiced in dental office by a computer and image processing program.

1.1 Digital Dental Radiograph (X-rays)

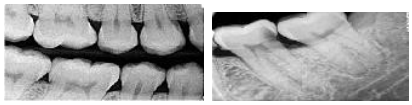
Dental Radiographs (X-rays) are a type of picture of the teeth and mouth. X-rays are a form of electromagnetic radiation, just like visible light. They are of higher energy and can penetrate the body to form an image on film. Structures that are dense (such as silver fillings or metal restoration) block most of the photons and appear white on developed film. Structures containing air appear as black on film while teeth, tissue, and fluid appear as shades of gray. Dental X-rays help to find problems with the teeth, mouth, and jaw. Dental X-ray pictures can show cavities,

hidden dental structures (such as wisdom teeth), and bone loss that cannot be seen during a visual examination. They are very useful in detecting the early stages of decay between teeth.

Compared to traditional X-rays, only half the dosage of radiation is needed for obtaining a dental X-rays of comparable quality. They do not require time for film development, so dentists need to wait for only a few seconds before the acquired image is displayed. Dentists can take another image instantly if the acquired image is not of good quality, so in general digital dental X-rays in a patient's record have better image quality than conventional dental X-rays. Mainly due to their advantages in speed, storage, and image quality, digital dental X-rays are now routinely used.

1.2 Types of Dental Radiographs: **-** There are four types of dental radiographs (X-rays) [4]:

- **Bitewing**: - The bitewing type of X-ray is when the patient bites on a paper tab and shows the crown portions of the top and bottom teeth together as shown in Figure 1(a). This type of X-ray shows the upper and lower back teeth and how the teeth touch each other in a single view [4]. These X-rays are used to check for decay between the teeth and how well the upper and lower teeth line up. They also show bone loss when severe gum disease or a dental infection is present. The planes of the detector and the cone are aligned parallel in bitewing X-rays. This arrangement makes bitewing X-rays give exact view of the internal structure of the teeth
- **Periapical**: - The periapical type of X-ray shows one or two complete teeth from crown to root as shown in Figure 1(b).

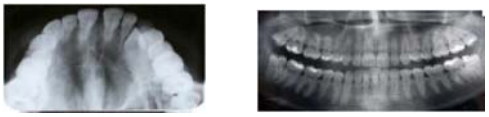


(a) Bitewing Dental X-ray (b) Periapical Dental X-ray

Figure 1 Various types of dental X-rays

{Courtesy: Dr. Ronak Panchal}

- **Palatal (also called occlusal)**:- This type of X-ray captures all the upper and lower teeth in one shot while the film rests on the biting surface of the teeth as shown in Figure 1(c).
- **Panoramic**: - A panoramic type of X-ray requires a special machine that rotates around the head. The X-ray captures the entire jaws and teeth in one shot as shown in Figure 1(d).



(c) Palatal Dental X-ray (d) Panaromic Dental X-ray Figure 1 Various types of dental X-rays

{Courtesy: Dr.Ronak Panchal}

These X-rays do not find cavities. They are used for dental implants, to check for impacted wisdom teeth, and to detect jaw problems. A panoramic X-ray is not good for detecting cavities, unless the decay is very advanced and deep. These X-rays show problems such as *impacted teeth, bone abnormalities, cysts, solid growths (tumors) , infections, and fractures*. With the development of digital imaging technology, digital X-ray machines are becoming popular in dental clinics [2].

Dentist manipulates the indicator cone behind the teeth where area of diagnosis is required. The indicator cone is operated from outside the position and orientation of the film adjusted inside the mouth to get exact projection.

The paper is organized as follows: Section 2 comprises of basic background related to oral radiology and tooth structure. Section 3 is divided into three parts. First part of this section provides a literature review on image enhancement in dental X- ray images. Second part of the survey section is literature review on image segmentation, feature extraction and involvement of dental X-ray images on forensic sciences. Major work done in this domain is concentrated towards human identification [4], [5], and [6]. Last sub section comprise of comparative analysis of software's available in the market that helps dentists to analyze based on dental radiographs.

2. BACKGROUND

2.1 Basics of Tooth Structure

Dental anatomy is a field of anatomy dedicated to the study of human tooth structures. The development, appearance, and classification of teeth fall within its purview. Tooth formation begins before birth, and teeth's eventual

morphology is detected during this time. This basis tooth structure is shown in Figure 2.

Dental anatomy is also a taxonomical science: it is concerned with the naming of teeth and the structures of which they are made, this information serves a practical purpose in dental treatment. Usually, there are 20 primary ("baby") teeth and 28 to 32 permanent teeth, the last four being third molars or "wisdom teeth", each of which may or may not grow.

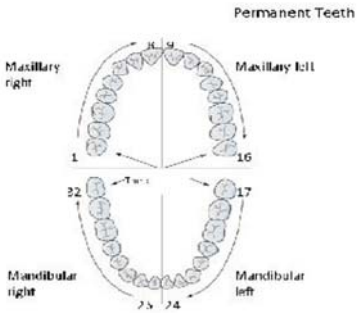


Figure 2 Dental Anatomy { Courtesy: Dr. Ronak Panchal }

Among primary teeth, 10 usually are found in the maxilla (upper jaw) and the other10 in the mandible (lower jaw). Among permanent teeth, 16 are found in the maxilla and the other 16 in the mandible. Most of the teeth have distinguishing features. Figure 3 refers to a healthy tooth cut in half lengthways showing the layers of the tooth and its internal structure, as well as how the tooth relates to the gum and surrounding jaw bone.

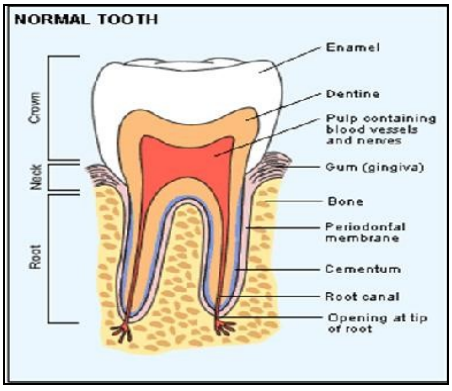


Figure 3 Tooth Structure [Courtesy by Dr. Ronak Panchal]

- **Crown.** It is the part of the tooth that is visible above the **gum (gingiva)** and is covered with enamel which protects the underlying dentine [7].
- **Neck.** It is the region of the tooth that is at the gum line, between the root and the crown.
- **Root.** It is the region of the tooth that is below the gum. Some teeth have only one roots, for example, incisors and canine ('eye') teeth, whereas molars and premolar shave 4 roots per tooth.
- **Enamel.** It is the hardest substance in the human body, harder even than bone. It gains its hardness from tightly packed rows of calcium and phosphorus crystals within a protein matrix structure. Once the enamel has been formed during tooth development, there is little turnover of its minerals during life. Mature enamel is not considered to be a 'living' tissue [9].
- **Dentine.** The major component of the inside of the tooth is **dentine**. This substance is slightly softer than enamel, with a structure more like bone. It is elastic and compressible in contrast to the brittle nature of enamel. Dentine is sensitive. It contains tiny tubules throughout its structure that connect with the central nerve of the tooth within the pulp. Dentine is a 'live' tissue.
- **Pulp.** The **pulp** forms the central chamber of the tooth. The pulp is made of soft tissue and contains **blood vessels** to supply nutrients to the tooth, and **nerves** to enable the tooth to sense heat and cold. It also contains small lymph vessels which carry white blood cells to the tooth to help fight bacteria.

3. REVIEW

The overall survey is presented into three subsections. The first subsection presents review of image enhancement methods for dental X-ray images. The second subsection focuses on review of various techniques used for image segmentation and feature extraction. This subsection also discusses the use of dental X-rays in forensic applications. The last subsection covers a brief review on the software's used by the dentists to analyze X-rays based on various parameters.

3.1 Review in Dental X Ray images based on image enhancement

Bardia Youseif et.al. [2] Developed a technique for image enhancement of digital dental X-ray using the wavelet image fusion and Bayesian classifier. One of the bases of such systems was generating better concepts of location of teeth and canals in dentistry applications such as Root

Canal Treatment (RCT). For this purpose, the Laplacian transform was applied to the image, and then structure element along with morphological operation was used. Afterward, the obtained image was fused by using wavelet transform with input image and the next step was Bayesian classifier which classified teeth and canals from achieved image. Finally, the outcome image was fused second time to original image by wavelet image fusion technique. Figure 4 infers to two such resultant images.

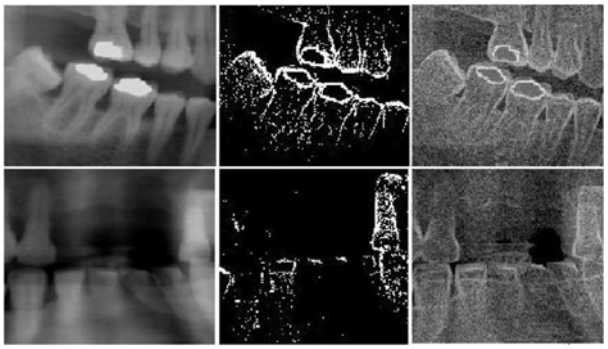


Figure 4 Two different samples of digital dental X-ray and the resultant images using the Bayesian classifier and wavelet fusion [2]

This approach was applied to the 30 dental radiographs. However the limitation of the suggested approach was that the number of teeth having the same intensity as the background cannot be detected. The classification accuracy was highly affected and fine particles of gum area were not visible for analysis purpose.

In 2008, Stefan Opera et.al. Proposed a method [3] showing how image processing techniques help to check the dental X-ray and examine the extent to which the caries lesion is present and then classify the type of caries present in the dental radiograph. Their software was based on object oriented concepts in which manual selection of threshold was required. Moreover, their database was limited to 5 images only. Hence, standardized method was not present to testify the pre diagnosis in a proper way. Ahmed et.al. [12] Have compared the original intra oral digital dental radiograph images with images that are enhanced using a combination of image processing algorithms. As these images are noisy, blur edges & lower in contrast. They have used three types of compound algorithms namely sharp adaptive histogram equalization (SAHE), sharp adaptive median histogram equalization (SMAHE) & sharp adaptive contrast histogram equalization (SCLAHE). Detection of three pathological problems namely periapical radiolucency, widen periodontal ligament space and loss of lamina dura was being tried using above methods.

3.2 Review on Image Segmentation, Feature Extraction & Forensic Sciences in Dental X Ray Images

Eyad Haj et.al. [4] Presented an over view about an automated dental identification system for *Missing* and *Unidentified* persons. This dental identification system can be used by both law enforcement and security agencies in both forensic and biometric identification. The various techniques for dental segmentation of X-ray images to address the problem of identifying each individual tooth and how the contours of each tooth are extracted is presented. Their technique was not able to properly segment an X-ray by a single segmentation technique and it varied from image to image.

Dental biometric system have also been used in forensic science. In this system, as proposed by Shubhangi Dighe et.al. in 2012 [6] AM radiograph is matched with PM radiograph to identify unidentified individual. Dental biometrics consists of four steps as: pre-processing of dental radiograph, segmentation, feature extraction and matching of AM and PM radiograph. Segmentation is a method used for feature extraction like shape and size of tooth. These features are used in matching of two radiographs and based on this matching, individuals can be identified. In this paper segmentation is used to extract single tooth and also for the dental work extraction as shown in figure 5.

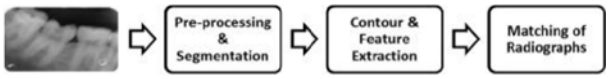


Figure 5: Block Diagram of Dental Identification System [6]

In [5] the authors present a match of X-ray teeth films using image processing based on special features of teeth. This method helps the dental doctors to match simply a pair of teeth using the special features of the teeth films. Teeth's pictures are scanned and adjusted by a scanner and a computer, respectively, as well as then they are converted into binary code and decoded to the direction code (chain code). Chain

code is a method for decoding a direction code from the binary images based on the special features of teeth. The chain code of each picture is compared with the statistical chain code. Therefore, the percentage of the same chain code is approximately 90% (i.e. matching same patterns) for the comparison of one root to one root (7 times) and two roots to two roots (7 times) while the percentage of the same chain code is reduced at relatively below 50% (i.e. matching different patterns) for comparison of one root to two roots (2 times). The percentage of the same chain code is approximately 90% (i.e. matching same patterns) for the comparison of one root to one root (7 times) and two roots to two roots (7 times) while the percentage of the same chain code is reduced at relatively below 50% (i.e. matching different patterns) for comparison of one root to two roots (2 times).

In [15], the degree of similarity/overlap between two radiographs is obtained by weighted sum of squared differences (SSD) cost function. This method was tested on a database of 571 radiographs belonging to 41 distinct individuals. Figure 6 shows an overview of this process. A total of 150 identification scenarios were taken then each single ROI was [identified/extracted] for comparing and matching with the dental x-ray images.

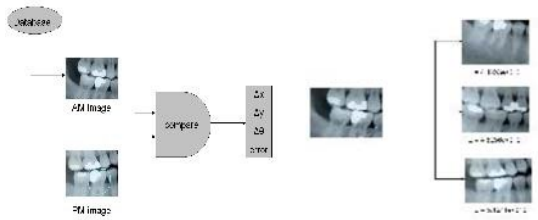


Figure 6 - Illustration of the identification test run & top three radiographs in the database ranked by the associated cost. [15]

The authors proposed a computer-aided framework for matching of dental radiographs based on a sum of squared differences cost criterion. In their framework, the operator would define the ROI by roughly circling the tooth of interest on a given post-mortem radiograph. Hence, even untrained staff able to participate in the identification efforts by roughly circles the tooth area. The system itself then matches the selected region to radiographs found in the ante mortem database. For all possible shifts, the best brightness and contrast adjustment and rotation were computed, and the parameters that yielded the lowest cost are recorded along with the associated cost (match score). The radiographs in the database were then ranked according to the cost, with the lowest cost indicating the best match. This work was not tested on multiple ROI's as well as on different dental images.

Lailee Shaiaf et.al. [18] Investigated the fundamental problems in image segmentation using traditional segmentation techniques and proposed an improved technique for segmenting images captured under natural environment. Due to non-uniform illumination it is difficult to produce a significant threshold value along with lack of difference in reflection. Since different illumination may produce different colour intensity of the object surface and thus lead to inaccurate segmented images. The widely used traditional method for thresholding is ostu and fuzzy c-means respectively. In this method, the authors have added a step extra after thresholding with ostu method by converting the gray scale image into binary & then integrating the modified threshold algorithm with an inversion technique. The results were analyzed based on rand index function. By this the authors have concluded that the images after ostu method and thresholding which were not able to get separate and provide the required information are now being able to separate the interest area & background easily. The ability of this technique therefore has the potential to classify the poor images with inconsistent illumination condition.

Dental biometrics can be used in forensic science for human identification. It utilizes dental radiographs. This radiograph provides information related to teeth shape, teeth contour and relative position of neighboring teeth, also it gives shapes of dental work like crowns, filling & bridges etc. Different methods used for dental biometrics and related information are included in [16]. Dental biometrics requires ante mortem (AM) and post mortem (PM) radiographs for finding unidentified subject. Dental biometrics having three stages: Pre-processing and segmentation of radiographs, contour extraction or dental work extraction, atlas registration and matching. Segmentation can be done by various methods. Contour or shape of teeth and dental work can be extracted. Method or code was developed by the authors to locate teeth this is known as dental atlas registration. Numbering to teeth from left to right of jaw and also

differentiation between upper jaw and lower jaw was done, which help in the matching stage [16].

Omaima Nomir et.al. [17] Presents a system in which, given a dental image of a post-mortem (PM), the proposed system retrieves the best matches from an ante mortem (AM) database. The system automatically segments dental X-ray images into individual teeth and extracts the contour of each tooth. Features are extracted from each tooth and are used for retrieval. During retrieval, the AM radiographs that have signatures closer to the PM are found and presented to the user. Matching scores are generated based on the distance between the signature vectors of AM and PM teeth.

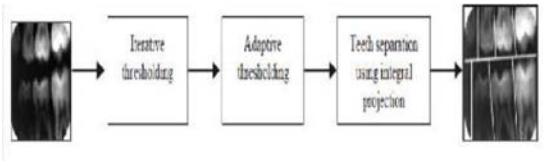


Figure 7 Block diagram of segmentation algorithm [17]

They introduced iterative and adaptive thresholding. Thereafter horizontal and vertical integral projection is used for separating the jaws as well as individual tooth. The block diagram of segmentation algorithm is as shown in Figure 7.This technique was not successful in matching images due to poor quality of images and shape of teeth could have changed with time as PM images were taken after a long time AM images were captured.

3.3 Review Based On Dental Software Programs

TM Lehmann et.al. [19] contributed greatly in a technical report regarding identifying and analyzing various methods for image processing provided by various commercial software programs used in digital dental imaging and to map them onto a standardized nomenclature. The features various software's like CDR, Clinicview,Dexis, Digora, Dimaxis, Emago Advanced, Friacom Dental, IOX Image Viewer, Multi X-ray, Proimage, Sidexis, Trophy, VixWin 2000 were discussed and compared in his work. The comparison of the software programs were analised based on following parameters:

Image Display: - Half of the programs mentioned above have only 1D line profiles. Trophy software offers 3D. Six out of thirteen software's (Dimaxis, Emago, IOX Image Viewer, Multi X-ray, Sidexis, and Proimage) provide interpolating images to various sizes rest do not. Friacom even do not allow the image to rotate.

Point processing: - More than 50% of the software's do not provide gamma correction & require image transforms for the purpose of diagnosis. Only Dexis and Emago provide direct thresholding out of 13 software's. Dexis do not provide contrast enhancement. Only 3 (CDR, Clinicview, Dimaxis) have histogram equalization facilities that to stretches or clips and does not actually equalize.

Spatial and frequency filtering: - Only Emago provides user defined masks up to 7*7 pixels rest do not. Only five (Dimaxis, Emago, Multi X-ray, Proimage, Sidexis) have spatial domain filter facility that to only non-linear median filter. They are able to remove salt & pepper noise rest doesn't. None incorporates frequency domain filtering.

Measurements and image analysis: - Dexis, IOX, Multi Xray, Proimage cannot determine angles from dental X-rays. Only 3(Sidexis, Emago & Vix Win 2000) provide area facility. None incorporates ROI selection, zooming, deblurring, denoising, morphological operations etc.

4. Discussion

The major researchers make use of thresholding and morphological operation for feature extraction and segmentation. However, in the existing software's used by doctors the option of adaptive or global threshold is not available. Hence, the benefits of these methods are not directly available. Much of the work have been done for human identification, but very few researchers have applied and realized the methods for diagnosis purpose. For the diagnosis of intra oral diseases specifically the region of interest selection, impacted 3rd molar using x ray rendering of 3-D images and other related problems of gums and idiopathic resorption is still a missing feature in most of the software's. Interactive portions of X-ray selected for further processing specifically for the purpose of

diagnosis is the need of the hour as it would help both doctor and patient to understand the problem and depth of disease. No software is using AI tools such as neural networking, fuzzy c-means, etc. for the better understanding and diagnosis purpose. Researchers up till now have been found concentrating on image enhancement or segmentation for extracting features for forensic sciences. No much research has effectively contributed for the diagnostic methods. Automated or semi-automated diagnosis of aforesaid objectives would be quiet useful for doctor as well as patient. It has been found through detail in depth discussion with selected dental experts that as radiographic imaging study in medical practice provides better clue for diagnosis. Image processing & enhancement functions are rarely incorporated in commercial software for direct digital imaging in dental radiology. Until now, comparison of software was limited by arbitrary naming used in each system. Standardized terminology and increased functionality of image processing should be offered to the dental profession.

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REFERENCES

[1] G.A.Kulkarni, A.S.Bhide, D.G. Patil, S.S.G.B.C.O.E. & T., Bhusawal, "Two Degree Greyscale Differential Method for Teeth Image Recognition", International Journal of computer Application, 2012

[2] B. Yousefi , H. Hakim, N. Motahir, P. Yousefi1, M. M.Hosseini, "Visibility Enhancement of Digital Dental X-ray for RCT Application Using Bayesian classifier and Two Times Wavelet Image Fusion", Journal of American Science, pp 713, 2012

[3] Ş. Oprea, C. Marinescu , I. Liţă, M. Jurianu, D. A. Vişan, I. B. Cioc, " Image Processing Techniques used for Dental Xray Image Analysis" , Electronics Technology, ISSE 2008, pp 125-129

[4] E. H, said, G. Fahmy, D. nassar, H. Amar, "dental X-ray image segmentation" Biometric Technology for Human Identification, Proceedings of the SPIE, Vol. 5404, pp. 409417, 2004.

[5] S. Kiattisin, A. Leelasantitham, K. Chamnongthai , K. Higuchi, " A Match of X-ray Teeth Films Using Image processing Based on Special Features of Teeth" , SICE Annual Conference 2008, pp 35-39

[6] S. Dighe, R. Shriram, "Pre-processing, Segmentation and Matching of Dental Radiographs used in Dental Biometrics", International Journal of Science and Applied Information Technology,Volume 1, No.2, pp 52-56, May – June 2012

[7] R. B. Tiwari, Prof. A. R. Yardi, "Dental X-ray image enhancement based on human visual system and local image statistics"., International Conference on Image Processing, Computer Vision and Pattern Recognition, 2006, pp 100-108

[8] C. K. Modi , K. J. Pithadiya ,J. D.Chauhan, K. R. Jain, " Comparative study of Optimal edge detection algorithms for liquid level inspection in Bottles", International conference on Emerging Trends in Engineering and Technology , pp 447-452 , 2009 .

[9] E. H. Said, D. E. M. Nassar, G. Fahmy, H. H. Ammar. "Teeth segmentation in digitized dental X-ray films using mathematical morphology," IEEE Transactions on information forensic and security, vol. 1, Issue. 2, pp. 178189, June. 2006.

[10] White & Pharoah "Oral Radiology-Principles and Interpretation", Fifth Edition (2005), selected illustration by Dr. Donald O'Connor. ISBN 0-323-02001,published by MOSBY (An affiliate of Elsevier)

[11] Shafer's Tb. "Textbook of Oral Pathology" sixth edition, 2006.

[12] S.A.Ahmed, M.N.Taib, N.E.A.Khalid, R.Ahmad, H.Taib "Performance of compound enhancement algorithms on dental radiograph images" WASET-2011 [13]Stefan Michel, Saskia M.Koller, Markus Ruh, Adrian Schwaninger, "Do "Image Enhancement" Functions Really Enhance X-ray Image

Interpretation?" Cognitive Science Journal Archieve 2007

[14] Nirav P. Desai, D. B. Prajapati "A simple and novel CBIR technique for features extraction using AM dental radiographs" CSNT (IEEE) 2013, Gwalior, pp.198-202 , 2012 [15] Maja Omanovic, Jeff J. Orchard "Exhaustive Matching of Dental X-rays for Human Forensic Identification "Journal of the Canadian Society of Forensic Science, 2008 [16] S.Jadhav, R. Shriram "Dental biometrics used in forensic science" IJERS/Vol.III/ Issue I/January-March, 2012/26-29

[17] Omaima Nomir, M.A.Mottaleb "A system for human identification from X-ray dental radiographs" Pattern Recognition 38 (2005) 1295 - 1305.

[18] Sharifah Lailee, Nursuriati Jamil "Segmentation of Natural Images Using an Improved Thresholding-based Technique" IRIS 2012, Elsevier Procedia engg. Conference pp938-944.

[19] TM Lehmann, E.Troeltsch, K Spitzer" Image processing and enhancement provided by commercial dental software programs: A Technical Report" Dentomaxillofacial Radiology (2002) 31, 264-272.

[20] T. N. Cornsweet, Visual Perception, Academic Press, New York, 1970.