Determination of the center of anteroposterior curve of occlusion in a selected local population: A cross-sectional cephalometric study

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Abstract

Objective: The objective of this paper was to cephalometrically determine the center of the anteroposterior curve of occlusion, and its relation to standardized landmarks, to establish a suitable occlusal curve for the restoration of maxillary and mandibular arches in a selected local population. To the best of the authors’ knowledge, this was the first cephalometric study identifying variations occurring in the anteroposterior curve in this population.

Materials and Methods: A total of 80 patients (40 males and 40 females) with Angle’s Class I occlusion and normal growth pattern were selected. Landmarks were established following tracings on standardized lateral cephalograms. The center of the occlusal curve was determined, and its distance from the nasion, lachryma, and orbitale was statistically compared using ANOVA, post hoc and proximal matrix tests in males and females. In addition, a relationship between the depth of occlusal curve and the condyle was established.

Results: The mean distances of the center from nasion, lachryma, and orbitale (statistically significant) were 11.15 mm ± 5.65 mm, 18.68 mm ± 8.6 mm and 33.10 mm ± 10.13 mm for females (P < 0.001) and 9.7 mm ± 4.69 mm, 16.80 mm ± 6.45 mm and 31.22 mm ± 8.51 mm (P < 0.001) for males, respectively. Depth of the curve and distance from the condyle had an inverse correlation.

Conclusion: Nasion is closest to the center of the curve of occlusion in both females and males followed by lachryma and orbitale. Hence, nasion can be considered as a point of reference clinically while determining anteroposterior curve of occlusion.

Keywords: Dental arch, dental occlusion, mandibular condyle, occlusal plane, radiology

INTRODUCTION

Cephalometric analysis has been extensively used as a diagnostic tool in the fields of orthodontics and dental research. In prosthodontics, cephalometric studies may help in the analysis of the relationship between various cranial landmarks and the position of teeth. Cephalometric tracings have already been used in the past to establish a correlation between the plane of occlusion and stable

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landmarks.\textsuperscript{[1]} Such correlations can help to determine the plane of occlusion at the time of restoration of arches in dentate and edentulous patients.

The Curve of Spee plays an integral part in the restoration of dental arches. This curve was first described by Ferdinand Graf Spee, and had a diameter of 2.5 inches.\textsuperscript{[2]} Based on anthropological observations, Monson described a three-dimensional sphere with a diameter of 4 inches, and it passed through the incisal edges and occlusal surfaces of the mandibular teeth.\textsuperscript{[3]} The Curve of Spee, in conjunction with posterior cusp height, condylar inclination, and anterior guidance, plays an important role in the development of the desired occlusal scheme. More recently, it has been also suggested that it may have a role to play in biomechanical function during food processing by increasing the crush shear ratio between the posterior teeth and the efficiency of occlusal forces during mastication.\textsuperscript{[4]} Thus, the curve of Spee is important in clinically determining a harmonious occlusal scheme.

Before we can clinically use the curve for developing a favorable occlusion, it is important to determine the center and the curve radius. At present, there are very few relevant clinical and cephalometric studies to determine the center of anteroposterior curve and thereby its radius, especially in the Indian population. Therefore, the objective of this study was to cephalometrically determine the center of anteroposterior curve of occlusion and its relationship to other cephalometric landmarks. Along with determining the center of the curve, this study also attempted to study the relationship between the center and its relationship with the depth of occlusion and the condylar position. The findings of this study will help in the clinical determination of anteroposterior curve and identifying the closest landmark to the its center.

To the best of the authors’ knowledge, this was the first cephalometric study which attempted to identify variations occurring in the anteroposterior curve based on gender in the Indian population.

**MATERIALS AND METHODS**

This was an observational, cross-sectional study using lateral cephalograms, consisting of a sample size of 80 patients (40 males and 40 females) and followed the STROBE guidelines.\textsuperscript{[5]} This study was conducted in the Department of Prosthodontics, Crown, Bridge and Oral Implantology at Dr. D. Y. Patil Vidyapeeth, Pune, Maharashtra, India with approval from the scientific and ethical committee (IRB approval no-DPU/535 [15/2013]) and was conducted in full accordance with the World Medical Association Declaration of Helsinki.

**Inclusion criteria**

- Age group: 18–25
- Full complement of permanent teeth
- Individuals with vertical growth pattern
- Individuals with skeletal class 1 occlusion with minor malocclusion like crowding, spacing, and rotation were accepted. Minor malocclusion was determined by dental esthetic index criteria (WHO).

**Exclusion criteria**

- Previous orthodontic treatment
- Extensive restoration, cast restoration, and cuspal-coverage restoration
- Anterior and posterior crossbite and deep bite
- Pathological periodontal conditions
- Temporomandibular joint disorders.

**Source of selection**

Samples were randomly selected from patients reporting to the Department of Prosthodontics, Crown, Bridge and Oral Implantology at Dr. D. Y. Patil Vidyapeeth, Pune, India. Written informed consent was obtained from each participant.

**Variables, data sources, and measurements**

For all 80 individuals, lateral cephalograms were made. These were developed using an automatic processor, which took 7 min for the process of developing, fixing and drying. To these radiograph films, a single-side tracing sheet (50 µm) was attached with the help of paper clips. Tracings were made by a single operator for all the lateral cephalograms, and the following anatomical landmarks were identified in males and females [Figure 1a and b].

**Figure 1:** The arc of curvature passed through the tip of the lower incisor, distal inter occlusal point and anterior border of the condyle in the cephalometric tracings in both (a) males and (b) females.
1. Nasion – The anterior point midway between the frontal and nasal bone on the fronto nasal suture
2. Orbitale – The lowest point on the inferior bony margin of the orbit
3. Porion – The superior-most point of the ear rod
4. The anterior border of the condyle-A tangent to the condyle, parallel to the anterior limit of the mandibular canal within the ascending ramus
5. A distal inter occlusal point was established where the occlusal surface of maxillary third molar met the distal surface of the lower third molar in occlusion or where the distal surface of the lower second molar occluded with upper second molar
6. The mesial inter occlusal point was established where the mesial portion of the maxillary first molar met the mesial portion of mandibular first molar
7. The point on the lower incisor was established as close as possible halfway between the labioincisal and linguoincisal angles
8. Lachryma was established halfway between the nasion and orbitale.

The X-axis was the Frankfort horizontal plane, and the Y-axis was drawn perpendicular to the Frankfort through the nasion (McNamara line). Initially, a tentative arc was sketched from the point on the lower incisor to the anterior border of the condyle which was determined as a tangent to the condyle, parallel to the anterior limit of the mandibular canal within the ascending ramus. Either mesial or distal inter-occlusal point form a part of the arc and at any given point both the mesial and distal inter-occlusal points do not form a part of the arc.

Two cords were drawn. One from the tip of the lower incisor to the mesial/distal inter-occlusal point and the second one from mesial/distal inter occlusal point to the anterior border of the condyle. Midpoints of chords were identified and perpendicular lines were drawn from the midpoint. The point where the two perpendicular lines met was identified as the center. With the help of a compass and a 1-mm marker (Camlin™) the arc was made more definitive. Thus, the center was determined. The method was adopted from the study of Kumar et al. On the basis of the arc which was passing either through the mesial inter occlusal point or through the distal inter occlusal point the individuals were then divided into two groups.

For Group 1, the arc passed through the tip of the lower incisor, distal inter occlusal point and anterior border of the condyle [Figure 1a and b]. For Group 2, the arc passed through the tip of the lower incisor, mesial inter occlusal point and anterior border of the condyle [Figure 2a and b].

For all the 80 individuals, measurements were made from the center of anteroposterior curve of occlusion to the nasion, lachryma, and orbitale.

Once the radius of the arc is measured, and the arc of anteroposterior curve was determined, the radius of the curve from the nasion was measured. The cephalometric radius in the Brodrick’s analyzer was used rather than using standard 4” radius to determine the occlusal plane for each individual.

To evaluate the relationship of curve of occlusion to the condylar axis, the depth of curve of occlusion was measured for all the 80 individuals. Once the curve was determined, a chord was drawn between incisal and distal points. The distance was measured from the chord to the deepest point of the curve of occlusion [Figure 3]. The deepest point was determined by measuring the distance between chord at each mm and the curve. Point with maximum distance is the deepest point of curve. The distance from the distal point of curve of occlusion to the condylar axis was calculated for each individual and males and females were divided on the basis on the depth ranging from 0 mm to 10 mm, respectively [Table 1].

Elimination of bias
To reduce selection bias, an attempt was made to randomly select patients reporting to the Department of Prosthodontics, Crown, Bridge and Oral Implantology at Dr. D. Y. Patil Vidyapeeth, Pune to eliminate selection bias. Further, tracings of the lateral cephalogram were made by a single operator.

Study size
The sample size was calculated from previous studies in the same population. The expected effect size was taken
to be 1.5 mm, and the standard deviation of outcome variable of approximately 2,\(^7\) was determined from the previous study. To achieve 90% power to detect this difference with a significance level of 5%, it was estimated that 37 individuals per group would be required. With a withdrawal/nonevaluable subject rate of approximately 5%, a total of 40 individuals per group were required leading to a total required sample size of 80 individuals.

**Statistical methods**

Data were collected and tabulated using Microsoft Excel (Microsoft Excel for Windows, Version 2013, Microsoft Corporation, Redmond, WA, USA). Statistical analysis was performed using SPSS software, (SPSS Statistics for Windows, Version 23.0. IBM Corp, Armonk, NY, USA). Samples with incomplete entries were not considered for analysis. Descriptive statistics were performed, and data were checked for normality using Kolmogorov–Smirnov Test. Further, ANOVA test was performed to determine if there is any significant difference between the three anatomic landmarks to the center of curve of occlusion. Multiple comparison (post-hoc) test was performed using Bonferroni method, to find if any significant difference existed between the genders. Furthermore, proximity matrix study was performed to confirm if nasion is the nearest to the center of anteroposterior curve of occlusion for both genders. In addition, the mean radius between the mesial and distal points was compared using the \(t\)-test.

**RESULTS**

A sample of 40 males and 40 females were collected as per the inclusion criteria, and the mean age of the participants was 22.9 for the males and 23.2 for the females.

Descriptive statistics of linear measurements from the center of curve of occlusion to various cephalometric landmarks such as nasion, lachryma, and orbitale showed that the mean distances were 11.15 mm ± 5.65 mm, 18.68 mm ± 8.6 mm and 33.10 mm ± 10.13 mm for females and 9.71 mm ± 4.69 mm, 16.80 mm ± 6.45 mm and 31.22 mm ± 8.51 mm for males, respectively [Table 2 and Figure 4].

![Figure 3: Determination of the depth of the antero-posterior occlusal curve on a lateral cephalometric tracing](image)

![Figure 4: Linear measurement from the center of curve of occlusion to various cephalometric landmarks included in the study. All differences are statistically significant with \(P < 0.001\)](image)

| Depth of the antero-posterior curve of occlusion (mm) | Females | Males |
|-----------------------------------------------------|---------|-------|
|           | \(n\) | Median distance from distal point to condylar axis (mm) | \(n\) | Median distance from distal point to condylar axis (mm) |
| 0         | 14   | 74.27 | 14   | 78.57 |
| 1         | 15   | 70.50 | 20   | 78.05 |
| 2         | 6    | 62.83 | 3    | 77.00 |
| 3         | 0    | -     | 1    | 72.00 |
| 4         | 0    | -     | 1    | 55.00 |
| 5         | 2    | 60.00 | 1    | 55.00 |
| 7         | 1    | 53.00 | 0    | -     |
| 9         | 1    | 51.00 | 0    | -     |
| 10        | 1    | 49.00 | 0    | -     |
| Total     | 40   |       | 40   |       |
ANOVA test was performed, and it showed a significant difference ($P < 0.001$) between the distances of the three anatomic landmarks from the center of curve of occlusion in both males and females [Table 3].

According to the multiple comparison (post-hoc) test using Bonferroni method, Nasion, among all three cephalometric points was significantly closest to the center of anteroposterior curve of occlusion for both females and males [Table 4]. In addition, as shown in Table 5, the distances between nasion and lachryma, lachryma, and orbitale and orbitale were statistically significant ($P < 0.001$) among the 40 females and 40 males.

The proximity matrix study confirms that the Nasion is the closest to the center of anteroposterior curve of occlusion for both genders [Tables 5 and 6].

Thus, the ANOVA, post hoc, and proximal matrix tests showed statistically significant and similar results for both females and males, and it was confirmed that the nasion is the closest point to the center of anteroposterior curve of occlusion in both genders.

Evaluation of the relationship of curve of occlusion to the condyle [Table 1 and Figure 5] in females revealed that 14 subjects had 0 mm depth of anteroposterior curve of occlusion whereas 15 subjects had 1 mm of depth. This shows that maximum number of subjects fell between 0 and 1 mm of depth of occlusion. Furthermore, mean distance from the distal point to condylar axis for the patients having 0 mm of depth of anteroposterior curve was the highest [Table 1]. Similarly, in males, 14 patients had 0 mm depth of anteroposterior curve of occlusion, whereas 20 patients had 1 mm depth. This showed that a maximum number of subjects fell between 0-1 mm of depth of occlusion. Furthermore, mean distance from the distal point to condylar axis for the subjects having 0 mm of depth of anteroposterior curve was the highest.

The mean radii between distal and mesial groups were compared using the $t$-test, and there was a significant difference between the groups ($P > 0.001$). The mesial group had a higher value as compared to the distal group [Table 7 and Figure 6].

**DISCUSSION**

A cephalogram may be used to determine areas in the base of the cranium which are not altered between certain ages. Therefore it can be a useful diagnostic tool in the analysis of teeth, jaws and the face. In the past, researches have studied several landmarks in dental populations have suggested that a predictable relationship can exist between certain fixed cranial landmarks and the plane of occlusion.
Such findings play an important role in determining the occlusal plane since similar relationships can be used to establish a plane of occlusion for dentate patients using cephalometric landmarks.

The Broadrick occlusal plane analyzer can be used in prosthodontics and restorative dentistry as an effective tool to locate the center of the curve of Spee. Mandibular excursive movements which are free from posterior interferences can be successfully designed by using this tool. Further, this tool can be utilized to predictably produce efficient prostheses which are in harmonious relationship with the condylar and the anterior and guidance.

The landmarks in this study were based on the research by Spee and Hitchcock. The suggested landmarks by Spee for determination of curve were-anterior border of the condyle, distal inter occlusal point, mesial inter occlusal point and tip of mandibular incisors. Hitchcock studied Spee’s prediction and concluded when condyle, mesial interocclusal, and distal interocclusal points were used, it generates the radius which is the closest in length and position to what Spee originally proposed. Hence, the study uses the same landmarks for the determination of the curve.

In this study, it was found that the center of the curve of occlusion was located at a mean distance of 11.15 mm, 18.68 mm and 33.10 mm from the Nasion, Lachryma, and Orbitale, respectively, in females and 9.71 mm, 16.80 mm and 31.22 mm from the same points in males. Therefore, Nasion was determined to be the nearest to the center of curve of occlusion followed by the Lachryma and Orbitale.

### Table 4: Post hoc test of Bonferroni for females and males

| Sex | Parameter (I) distances from the center to | Parameter (J) distances from center to | Mean difference (I-J) | Significant | 95% CI Lower bound | 95% CI Upper bound |
|-----|------------------------------------------|---------------------------------------|-----------------------|-------------|--------------------|--------------------|
| Female | Nasion | Lachryma | −7.525 | <0.001* | −12.05 | −3.00 |
|       | Orbitale | Nasion | −21.950 | <0.001* | −26.48 | −17.42 |
|       | Orbitale | Orbitale | −14.425 | <0.001* | −18.95 | −9.90 |
| Male | Nasion | Lachryma | −7.095 | <0.001* | −10.754 | −3.436 |
|       | Lachryma | Nasion | −21.520 | <0.001* | −25.179 | −17.861 |
|       | Orbitale | Nasion | −14.425 | <0.001* | −18.084 | −10.766 |
|       | Lachryma | Orbitale | 7.095 | <0.001* | 3.436 | 10.754 |

*Statistically significant differences. CI: Confidence interval

### Table 5: Proximity matrix test for females

| Proximity matrix |
|------------------|
| Case | Matrix file input |
| Center | Nasion | Lachryma | Orbitale |
| Center | 0.000 | 6216.000 | 16831.000 | 47826.000 |
| Nasion | 6216.000 | 0.000 | 4759.000 | 23278.000 |
| Lachryma | 16831.000 | 4759.000 | 0.000 | 8809.000 |
| Orbitale | 47826.000 | 23278.000 | 8809.000 | 0.000 |

### Table 6: Proximity matrix test for males

| Proximity matrix |
|------------------|
| Case | Matrix file input |
| Center | Nasion | Lachryma | Orbitale |
| Center | 0.000 | 4625.240 | 12914.000 | 41827.000 |
| Nasion | 4625.240 | 0.000 | 4113.640 | 21625.840 |
| Lachryma | 12914.000 | 4113.640 | 0.000 | 9169.000 |
| Orbitale | 41827.000 | 21625.840 | 9169.000 | 0.000 |

### Table 7: T-test to compare the radii of curve of occlusion among the distal and mesial groups

| Points | n | Mean±SD | Mean difference | t | P |
|--------|---|---------|-----------------|---|---|
| Distal | 10 | 5.730±0.6183 | −1.8243 | −8.133 | <0.001 |
| Mesial | 70 | 7.554±0.9195 | 57.3 | 7.54 | <0.001 |

SD: Standard deviation

Spee for determination of curve were-anterior border of the condyle, distal inter occlusal point, mesial inter occlusal point and tip of mandibular incisors. Hitchcock studied Spee’s prediction and concluded when condyle, mesial interocclusal, and distal interocclusal points were used, it generates the radius which is the closest in length and position to what Spee originally proposed. Hence, the study uses the same landmarks for the determination of the curve.

### Figure 6: Comparison of the radii of curve of occlusion among the distal and mesial groups. Difference is statistically significant with P < 0.001
relationship between the curve of Spee and any of the other cephalometric variables and that the curve of Spee was not influenced by age and gender of the patients investigated. In this study, however, similar results were seen in both the genders.

The Broadrick flag is a useful tool in prosthodontic and restorative dentistry, as it identifies the most likely position of the center of the curve of Spee. However, this position should not be regarded as fixed or immutable. Esthetics and function place a considerable demand on the design of the occlusal plane.[17] Broadrick’s analysis uses 4 inch radius as an average for most of the cases. With the present study, we can determine the exact radius of curve of Spee in an individual using nasion as the center. Hence, along with the Broadrick analysers and the specific cephalometric radius it is possible to clinically establish the exact curve for each individual. Thus, this study tried to provide a cephalometrically and clinically relevant analysis to determine the center of anteroposterior curve and thereby its radius in an Indian population.

In this study, a comparison of radii of the occlusal curve between distal and mesial groups showed that the mean radius of the distal group was 57.30 mm ± 0.6183 mm and for the mesial group, it was 75.54 mm ± 0.9195 mm. It was noticed that there was significant difference between the distal and the mesial groups concerning the radius as represented in Figure 6 and Table 7. The results of the current study are in confirmation with the findings of the study done by Hitchcock.[13]

The results of the study showed that the nasion was the nearest point to the center of the curve. For this study, the cephalometric radius in the Broadrick’s analyzer was used to determine the occlusal plane for each individual and not the standard 4” radius. Using this procedure, a more accurate radius can be determined for each patient and the same can clinically incorporated using Broadrick’s flag to establish better occlusal plane.

Another interesting finding was inverse relation seen between the depth of curve of occlusion and the linear distance from the distal inter occlusal point to the condylar axis in both the male and female samples. The results revealed that an increased depth of curve of occlusion was seen when the distance of the center of the curve from the distal inter occlusal point to condylar axis decreased for both the sexes.

Although the literature is divided on the use of cephalometric landmarks to obtain a suitable plane of occlusion, the authors strongly feel that determining the center of the occlusal curve would help in the restoration of posterior teeth such that they disocclude during mandibular protrusion and lateral excursion, given proper anterior tooth guidance.

This study has its share of limitations. In this study, only patients with Angles class I occlusion (Angle’s molar relationship) were studied whereas subjects with angles class II and class III were not considered. Furthermore, the length of the face was not standardized cephalometrically, and the patients were selected at random, without taking into consideration the facial type (short, long, and average).

CONCLUSION

Within the limitations of this study the following conclusions can be drawn:

1. The center of anteroposterior curve of occlusion is closest to the Nasion for both the genders. Lachryma is the next closest, followed by the Orbitale. Gender variations do not change the sequence
2. There is an inverse co‑relation between the depth of the anteroposterior curve of occlusion and its distance to the condyle for both males and females
3. There was a significant difference between the radii of curve of occlusion between mesial and distal groups with the mesial group having higher values.

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Conflicts of interest
There are no conflicts of interest.

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