A comparative study of sagittal dental relationship using digital method of bite mark evaluation

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Abstract

Introduction: Intercuspalpation of teeth depends on position of teeth and jaws. Bite mark is the resultant of the intercuspation of teeth produced by an individual.
Aims and Objective: Comparative evaluation of bite marks in Angle’s Class I, II, and III sagittal occlusion.
Materials and Methods: Three groups as per Angle’s classification-Class I, Class II, and Class III relation were taken. Each group comprised 30 samples each. The dental casts were scanned to create digital images. “IC Measure” software was used to determine the angular and linear measurements on scanned images of study model after calibration. Internal angles of odontometric triangle, intercanine width, shape of the arch, size, and shape of the individual teeth was recorded and subjected to the statistical analysis.
Results: All incisors had rectangular and canine had triangular shape. Bilateral maxillary lateral incisors and mandibular left central incisor were significantly small in size for Class III. Square arch form was found more commonly in Class III and ovoid arch form in Class I and Class II occlusion. Intercanine width was insignificant among all occlusions. All the angles of the odontometric triangle in the maxillary and mandibular arches were significant for Class III.
Conclusion: Class III occlusion individuals were distinct for shape of the arch and angles of maxillary and mandibular odontometric triangle. The quantified values of odontometric triangle can be utilized for the identification of Class III individuals.

Key words: Dental arch, dentition, DNA, forensic dentistry, individuality, occlusion, odontometry, orthodontics, software

Introduction

Human identification is the need of the hour in the wake of the increased number of crimes and calamities all over the world. Wide spectrum of techniques for identification exists like finger prints and other biometric techniques; ear prints, handwriting analysis, voice analysis, DNA fingerprinting, forensic odontology, etc., Forensic odontology deals with the study of dental applications

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Relationship of the teeth and/or occlusion is analyzed based on the intercuspation of maxillary and mandibular deciduous or permanent teeth in transverse, sagittal, and vertical dimension. First molars are the foremost permanent teeth to erupt in the oral cavity. Hence, bears an impact on the establishment of the final occlusion. EH. Angle-Father of modern orthodontics – classified sagittal relation of teeth into three types, namely Class I, Class II, and Class III occlusion.[5] All the three occlusions are different and distinct in their dental arch characteristics. The literature was appraised for analyzing the distinctiveness of different sagittal dental relations with the overlays of incisors and canines most commonly found in the bite mark, a lacuna of evidence was observed in this pretext. Hence, there was a need to analyze the various parameters of the anterior dentition and compare them with different sagittal relation groups. Thus, the aim of this study was to assess and correlate bite marks to Class I, Class II, and Class III sagittal dental relation.

Materials and Methods

A retrospective cross-sectional study was planned. The study was conducted in the Department of Orthodontics. The sample for the study was collected from the orthodontic record archives present in the department. Keeping a confidence interval of 95%, the required sample size estimated for the study was 90. The estimated sample group was further divided into three groups, namely Class I, Class II, and Class III as per Angle’s classification [Figure 1 and Table 1]. Hence, each group comprised 30 samples, respectively.[6] Only good quality study models in permanent dentition with fully erupted teeth till the second permanent molars in the age range of 16–25 years without having any type of distortions were selected. The presence of grossly destructed teeth in the upper and lower arches, developmental anomaly, missing, fractured or restored teeth, and transpositions of teeth and posttreatment models of orthodontically treated patients were excluded.

An indirect method of bite mark evaluation was utilized in our study. The dental casts were scanned to create digital images of the dental casts. Only the occlusal aspects of the maxillary and mandibular casts were scanned. The code for individual set of the scanned image was formulated and stored. A total of 20 scanned images were randomly selected on which the measurements were made by the two authors. Statistical test to assess interobserver agreement between two judges was carried out using Cohen’s kappa. According to Cohen values between 0.81–1.00 suggest almost perfect agreement, we obtained a value of 0.85. The investigator who conducted the bite mark analysis on the scanned images was blinded for the code formulated for assorting the scanned models as Class I, Class II, and Class III.

The shape of the upper and lower arch was noted as ovoid, tapered, and square arch forms as suggested by McLaughlin et al. [Figure 2].[7] ‘IC Measure’ Software - The Imaging Source, Breman, Germany was used to determine the angular and linear measurements on scanned images of the study model. The images were calibrated in the ratio of 1:1 (actual cast: Digital image). Measurements were recorded to the level of two decimals. Mesiodistal widths of all six anterior teeth were measured individually in both upper and lower arches [Figure 3]. Odontometric triangle measurement method was used, in which a triangle was made on the incisal edges of the anterior by marking three points, two on the outer most convex point of canines and one in the midline between the upper central incisors. The three internal angles of the triangles were measured and compared between groups [Figures 4-6].[8-10] The length of the base of the odontometric triangle was taken as the
intercanine width; that is the distance between the outer most convex points of both canines [Figure 7]. The shape of permanent maxillary and mandibular anterior teeth from incisor to canine was also analyzed. All the measurements were measured and tabulated in Microsoft Excel sheet.
SPSS Software version 21 - The International Business Machines Corporation (IBM), New York, USA was utilized in the study to conduct the statistics. The confidence interval was set at a 95% interval. One-way analysis of variance analysis was conducted to determine the significance within and between the groups of Class I, Class II, and Class III dental relation. A multi comparison post hoc test was done to make a comparison of each group with every other group.

Results

Males showed a greater number of square arches (26) followed by ovoid arches (17). None of the males in the study had a tapered arch form. Whereas females showed a greater number of ovoid arch forms (27) followed by square arch forms (17) and tapered arch forms (3) in the given sample [Graph 1]. Both Class I and Class II occlusion individuals showed ovoid, square, and tapered arch forms in descending order. In Class III, occlusion individuals revealed the maximum number of square arch forms (25) followed by ovoid arch forms (5). None of the class III individuals had a tapered arch form [Graph 2]. All the central and lateral incisors had a rectangular shape when viewed from the occlusal aspect and all canines had a triangular shape.

Statistical significance for in-between group comparison ($P < 0.05$, confidence interval 95%) as per the ANOVA test was found for the following variables – mesiodistal width of the upper right and left lateral incisor and lower left central incisor and all the three internal angles of the odontometric triangle in the upper as well as the lower arch [Table 2]. A multi comparison post hoc test was performed to compare the three groups. All of the above parameters were statistically significant when the comparison was made between Class I–Class III and Class II–Class III. The mesio-distal width of the lower left central incisor was only significant between Class II and Class III [Tables 3-5]. The mean values and standard deviation for all the parameters in Class I, Class II, and Class III samples are given in Table 6. The value of the odontometric triangle angles that were significant for Class III occlusion were $21.02 \pm 7.37$, $20.85 \pm 7.05$, and $138.52 \pm 14.44$ in the mandibular arch and $29.0 \pm 1.32$, $30.72 \pm 1.34$, and $118.43 \pm 3.08$ in the maxillary arch.

Discussion

Forensic odontology has developed great importance in the field of personal identification in the last few decades. At

![Graph 1: Arch form distribution in males and females](image1)

![Graph 2: Arch form distribution in Class I, II, and III sagittal dental relation](image2)
the same time, digital technologies have enhanced precision and reliability in diagnosis. Bite mark analysis first entered as evidence in the judicial system in 1954 in the Texas case of Doyle versus state.\cite{11} Odontologists have often been called upon by prosecutors investigating a criminal case to generate information about the pattern of bite marks left in human skin or food items. This may help to establish the identification of the suspect. The basic premise of such a conviction, as literature describes it, is the uniqueness of the human dentition. Every person has a set of 32 teeth and 160 dental surfaces with deviations in positions, altered angulations, presence of restorations and crowns all of which result in a highly individualistic dentition.\cite{12} Rawson RD mathematically proved the unique nature of the human dentition.\cite{13} Sognnaes et al. and Franco et al. showed similar results supporting UHD.\cite{14,15} However, there is controversy in literature regarding this concept especially with respect to twins and orthodontically treated patients.\cite{16,17}

Direct and indirect techniques of bite mark registration are utilized to evaluate bite marks of an individual. The direct method of evaluation involves identifying the potential suspect and using his dental cast for direct comparison to the tooth indentations on the skin. Direct comparison can also be made on excised tissue, bitemark impression, and bitemark photograph.\cite{18} The indirect method of bite mark analysis normally comprises overlays which are used to compare the biting edges of a suspected biter’s dentition to the bite mark photograph printed in 1:1 ratio.\cite{19,20} Various methods of comparison overlays have been mentioned in literature. Tai et al. and Pajigara et al. compared the various methods and suggested the computer-assisted overlay generation method to be reliable and better than other methods such as xerographic, radiographic, and hand traced overlays, especially in terms of area and rotation of teeth.\cite{21,22} Pretty found digital overlay to be the most popular among odontologists in a web-based survey.\cite{23}

Hence, we chose to scan all the pretreatment dental casts and made measurements on the digitized images of the same. The computer-based measurement method had many advantages. Since the procedure is digital, it facilitates easy storage. It also allows securing evidence via multiple storage options. This technique involves scanning, hence avoids observer bias. Digitalization also provides better accessibility and makes it easier and uncomplicated for a third party to study the materials.\cite{19}

The size and shape of the teeth, dental arch form, intercanine width and odontometric triangle were appraised.
Measurements were made directly onto 1:1 calibrated occlusal scans of the maxillary and mandibular dentition using “IC Measure” software. In this study, both subjective and objective methods of bite mark evaluation were utilized. Subjective refers to something that is open to greater interpretation and relies on the individual’s own particular traits, emotions, and viewpoints. Objective means something that can be observed by anybody, is not influenced by opinions or personal feelings and is quantifiable and measurable. The shape of teeth and arch forms of the upper and lower jaws were the parameters for the subjective method of evaluation. Mesio-distal width of teeth, intercanine width, and odontometric triangle method were the objective method of bite mark evaluation. A higher number of parameters were observed with the objective method of evaluation.

In this study, measurement of the intercanine width was taken from the base of the odontometric triangle since the outer most convex point of the canine is most easily identifiable on the bite mark. This method of evaluation of intercanine width differs from Tarvadi et al. who measured the intercanine width using cusp tips. He found that using intercanine width as a parameter for bite mark analysis is an unreliable method. This may be because the canine cusp tips are not as discernible in the bite mark as the outline of the canine is. Moreover, skin is poor registration material. Therefore, the base of the odontometric triangle,

\[\text{MDW41} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.190                | 0.1823 | 0.552       | 0.625 0.245     |
| Class II           | 0.010                 | 0.1823 | 0.998       | −0.425 0.445    |
| Class III          | 0.200                 | 0.1823 | 0.518       | −0.235 0.635    |

\[\text{MDW42} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.038                | 0.1378 | 0.960       | −0.3663 0.2909  |
| Class II           | 0.172                 | 0.1378 | 0.427       | −0.1563 0.5009  |
| Class III          | 0.210                 | 0.1378 | 0.285       | −0.1186 0.5386  |

\[\text{MDW43} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.028                | 0.2122 | 0.821       | −0.5342 0.4775  |
| Class II           | 0.040                 | 0.2122 | 0.975       | −0.382 0.8192   |
| Class III          | 0.097                 | 0.2122 | 0.864       | −0.351 0.544    |

\[\text{MDW21} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.057                | 0.1876 | 0.504       | −0.540 0.391    |
| Class II           | 0.040                 | 0.1876 | 0.407       | −0.407 0.487    |
| Class III          | 0.097                 | 0.1876 | 0.864       | −0.351 0.544    |

\[\text{MDW22} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.217                | 0.1689 | 0.409       | −0.619 0.186    |
| Class II           | 0.023                 | 0.1689 | 0.001       | 0.221 1.026     |
| Class III          | 0.840                 | 0.1689 | 0.000       | 0.437 1.243     |

\[\text{MDW23} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | 0.010                 | 0.1643 | 0.998       | −0.382 0.402    |
| Class II           | 0.035                 | 0.1643 | 0.082       | −0.035 0.749    |
| Class III          | 0.347                 | 0.1643 | 0.094       | −0.045 0.739    |

\[\text{MDW31} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.193                | 0.1366 | 0.337       | −0.519 0.132    |
| Class II           | 0.373                 | 0.1366 | 0.021       | 0.048 0.699     |
| Class III          | 0.5667                | 0.1366 | 0.000       | 0.241 0.892     |

\[\text{MDW32} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | 0.037                 | 0.1589 | 0.971       | −0.342 0.416    |
| Class II           | 0.247                 | 0.1589 | 0.272       | −0.132 0.626    |
| Class III          | 0.210                 | 0.1589 | 0.387       | −0.169 0.589    |

\[\text{MDW33} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.190                | 0.1823 | 0.552       | 0.625 0.245     |
| Class II           | 0.010                 | 0.1823 | 0.998       | −0.425 0.445    |
| Class III          | 0.200                 | 0.1823 | 0.518       | −0.235 0.635    |

\[\text{MDW41} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.157                | 0.1281 | 0.443       | −0.462 0.149    |
| Class II           | 0.117                 | 0.1281 | 0.635       | −0.189 0.422    |
| Class III          | 0.273                 | 0.1281 | 0.089       | −0.032 0.579    |

\[\text{MDW42} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.038                | 0.1378 | 0.960       | −0.3663 0.2909  |
| Class II           | 0.172                 | 0.1378 | 0.427       | −0.1563 0.5009  |
| Class III          | 0.210                 | 0.1378 | 0.285       | −0.1186 0.5386  |

\[\text{MDW43} \]

| Dependent variable | Mean difference (I-J) | SE | Significant | 95% CI          |
|--------------------|-----------------------|----|-------------|-----------------|
| Class I            | −0.028                | 0.2122 | 0.821       | −0.5342 0.4775  |
| Class II           | 0.285                 | 0.2122 | 0.375       | −0.2209 0.7909  |
| Class III          | 0.313                 | 0.2122 | 0.307       | −0.1925 0.8192  |

*P<0.05. MDW: Mesio-distal width, SE: Standard error, CI: Confidence interval

In this study, measurement of the intercanine width was taken from the base of the odontometric triangle since the outer most convex point of the canine is most easily identifiable on the bite mark. This method of evaluation of intercanine width differs from Tarvadi et al. who measured the intercanine width using cusp tips. He found that using intercanine width as a parameter for bite mark analysis is an unreliable method. This may be because the canine cusp tips are not as discernible in the bite mark as the outline of the canine is. Moreover, skin is poor registration material. Therefore, the base of the odontometric triangle,
No study so far has evaluated the relationship between sagittal dental relation and bite marks. Statistical significance was observed in Class III individuals for the angles of the odontometric triangle in both maxillary and mandibular arches. The mean values of the angles adjoining the base of the triangle at the canine region were lesser, and the mean value of the angle at the apex (midline) was larger in Class III suggesting shorter and broader maxillary and mandibular odontometric triangles in Class III compared to Class II and Class I. The angle at the apex of the odontometric triangle is affected by the anteroposterior position of incisors and the intercanine width. We found no significance in the linear measurement of intercanine width between all the classes. Our observations correlated to the observations made by Koo et al. who compared the arch widths between Class I and Class III and found that the arch width discrepancy in Class III revealed itself at the basal arch width level rather than the dental level. Thus, a larger angle at the apex of the odontometric triangle may have been observed due to the lingual inclination of the teeth; which often occurs in Class III dental compensation.

When the mesiodistal width of the teeth was appraised, the left and right maxillary lateral incisors of Class III occlusion were found to be significantly smaller compared to their Class I and Class II counterparts. Similarly, the left mandibular central incisor of Class III occlusion was significantly smaller compared to the same tooth of Class II occlusion. This was in contrast to the observations made by Hussein et al. who found smaller maxillary laterals in Class I occlusion in Malay school children. The difference in results could be attributed to a variation in the size of teeth occurring due to different ethnic origins. Yang et al. found that Bolton’s anterior and overall ratio for skeletal Class III are greater than for skeletal Class I and Class II occlusion. This will happen either when the mandibular teeth are large or maxillary teeth are small. The presence of small maxillary laterals observed in this study affirms the above. In relation to arch forms this study showed the maximum number of ovoid arches in Class I and Class II occlusions and square arches in Class III occlusions. The observation of this study correlated with the observations made by Omar et al. All the incisors and canines revealed rectangular and circular shapes, respectively, in cross-sectional view. This finding was similar to that made by Sandeep et al.

The results of this study can be useful during litigation to help rule out individuals in the search for suspects. Nonmatching individuals can be separated from the pool of suspects and this helps to narrow down the search process. However, this is only supplemental evidence and should not be used as primary evidence in conferring a criminal charge upon an individual as many factors contribute to the accurate production of the bite marks such as position, pressure, etc. Understanding the gravity of the implications bite mark analysis results can have on the life of an individual caught in the suspicious circle, the American Board of Forensic Odontology has introduced guidelines for the evaluation of bite marks. Despite the guidelines, wrongful convictions have occurred in the past.

From 2000 to 2010, there have been approximately 10 DNA exoneration cases involving bite mark evidence in the US. DNA profiling is the gold standard for criminal prosecutions but is expensive, labor intensive, and time consuming. Bite mark analysis only assist in limiting the number of individuals on whom DNA profiling is done to reach a proper conclusion –enough to convict someone. Newer methods using three-dimensional (3D) technologies are also being introduced for bite mark analysis. It is necessary to expand the scientific knowledge and further research is required to evaluate the existing digital and newer 3D techniques in bite mark analysis.

### Conclusion

Class III occlusion individuals were distinct for the shape of the arch and angles of the maxillary and mandibular odontometric triangle. The quantified values of odontometric triangle can be utilized for the identification of Class III sagittal dental relation. There is a scope for another study to be done for evaluating the size of the teeth in relation to sagittal occlusions.

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**Table 6: Descriptive statistics for Class I, II, and III occlusions**

| Mean±SD         | Class I       | Class II      | Class III     |
|-----------------|---------------|---------------|---------------|
| ICW13-23        | 40.48±2.90    | 39.83±2.87    | 40.42±2.63    |
| MDW11           | 9.05±0.55     | 9.09±0.75     | 8.73±0.54     |
| MDW12           | 7.37±0.53     | 7.53±0.57     | 6.88±0.63     |
| MDW13           | 8.29±0.53     | 8.41±0.86     | 7.98±0.76     |
| MDW21           | 9.04±0.65     | 9.10±0.89     | 9.00±0.61     |
| MDW22           | 7.34±0.57     | 7.56±0.67     | 6.72±0.71     |
| MDW23           | 8.31±0.57     | 8.30±0.65     | 7.95±0.72     |
| 13-M-23         | 106.44±5.25   | 104.68±10.27  | 118.43±3.08   |
| M-23-13         | 37.02±3.18    | 37.60±4.94    | 30.72±1.34    |
| 23-13-M         | 36.85±3.10    | 37.40±5.03    | 29.90±1.32    |
| ICW33-43        | 31.94±2.50    | 31.39±3.24    | 33.79±3.12    |
| MDW31           | 5.77±0.43     | 5.97±0.56     | 5.40±0.59     |
| MDW32           | 6.41±0.47     | 6.38±0.50     | 6.17±0.82     |
| MDW33           | 7.16±0.53     | 7.35±0.70     | 7.15±0.85     |
| MDW41           | 5.80±0.40     | 5.96±0.56     | 5.68±0.51     |
| MDW42           | 6.41±0.43     | 6.44±0.46     | 6.23±0.68     |
| MDW43           | 7.25±0.55     | 7.28±0.67     | 6.97±1.13     |
| 43-M-33         | 118.89±7.56   | 116.03±8.06   | 138.52±14.44  |
| M-33-43         | 30.48±3.45    | 31.90±4.04    | 20.85±7.05    |
| 33-43-M         | 30.22±3.58    | 31.78±4.15    | 21.02±7.37    |

13, 23, 33, 43 - FDI tooth number. ICW: Inter Canine Width, MDW: Mesiodistal width, M: Midline, SD: Standard deviation, FDI: Fédération Dentaire Internationale
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Conflicts of interest
There are no conflicts of interest.

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