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ORIGINAL ARTICLE

A Comparative Study on Determination of Pulp/Tooth Area Ratio Using MIMICS® and ADOBE PHOTOSHOP CS® for Estimation of Age by Cameriere's Method

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ABSTRACT

Aim: To assess and compare the efficacy of materialise Interactive Medical Image Control System (MIMICS®) software with ADOBE® in determining pulp to tooth area ratio and age estimation on maxillary canines.

Materials and methods: Intraoral periapical radiographs (IOPA's) of maxillary canines were taken using the paralleling technique. Radiographs were digitized using Flatbed scanner. digitized images were exported into ADOBE® and materialise MIMICS software. Their tooth and pulpal area was calculated and age was determined.

Results: The regression equation derived from ADOBE®: age = 72 + (–282.206 x pulp to tooth area ratio from ADOBE®). The regression equation derived from MIMICS®: age = 77.13 + (–324.583 x pulp to tooth area ratio from MIMICS®. Correlation coefficient of estimated age versus the actual age with ADOBE® 'r' value of –0.595. The correlation coefficient of estimated age versus the actual age with MIMICS® r-value of –0.649.

Conclusion: This study showcases the use and limitations of new software MIMICS® in measuring the tooth to the pulp area ratio. Although IOPAs failed to produce three-dimensional volumetric analysis, the applicability of this software in other areas like maxillofacial trauma management and implant planning were revealed, further opening scope for newer research

Clinical significance: Materialise MIMICS® software has various applications in dentistry. It can create a 3D surface model and give volumetric measurements, from scanned images, hence can be applied in Implantology and Oral and Maxillofacial Surgery.

Keywords: ADOBE®, Age estimation, MIMICS®, Pulp to tooth area.

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INTRODUCTION

Radiology and radiographic techniques adapted in the field of forensic science plays a momentous role. These techniques aid in the valuation of the age of living individual and reconstructive identification of the deceased.[1] In addition to the routine age assessment casework, the relevance of the method becomes very important in mass fatalities that may be caused due to natural disasters and human-made catastrophic events.[2] Age estimation can be done using various parts of the body like long bones, skull bones, and teeth. Teeth are the strongest part of the body that remains intact even after several years of death. Teeth also have an added advantage that they can clinically be examined in living individual owing it to be a preferred choice. With an increase in age, teeth undergo a number of changes such as secondary dentin deposition, root translucency, cementum apposition, root resorption, various color changes, and increased root roughness.[3] Hence age estimation using teeth can be done through morphologic, radiographic, histological and biochemical methods.[4]

Many studies have evaluated the secondary dentin deposition and ascertained methods of age estimation. Gustafson visualized the dentin transparency, Philippas was the first to radiographically assess the influence of age on the formation of dentine, Kvaal developed new method based on pulp size in periapical radiographs, Paewinsky et al. tested Kvaal's method on digital panoramic radiographs. Cameriere et al. derived regression equation using pulp to tooth area ratio (P/T ratio) on intraoral periapical radiographs (IOPA) of canine, premolars, incisors. They found a high level of accuracy in canines and premolars compared to other teeth.[5]

Even though earlier the age assessment was noted as "an art, not a precise science," in the current era new methods of validation and substantial advances in old methods, have resolved these issue. In age estimation using the pulp to tooth area ratio, till date the outline of the teeth and pulp used to be manually selected by the operator using ADOBE®, AUTOCAD methods, which are very technique sensitive, time-consuming and might lead to subjective errors.

Materialise Interactive Medical Image Control System (MIMICS®) is an image processing software which is used to create 3D surface models, 3D design, 3D measurements.[6] Muhammad Kahn et al. used this

technique for age estimation by volumetric analysis of the pulp to tooth area ratio on cone beam computed tomography (CBCT) images.[7] This technique has not been previously used on IOPA's, hence we conducted this study with an aim to assess and compare the efficacy of MIMICS® software with ADOBE® in determining pulp to tooth area ratio and age estimation on maxillary canines.

MATERIALS AND METHODS

Study Design

This study was conducted in the Department of Oral Medicine and Radiology, Manipal College of Dental Sciences, Manipal in association with Department of Mechanical Engineering, Manipal Institute of Technology, Manipal for a period of 3 months. Intraoral periapical radiographs (IOPA's) of maxillary canines were taken using paralleling technique and with exposure parameters of 60 kVp, 7 mA, and 0.4 seconds. As this was pilot study intended to be performed on a new software, a small sample size of 20 canine IOPAS was considered. All the radiographs were digitized using Flatbed scanner and saved in joint photographics experts group (JPEG) format. The age of the patient and date of birth were noted down separately.

Sample Inclusion Criteria

- Intraoral periapica (IOPA's) of Patients age ranging from 10 to 70 years were included.
- Patients for whom canine IOPA was indicated only were included in the study. No separate IOPA's were taken specifically for the study, so as to avoid radiation exposure.
- Residents from Karnataka state of India, who agreed to perform in this study were only considered.

Sample Exclusion Criteria

- Canines with caries, fractures, impacted, or endodontically treated were excluded.

The digitized images obtained were exported into ADOBE® CS5 image editing software. The magnetic lasso tool was used to draw the outlines of canine tooth and pulp separately. The measurement bar displayed the area of the selected region. The area of the selected tooth and its pulp was recorded and the pulp to tooth area ratio was ascertained as shown in Table 1.

The images were next exported into MIMICS® Materialise software. MIMICS® software can create a 3D surface model and give volumetric measurements, from scanned images loaded into the software. But when IPOA's were exported into the software, it failed to produce a 3D model. But the new observation was that the software could automatically select the tooth outline and pulpal outline separately based on the difference in their grayscale and give the areas of the selected region. Some manual modification was required in IOPAs with low contrast. The toolbar called "mask properties" where thresholds (i.e., numerical value) according to the

Table 1: Pulp to tooth area derived from ADOBE® and MIMICS® and estimated age using the regression equation derived

Sample No.	*Actual age (years)*	*Pulp to tooth area ratio ADOBE®*	*Pulp to tooth area ratio MIMICS®*	*Estimated age (years) using ADOBE®*	*Estimated age (years) using MIMICS®*
1	46	0.087	0.09	47.57	46.61
2	31	0.088	0.089	47.17	46.88
3	12	0.203	0.2	14.71	15.55
4	46	0.099	0.102	44.00	43.21
5	49	0.096	0.098	44.08	44.34
6	47	0.103	0.103	42.93	42.93
7	52	0.131	0.105	47.03	42.36
8	33	0.11	0.113	40.95	40.11
9	45	0.104	0.11	42.65	40.54
10	48	0.099	0.097	44.06	44.62
11	21	0.115	0.111	39.54	40.67
12	65	0.109	0.108	41.23	41.53
13	49	0.111	0.111	40.67	40.67
14	26	0.143	0.142	31.64	31.92
15	41	0.105	0.103	42.36	42.93
16	32	0.14	0.1	33.00	32.8
17	15	0.18	0.18	22.00	22.00
18	28	0.1	0.12	43.77	43.56
19	18	0.16	0.14	26.84	26.7
20	55	0.01	0.01	69.17	60.6

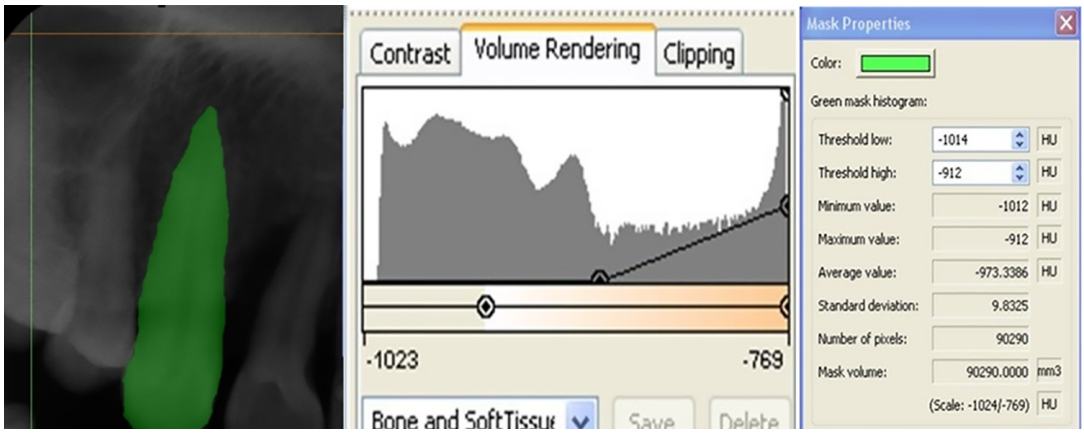

Fig. 1: Selection of tooth and pulp area in MIMICS® materialise software based on gray scale

required grayscale had to be given and adjusted to select the required portion of the teeth and pulp. The measurement tool provided the area of the selected region. First, the entire tooth outline was selected, and the area was recorded, after which only pulpal outline was selected and the area was determined (Fig. 1). The ratio of pulp to tooth area was calculated, depicted in Table 1. All the measurements were done by two trained observers, with good interobserver agreement (Kappa value of 0.92 for ADOBE® and 0.95 for MIMICS®)

The pulp to tooth area ratios obtained from both the techniques - MIMICS® and ADOBE® CS5 were then subjected to statistical evaluation.

Statistical Analysis

- The analysis was done using SPSS 14 version.
- Linear regression analysis was used to calculate the regression equation from pulp to tooth area ratios obtained from both the techniques–MIMICS® and ADOBE® CS5.
- The validity of the regression equation was evaluated by the correlation coefficient (r-value)

RESULTS

A total of 50 canine IOPAs were included in the study and digitized and saved in JPEG format. Amongst these 20 IOPA's fulfilled the inclusion criteria. Out of which 13 IOPA's belonged to females and 7 IOPAs were of males. The regression equation derived from ADOBE®: Age = 72 + (–282.206 × pulp to tooth area ratio from ADOBE®). The regression equation derived from MIMICS®: age = 77.13 + (–324.583 × pulp to tooth area ratio from MIMICS®. The correlation coefficient of estimated age versus the actual age with ADOBE® 'r' value of –0.595. The correlation coefficient of estimated age versus the actual age with MIMICS® r-value of –0.649. Mean prediction error in estimation of age between two techniques is given in Table 2.

Table 2: Accuracy of both the techniques in estimating the age calculated through mean prediction error

Particulars	*Mean difference*
Actual age versus Adobe Predicted	0.773
Actual age versus Mimics predicted	0.009

DISCUSSION

Dental age estimation can be done morphologically and radiologically. The radiological method is commonly preferred as they are less complex, nondestructive, do not require extraction of teeth hence no loss of evidence and can be applied for both dead and living. To further support this, digitization has played a significant role and has strengthened the reliability and accuracy of radiological techniques.[3] Radiological age assessment in children is done through evaluation of developmental stages of teeth, whereas in the adult by assessment of the continuous deposition of secondary dentin throughout life, depicted by a reduction in pulp area.[8]

Cameriere et al. in 2004 for the first time conducted a preliminary study to evaluate the variation in pulp to tooth area ratio as an indicator of age and their method of age estimation seemed promising. They originally examined canine and found a high level of accuracy in age prediction (mean error–4.5 years), they believed that further research with different races and culture is required.[9] Babshet et al. in 2010 evaluated Cameriere's formula and found it slightly inaccurate for Indian population.[2] Also a concern regarding the precision and accuracy in measurement of pulp and tooth area during manual selection has been frequently reflected in the literature.[8]

Materialise interactive medical image control system (MIMICS®) is an image processing software which can create 3D models, 3D designs, and give 3D measurements. It is a general purpose segmentation program for grey value images and can process any number of 2D

image slices.[6] This software has been used in various settings of medicine and dentistry. It has been used for 3D virtual planning of osteotomies of hand and knees and for cardiovascular phantom/modeling for *in vitro* patient specific experiments like reconstructing anatomy of ascending, descending aorta and measuring the aorta cross-sectional area.[10-12] It has also been used for orbital soft tissue volume measurement for an understanding of various eye pathologies like Graves' orbitopathy, orbital myositis.[13] In dentistry is it has been mainly used in maxillofacial set up in traumatic maxillofacial deformities. Where MIMICS® is used to perform virtual reconstructions, using uninjured segments. Pham et al. have reported three cases of fronto-orbito zygomatic fractures and open skull fractures where this software was used for reconstruction.[14]

Muhammad et al. performed a study to assess the correlation between chronological age and pulp/tooth volume ratio using MIMICS® with CBCT images.[7] Hence, we conducted this study to evaluate the efficacy of MIMICS® over ADOBE® in determining the pulp to tooth area ratio using IOPAs. We opted for a canine tooth as it is a single rooted tooth, often present in old age, less likely than anterior and other posterior teeth to suffer alteration and abrasion, has a large pulp area, hence easy to calculate.[4]

In our study, a total of 50 maxillary canines were chosen out of which 20 matched the inclusion criteria. 20 canines were examined and pulp to tooth area was derived using ADOBE® and MIMICS®. Intraobserver agreement for the techniques using ADOBE®–0.45, indicating high reproducibility of measurements. This was in accordance with Cameriere et al. study in 2007.[15] Although previous studies on ADOBE® by Babshet et al. and Jeevan et al. have shown good intraobserver reliability in measuring pulp to tooth area ratio, they felt the requirement for repetitive measurement of pulp to tooth area ratio by different observers to verify and validate it.[2,4] In our study, all the measurements were repeated by a second trained observer and interobserver agreement was calculated by deriving a Kappa value between the two observers for both ADOBE® and MIMICS®. Kappa value of 0.92 for ADOBE® and 0.95 for MIMICS® were obtained. This confirmed the two observers to be in high agreement.

From the pulp to tooth area ratio calculated from both techniques, a regression equation was derived. Regression equation can vary from previous studies due to different sample size, technique used, geographic variation of an individual from our study.[4,9] The derived equations were used on random samples and age was calculated and the correlation between chronological age and derived age was assessed. The correlation coefficient of estimated age vs the actual age with ADOBE was r-value = –0.595 and with MIMICS® was r value = –0.649. Jeevan et al. in their study had obtained r-value of Upper canine = –0.807.4 Our study showed slightly less correlation between the actual age and estimated age for ADOBE®.[4] But in comparison to ADOBE®, MIMICS® showed better correlation and validity in our study. The mean difference between the actual age versus ADOBE® predicted age was 0.773 and MIMICS® provided an excellent result with a minimal difference of 0.009. Although MIMICS® software failed to produce a 3D model and volumetric analysis from 2D IOPA images, which is the limitation of our study, it was able to automatically select the pulpal outline and tooth outline separately. Hence the bias of manual selection, the technique sensitivity and time consumption was reduced in MIMICS® compared to ADOBE®.

CONCLUSION

This study showcases the use and limitations of new software MIMICS® in measuring the tooth to the pulp area ratio. Although IOPAs failed to produce three-dimensional volumetric analysis, the applicability of this software in other areas like maxillofacial trauma management and implant planning were revealed, further opening scope for newer research.

CLINICAL SIGNIFICANCE

The process of the study revealed various other applications of Materialise MIMICS® software. This can be applied in the field of Implantology, Oral Surgery as it can create a 3D surface model and give volumetric measurements, from scanned images. Further studies with large sample size are required to unveil its use in various fields of dentistry.

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