APPLICATION OF KVAAL’S METHOD FOR DENTAL AGE ESTIMATION USING CBCT

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ABSTRACT

Aim: The aim of the study is to determine the accuracy of CBCT in dental age estimation using Kvaal’s method and thereby comparing the standard error of estimate between the actual and predicted age.

Materials and methods: The study included 200 CBCT images of the individuals with the age ranging from 15-60 years. CBCT images were evaluated for maxillary central and lateral incisor, second premolar; mandibular lateral incisor, canine and first premolar and 9 metric measurements were taken from each tooth and from which 10 ratios were derived. Using the ratios, multiple regression equation was derived, from which the age of the individual was predicted.

Results: The correlation between individual ratio and the actual age of the sample was calculated using Pearson correlation coefficient and the ratio M was found to have significant correlation with actual age for almost all teeth with a p-value of 0.00. The age of the individual was predicted using multiple linear regression equation, maxillary lateral incisor was found to be a better predictor with a SEE of 7.16 years. When the samples were divided into various age groups, the SEE was highly significant.

Conclusion: The study provides a new concept in Kvaal’s method that the SEE will be much better when the samples are divided based on age groups and the multiple regression equation is derived for each group separately.

INTRODUCTION

Age determination or age assessment is important in Forensic medicine as accurate age is essential for various social and legal issues. The need for accurate methods of age estimation is increasing in recent days because of increase in the number of crimes, unidentified cadavers and human remains and for living individuals with no valid age proof (Karkhanis et al, 2013). Numerous maturity markers like morphological age, skeletal age, secondary sexual characteristics, psychological development and dental age have been utilised for age estimation in situation where the accurate age of the individual is not known or uncertain (Mani et al, 2008). The utilization of teeth for identification has few unique reasons like, it is the most indestructible part of the body, can be used to inflict serious injury on an attacker and may be the only available defensive method for victim, dental treatment such as restoration, prosthesis etc helps in the identification. Forensic Odontology or Forensic dentistry was defined by Keiser and Neilson in 1970 as “that branch of forensic medicine which in the interest of justice deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of the dental findings” (Keiser-Nielsen et al, 1981). The utilization of teeth for individual identification is not a new technique; it dates back to 49 A.C. The first known attempt where teeth were used for age determination originates in England in the early 19th century (Landa MI et al, 2009). Wedl in 1872 was the first one to observe the changes with age in the permanent dentition like fatty degeneration, calcification, colloid and pigment deposits in the pulp cavity (Kvaal SI et al, 2006). Various changes like attrition, periodontosis, secondary dentin deposition, root resorption, root transparency of the teeth are considered for age estimation, but however all these methods requires extraction, preparation of microscopic sections, and are time consuming and moreover they cannot be utilised in living individuals, hence a non-destructive methods of age estimation are always warranted.

Radiography being a non-destructive, less time-consuming method plays an important role in forensic dentistry to uncover the hidden facts which cannot be done by physical examination and can be applied to both living and deceased individuals, since 1896 its been utilised in forensic sciences (Panchbhai AS et al, 2011 and Whittaker DK, 1987). The analysis of digital

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images has provided a new perspective in the field of age estimation. CBCT (Cone Beam Computed Tomography) is an innovative invention in the field of dentistry and was first introduced in 1997 for imaging of oral and maxillofacial region and it provides images in three orthogonal planes (axial, sagittal and coronal). Yang et al in 2006 was the first to utilise CBCT in age determination, since then various studies on age estimation using various methods have been carried out utilizing CBCT (Yang et al, 2006). Kvaal and Solheim in 1994 developed a method for age estimation using both radiological and morphological methods but extraction of teeth was warranted still. In an attempt to overcome this Kvaal’s developed another method based on radiological measurements only, taking the concept of pulp size regression due to secondary dentin deposition as the age progresses (Kvaal et al, 1994 and Kvaal SI et al,1995). In the forthcoming years various studies were done on Kvaal’s method using various imaging modalities. So far CBCT has not been utilised in this method, hence the study was carried out with an aim to determine the accuracy of CBCT in dental age estimation using Kvaal’s method.

MATERIALS AND METHODS

A prospective study conducted in the department of radiology with a total sample size of 200 individuals of age 18-58 years. The CBCT images of those individuals who reported to the department for routine diagnostic purposes like for implant placement, impaction and other pathologies were utilised for the study. The inclusion criteria were CBCT images containing maxillary central incisor, lateral incisor, second premolar and mandibular lateral incisor, canine and first premolar. Those images with severely attrited, malposed, restored, teeth with dental caries and any other pathologies were excluded. CBCT images were taken with SIRONA Orthophos XG 3D machine, Sirona INC, Germany under the parameters 85 kVp, 7 mA and 5.1 seconds; the voxel size of 400µ and the field of view (FOV) of 8×8 cms. The tangential slice of the image was used for the study. After exposure the images were calibrated using Galileos software and read in DICOM format. Before proceeding with the study, ethical clearance was obtained from the institutional ethical board. Teeth from either right or left side of the maxillary and mandibular arch were taken depending on whichever is suited for measurement. From each of the selected CBCT images, the measurements were taken from six included teeth, which include

1. Maximum tooth length (T)
2. Pulp length(P)
3. Maximum root length on the mesial side(R)
4. Pulp width at level a, c, b (a-cementoenamel junction, c-midroot level, b- midpoint of c and a)
5. Root width at level a, c, b (a-cementoenamel junction, c-midroot level, b- midpoint of c and a).(Fig: 1, 2, 3, 4)

From these 9 measurements a total of 10 ratios were derived in order to compensate for the magnification error. The ratios determined were

1. T- Root length/tooth length
2. R- Pulp length/tooth length
3. P- Pulp length/root length
4. A- Pulp width/root width at level a
5. B- Pulp width/root width at level b
6. C- Pulp width/root width at level c
7. M- mean values of all ratios
8. W- Mean value of width ratios from levels b and c
9. L- Mean value of length ratios P and R
10. W-L- Difference between W and L
Age of all subjects was assessed by multiple linear regressions using the two predictors M (mean values of all ratios) and W-L (Difference between W and L). The correlation between each variable and the actual age was determined before running a regression. Regression formula was derived separately for all 6 teeth, maxillary 3 teeth, mandibular 3 teeth and each individual tooth and the age was assessed.

**RESULTS**

The study comprised total of 200 individuals of age range 18-58 years. The correlation between the variables and the actual age was calculated using Pearson correlation coefficient and is depicted in Table 1. The first predictor, ratio M was found to have significant correlation in all teeth (p-value 0.00) except in mandibular lateral incisor.

**Table 1** Correlation between age and ratios of measurement

<table>
<thead>
<tr>
<th>Ratios</th>
<th>11-21</th>
<th>12-22</th>
<th>15-25</th>
<th>32-42</th>
<th>33-43</th>
<th>34-44</th>
<th>Upper 3 teeth</th>
<th>Lower 3 teeth</th>
<th>All 6 teeth</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>0.28</td>
<td>-0.14</td>
<td>0.06</td>
<td>-0.02</td>
<td>0.09</td>
<td>0.02</td>
<td>0.09</td>
<td>0.02</td>
<td>0.07</td>
</tr>
<tr>
<td>R</td>
<td>0.02</td>
<td>-0.06</td>
<td>0.09</td>
<td>-0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.09</td>
<td>0.04</td>
<td>0.08</td>
</tr>
<tr>
<td>P</td>
<td>0.01</td>
<td>-0.10</td>
<td>-0.18</td>
<td>0.05</td>
<td>-0.17</td>
<td>-0.09</td>
<td>-0.04</td>
<td>0.06</td>
<td>-0.06</td>
</tr>
<tr>
<td>A</td>
<td>-0.15</td>
<td>0.10</td>
<td>0.13</td>
<td>0.05</td>
<td>0.03</td>
<td>-0.02</td>
<td>0.03</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>B</td>
<td>0.05</td>
<td>-0.01</td>
<td>0.13</td>
<td>0.07</td>
<td>0.05</td>
<td>0.04</td>
<td>-0.00</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>C</td>
<td>0.22</td>
<td>-0.06</td>
<td>-0.10</td>
<td>0.08</td>
<td>0.04</td>
<td>-0.01</td>
<td>-0.08</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>M</td>
<td>0.70</td>
<td>-0.31</td>
<td>-0.36</td>
<td>0.13</td>
<td>-0.35</td>
<td>-0.23</td>
<td>-0.18</td>
<td>-0.16</td>
<td>-0.15</td>
</tr>
<tr>
<td>W</td>
<td>-1.06</td>
<td>0.01</td>
<td>-0.16</td>
<td>-0.02</td>
<td>-0.00</td>
<td>-0.09</td>
<td>-0.05</td>
<td>-0.08</td>
<td>-0.02</td>
</tr>
<tr>
<td>L</td>
<td>0.08</td>
<td>-0.07</td>
<td>-0.19</td>
<td>-0.03</td>
<td>0.14</td>
<td>-0.07</td>
<td>0.05</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>W-L</td>
<td>0.02</td>
<td>-0.09</td>
<td>-0.19</td>
<td>-0.06</td>
<td>0.10</td>
<td>-0.02</td>
<td>0.07</td>
<td>0.05</td>
<td>0.04</td>
</tr>
</tbody>
</table>

*denotes significant correlation

Using the multiple linear regression equation, the age of the individual was determined and the derived regression formula with SEE (Standard Error of Estimate) in years of all teeth is depicted in Table 2. Using the predictors M and W-L, the maxillary lateral incisor was found to be a better predictor of age with a highest R² (coefficient of determination) of 0.554 and the SEE of 7.16 years. Maxillary central incisor was found to be the least predictor using the ratios M and W-L with a SEE of 10.57 years and the R² of 0.028.

**Table 2** Multiple regression analysis

The actual and predicted age distribution obtained using maxillary lateral incisor represented by scatter diagram is given in fig 5.

In order to obtain further better results, the study groups were divided into four age groups based on the age range (18-28 years, 29-38 years, 39-48 years and 49-58 years) and the regression formula was derived for each group separately and for all 6 teeth, maxillary 3 teeth, mandibular 3 teeth and all individual teeth in each group. The age of the individual was determined using the predictors M and W-L and regression formula was derived. For the age group 18-28 years, the ratio M and A of maxillary lateral incisor had significant correlation with age with a p-value of 0.00 and 0.001 respectively. Maxillary lateral incisor was determined to be better predictor of age in this age group with the SEE of 2.15 years. The SEE and R² of age group is given in Table 3.

**Table 3** Multiple linear regression equation for age range 18-28 years

For the age group 29-38 years the ratios B of maxillary central incisor, C of maxillary canine, M of mandibular canine, W of maxillary central incisor had significant correlation with age with p- values < 0.05. From the regression equation derived, mandibular canine was found to be a better predictor of age in this age range with the SEE of 2.87 years (table 4).

**Table 4** Multiple linear regression equation for age range 29-38 years
DISCUSSION

For the age group 39-48 years, the ratio M of mandibular lateral incisor had better correlation with actual age with a p-value of 0.02. The SEE obtained from 32/42 was found to be less i.e. 2.30 years, when compared to other teeth (Table 5).

Table 5 Multiple linear regression equation for age range 39-48 years

<table>
<thead>
<tr>
<th>Teeth</th>
<th>Regression equation</th>
<th>R²</th>
<th>Adj R²</th>
<th>SEE in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>All 6</td>
<td>Age = 49.867 – 22.071 (M) – 5.301 (W-L)</td>
<td>0.17</td>
<td>0.09</td>
<td>2.62</td>
</tr>
<tr>
<td>11-21</td>
<td>Age = 69.864 – 74.089 (M) – 16.049 (W-L)</td>
<td>0.09</td>
<td>0.03</td>
<td>2.61</td>
</tr>
<tr>
<td>12-22</td>
<td>Age = 58.987 – 75.302 (M) – 31.651 (W-L)</td>
<td>0.16</td>
<td>0.11</td>
<td>2.50</td>
</tr>
<tr>
<td>15-25</td>
<td>Age = 46.788 – 7.203 (M) – 0.833 (W-L)</td>
<td>0.02</td>
<td>0.05</td>
<td>2.73</td>
</tr>
<tr>
<td>32-42</td>
<td>Age = 116.532 – 183.575 (M) – 31.884 (W-L)</td>
<td>0.28</td>
<td>0.24</td>
<td>2.30</td>
</tr>
<tr>
<td>33-43</td>
<td>Age = 56.245 – 15.294 (M) – 7.065 (W-L)</td>
<td>0.02</td>
<td>0.03</td>
<td>2.70</td>
</tr>
<tr>
<td>34-44</td>
<td>Age = 44.264 – 3.420 (M) – 4.764 (W-L)</td>
<td>0.07</td>
<td>0.04</td>
<td>2.72</td>
</tr>
<tr>
<td>Upper 3 teeth</td>
<td>Age = 49.485 – 25.062 (M) – 7.964 (W-L)</td>
<td>0.02</td>
<td>0.02</td>
<td>2.62</td>
</tr>
<tr>
<td>Lower 3 teeth</td>
<td>Age = 49.738 – 17.018 (M) – 2.136 (W-L)</td>
<td>0.01</td>
<td>0.00</td>
<td>2.64</td>
</tr>
</tbody>
</table>

For the age group 49-58 years, the ratio T of mandibular first premolar had significant correlation with age (p-value<0.05). From the regression equation derived, maxillary central incisor was found to be a better predictor of age with a SEE of 2.73 years (Table 6).

Table 6 Multiple linear regression equation for age range 49-58 years

<table>
<thead>
<tr>
<th>Teeth</th>
<th>Regression equation</th>
<th>R²</th>
<th>Adj R²</th>
<th>SEE in years</th>
</tr>
</thead>
<tbody>
<tr>
<td>All 6</td>
<td>Age = 53.296 – 12.651 (M) – 4.658 (W-L)</td>
<td>0.17</td>
<td>0.04</td>
<td>2.77</td>
</tr>
<tr>
<td>11-21</td>
<td>Age = 58.489 + 23.302 (M) + 21.935 (W-L)</td>
<td>0.13</td>
<td>0.01</td>
<td>2.73</td>
</tr>
<tr>
<td>12-22</td>
<td>Age = 194.569 + 274.114 (M) + 0.277 (W-L)</td>
<td>0.10</td>
<td>0.05</td>
<td>2.74</td>
</tr>
<tr>
<td>15-25</td>
<td>Age = 65.499 + 12.103 (M) + 23.493 (W-L)</td>
<td>0.07</td>
<td>0.04</td>
<td>2.82</td>
</tr>
<tr>
<td>32-42</td>
<td>Age = 112.835 – 139.000 (M) – 19.538 (W-L)</td>
<td>0.18</td>
<td>0.04</td>
<td>2.76</td>
</tr>
<tr>
<td>33-43</td>
<td>Age = 17.420 + 68.167 (M) + 1.166 (W-L)</td>
<td>0.06</td>
<td>0.01</td>
<td>2.84</td>
</tr>
<tr>
<td>34-44</td>
<td>Age = 57.831 + 12.505 (M) + 14.780 (W-L)</td>
<td>0.06</td>
<td>0.01</td>
<td>2.84</td>
</tr>
<tr>
<td>Upper 3 teeth</td>
<td>Age = 55.949 + 14.722 (M) + 13.396 (W-L)</td>
<td>0.03</td>
<td>0.01</td>
<td>2.76</td>
</tr>
<tr>
<td>Lower 3 teeth</td>
<td>Age = 52.526 + 8.014 (M) + 4.596 (W-L)</td>
<td>0.05</td>
<td>0.02</td>
<td>2.81</td>
</tr>
</tbody>
</table>

The SEE obtained using CBCT in this study was almost similar to those obtained from two-dimensional imaging modalities in various studies. The regression equation derived separately based on each age group gave the better prediction of age with the SEE of 2-3 years.

DISCUSSION

Various studies on dental age estimation have been conducted utilising various imaging modalities and they were unique in its own way. Kvaal et al proposed a method for dental age estimation in adults based on the principle of pulp size regression with progression of age of an individual (Kvaal SI et al, 1995). Based on the method of age estimation using measurements made from teeth done by Kvaal et al in the year 1995 using IOPA, this study was formulated and was conducted in CBCT. The digital metric riler in the software was used for taking measurements.

In a study done by Kvaal et al, the highest coefficient of determination was obtained when the ratios of all 6 teeth were taken (0.76) and lowest when mandibular canine was taken (0.56). The SEE 8.6 years was obtained from all 6 teeth, which was proved to be less compared to SEE obtained from other teeth.

In a study done by Kanchan et al in 2012 using digital IOPA, maxillary central incisor was proved to be a better predictor of age with the SEE of 11-14 years. Nitin Agarwal et al in the year 2013 using paralleling method in IOPA proved maxillary central incisor as a better predictor (Kanchan-Talreja et al, 2012 and Agarwal N et al, 2012). Shalmiria Karkhanis et al and Shruthi K.Patil et al, in their studies done in OPG also proved maxillary central incisor as a better predictor compared to other teeth with a SEE of 7.963 and 6.5 years respectively (Karkhanis S et al, 2014 and Patil SK et al, 2014). In this study a SEE of 10.57 years was obtained using maxillary central incisor.

Maxillary lateral incisor was proved to be a better predictor of age in a study done by Parikh et al using digital OPG with a SEE of ±5.49-8.56 years and in the current study lateral incisor is proved to be a better predictor compared to other teeth with a SEE of 7.16 years (Neelamparigirik et al, 2013).

Chandramala et al and Talreja et al in their studies proved upper second premolar as the better predictor compared to other teeth, the SEE of 9.76 years was obtained using this particular tooth in the present study (Kanchan-Talreja et al, 2012 and Chandramala et al, 2012). The SEE of 9.99 years was obtained using the regression equation derived from mandibular lateral incisor in the present study which is significant in comparison with the study done by Erbudak et al in the year 2012 using digital OPG with a SEE of more than 12 years (Erbudak HÖ et al, 2012). The SEE of 10.46 years using the regression formula derived from mandibular canine.

Mandibular first premolar was proved to be a better predictor of age in a study done by Bosmans et al in 2005, using OPG with a SEE of 9.5 years and the SEE of 9.98 years was obtained using this particular tooth in the present study (Bosmans N et al, 2005). The ratio M was found to be highly significant with a p-value of <0.05 with a highest correlation with age in most of the teeth.

In the present study, maxillary lateral incisor was found to be a better predictor of age when compared to other teeth when the regression equation was derived for all the study samples together. Most of the predicted age was in the range of 30-40 years, indicating that this study will be more accurate for that age group. This result guided us whether the SEE will be better if a regressive equation is derived according to age group; and hence the sample was divided into four groups like 18-28, 29-38, 39-48, and 49-58 and the regression equation was derived accordingly. Unbelievably, the result was drastically improved, for the age group 18-28 and maxillary lateral incisor was found to be a better predictor of age with the SEE of 2.15 years; for age group 29-38 years, mandibular lateral incisor had the least SEE of 2.80 years and was found to be a better predictor of this group. Again, mandibular lateral incisor was found to be a better predictor of age for the age group 39-48 years with the SEE of 2.30 years. For the age group 49-58 years, maxillary central incisor was found to be a better predictor with the SEE of 2.73 years suggesting that the result will be much better with this method if the regression equation is derived according to the age group.

This is the first study to use three-dimensional imaging modality (CBCT) for dental age estimation using Kvaal’s method. The literature search did not reveal any studies in which the age was derived according to age groups and this is the first study to derive the regression equation based on age group and proved the better results.

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CONCLUSION

Newer innovations in age estimation methods are always appreciable and gain interest due to the increase in the demand for appropriate methods of age estimation. The application of CBCT in dentistry is tremendous and used for various purposes. In this study, maxillary lateral incisor was found to be a better predictor of age compared to other teeth when the regression equation derived for a wide age range was used. Very significant result is achieved when a regression equation was derived separately for each age range. Further research comparing two imaging modalities for age estimation using Kvaal’s method and also various other views in CBCT can be done. Comparison of various methods of age estimation in the same age range is needed so as to determine which method provides the better result. Since CBCT is widely used at present day, utilisation of this modality in other radiological methods of dental age estimation can also be tried to find out any possible difference that could occur in the result in comparison with the two-dimensional modalities.

References


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