Influence of demographic characteristics, tooth loss, and tooth wear on condylar movements: Cross-sectional study

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Abstract  Objectives: The study’s aim was to assess and compare the values of the sagittal condylar angle (SCA), the Bennett angle (BA), and the immediate side shift (ISS) between fully dentate and partially dentate patients, male and female patients, and Saudi and non-Saudi patients. The study also aimed to statistically analyze the correlation of the different condylar movements with tooth loss and tooth wear.

Materials and Methods: Using the electronic pantograph (Cadiax Compact II), the SCA, BA, and ISS were recorded at a 10-mm condylotrack distance in dentate and partially dentate patients, from both genders, older than 20 years, medically stable, and with normal temporomandibular joint movements and normal activity of masticatory muscles. The recorded average values were compared between the groups using an unpaired t-test.

Results: The average condylar movements between dentate (n = 57) and partially dentate (n = 39) groups revealed no significant differences concerning right SCA, left SCA, right BA, right ISS, and left ISS. However, the left BA showed significant differences (P = 0.011) in the dentate compared with the partially dentate group. Gender (male: n = 24, female: n = 72) showed no statistical significance between groups when measuring SCA, BA, or ISS. When comparing Saudi (n = 78) with non-Saudi patients (n = 18), it was found that the mean right SCA was significantly higher in Saudi than in non-Saudi patients (P = 0.024). Condylar inclination values in relation to tooth wear showed no statistical significance (P > 0.05), except left ISS, which was significantly higher among those who had tooth wear (P = 0.040).
1. Introduction

The mandibular musculoskeletal system can perform a variety of biomechanical movements precisely and with a coordinated function while chewing and speaking. Studying mandibular movement is of great importance in evaluating the temporomandibular joint (TMJ) function along with the muscles of mastication (Pinheiro et al., 2008). Any dental prosthesis placed in the mouth should be in harmony with this predetermined system to inhibit any future complications (Ghodsi and Rasaeipour, 2018).

The translatory (mediolateral) movement of the mandible when viewed in the frontal plane is known as the “Bennett immediate side shift (ISS) or mandibular lateral translation,” whereas “Bennett’s movement” is the condylar movement on the working side in the horizontal plane (The Academy of Prosthodontics, 2005). The average value of the Bennett angle (BA) obtained using the Hanau formula is 15° (Ghodsi and Rasaeipour, 2018). ISS, which takes place on the non-working side of the condyles, is considered an important factor because it impacts the horizontal and vertical elements of the occlusion. However, the shape of the condyle plays a major role in the nature of the ISS. Most of the population, about 80%, have ISS to some degree, and it occurs either unilaterally or bilaterally (Zakaria, 2014).

Condylar inclinations dictate a critical role in mandibular movements and in fabricating any type of prosthesis (Ghodsi and Rasaeipour, 2018). The average proposed mean value for sagittal condylar angle (SCA) is 33° ($P < 0.05$) (Ghodsi and Rasaeipour, 2018). Various methods were used for registering condylar inclinations. One of these recording devices is the electronic pantograph, which plays a pivotal role in clinical practice and for research purposes (Celar and Tamaki, 2002). Using the pantograph could help in measuring the ISS on the horizontal plane orbiting path record with units of tenths of a millimeter (Zakaria, 2014). It was recommended to use the 10-mm condylotrack distance for programming the articulators tested since it has provided more reliable and valid readings compared to the 5-mm and 3-mm distances (Chang et al., 2004).

A study conducted previously, have used the pantograph in patients who required full-mouth rehabilitation, showed ISS through eccentric mandibular movements. This result has supported the belief that the ISS is a result of adaptive morphofunctional changes in the fossa as a consequence of any occlusal interference and/or other forces applied to the joint. ISS varied among the patients and bilaterally between them. (Zakaria, 2014).

However, to the authors’ knowledge, there is limited evidence of measuring the horizontal and lateral condylar movements in fully dentate and partially dentate patients and assessing its correlation to tooth loss and tooth wear. Therefore, this study’s goal was to assess and compare the SCA, ISS, and BA using an electronic pantograph among dentate and partially dentate, male and female, and Saudi and non-Saudi patients. Also, the other goal was to statically analyze the correlation of the condylar movements with tooth loss and tooth wear. The null hypothesis of this study was that there would be no difference in the value of the condylar movements between dentate and partially dentate, male and female, and Saudi and non-Saudi patients. Another null hypothesis was that there would be no significant correlation of the different condylar movements with tooth loss types or tooth wear.

2. Materials and methods

This cross-sectional study was conducted from September 2020 to May 2021 by recruiting participants from patients, dental students, interns, and staff visiting and working in IAU Dental Hospital in Al Khobar, Saudi Arabia. Ethical approval was obtained from the IAU University Research Ethics Committee with the IRB number 2020-02-287. A written informed consent, in both English and Arabic languages, was prepared and obtained from the participants before data collection.

Since there is no similar study available to refer to for average condylar inclination measurements between dentate versus partially dentate groups, a 3:2 ratio of fully dentate to partially dentate patient turnover was used in our setup. Hence, the effect size was taken as 0.66, with a 5% significance level ($\alpha$), a 95% confidence interval, and an 80% power of the test ($1-\beta$), and the minimum required sample size was 38 cases for each group. Following a 3:2 ratio, it was decided to recruit almost 40 samples of partially dentate and 60 fully dentate patients in the study.

The inclusion criteria of this study include fully and partially dentate participants, both genders, 20 years and older to confirm the complete development of the facial bones, medically stable, normal TMJ movements, and normal activity of masticatory muscles. The exclusion criteria oppose the inclusion criteria, in addition to eliminating subjects having limited mouth opening (< 40 mm).

Initially, clinical examination was performed for all patients. Then, data collection forms were filled out. Next, recordings of condylar movements were made using an electronic pantograph (Cadiax Compact II, Gamma Medizinisch, Klosterneuburg, Austria) by one trained operator following the manufacturer’s instructions. To register the mandibular movements, an occlusal covering tray clutch was attached to the teeth in the lower jaw, after disinfecting the clutch and blocking any undercuts, if present. Next, the upper facebow was attached by guiding the porous knobs into the ear canals in a painless position, with moderate pressure from the glabella support on the bridge of the nose, and the retaining straps were stretched and placed behind the head on both sides. After that, the lower facebow was attached to the occlusal covering tray and the upper facebow by axis locators. Then, axis locators were removed while making sure that both side arms did not change in position. Finally, the writing bows were fixed and screwed onto the desig-
nated sockets on both the left and right sides of the upper facebow, followed by attaching and firmly screwing the styli tips into the retainer of the lower facebow (Fig. 1).

Each patient was guided to his/her centric relation position as a reference point, and all movements (protrusion, lateral movements, and opening/closing) were recorded. Each record was performed three times, and before each recording, the system was calibrated. During these movements, SCA, BA, and ISS measurements were obtained of both the right and left condyles for each participant at a 10-mm condylotrack distance (Fig. 1).

The statistical analysis was performed using IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp. The categorical variables, including gender, nationality, TMD, tooth loss, prosthesis, and tooth wear, were presented in terms of frequencies and percentages. A chi-square test or Fisher exact test was used, as appropriate, to compare the distributions between dentate versus partially dentate groups. Numeric response variables, such as age, and measurement of condylar inclination, were presented in terms of mean ± SD, which were tested for normality by using the Kolmogorov–Smirnov test within the control and palatal group, and a normal distribution was revealed. An unpaired t-test was applied to compare condylar inclination measurements between dentate versus partially dentate groups, between genders, nationalities, TMD, and tooth wear. Average differences of condylar inclination measurements associated with tooth loss in terms of anterior, premolar, and molar teeth were compared by using a one-way ANOVA test. A result was considered statistically significant if the \( P \)-value \( \leq 0.05 \).

### 3. Results

A total of 96 patients were recruited in this study, 57 (59.4%) of which were dentate and 39 (40.6%) of which were partially dentate. Out of all participants, the number of female patients was triple the number of male patients (75.0%), over half of the participants (81.2%) were Saudi, and the average ages of dentate and partially dentate participants were 26.04 ± 5.56 and 35.33 ± 13.04, respectively (Table 1).

The SCA in both dentate and partially dentate patients was found to be insignificant in relation to the right and left SCA (\( P = 0.702 \) and \( P = 0.183 \)) (Table 2). Whereas for the BA, there was an insignificant difference for the right BA (\( P = 0.409 \)), while there was a significant difference in relation to the left BA (\( P = 0.011 \)) (Table 2). ISS was presented in 69.8% of the patients. The number of patients varied as follows: “both right and left ISS,” “right side ISS,” or “left side ISS” by n = 11, n = 33, and n = 23 patients, respectively. There were insignificant differences between the two groups in relation to the right and left ISS (\( P = 0.246 \) and \( P = 0.552 \)) (Table 2). The results of this study showed that the difference in condylar inclination measurements was nonsignificant in relation to types of tooth loss (\( p > 0.05 \)), as presented in Table 3.

According to Table 4, it was noticed that there was an insignificant difference between male and female patients. In respect to nationality, the average value for the right SCA was the only statistically significant between Saudi and non-Saudi groups (\( P = 0.024 \)). As shown in Table 5, although patients with tooth wear showed higher right and left SCA

### Table 1 Comparison of demographic characteristics, occlusion, and prosthetic status between fully dentate versus partially dentate (n = 96).

| Variables      | Total (n = 96) | Dentate (n = 57) | Partially Dentate (n = 39) | P-value |
|----------------|----------------|------------------|-----------------------------|---------|
| Gender         |                |                  |                             |         |
| o Male         | 24 (25.0)      | 11 (19.3)        | 13 (33.3)                   | 0.119   |
| o Female       | 72 (75.0)      | 46 (80.7)        | 26 (66.7)                   |         |
| Nationality    |                |                  |                             |         |
| o Saudi        | 78 (81.2)      | 49 (86.0)        | 29 (74.4)                   | 0.152   |
| o Non-Saudi    | 18 (18.8)      | 8 (14.0)         | 10 (25.6)                   |         |
| Tooth wear     |                |                  |                             |         |
| o Yes          | 31 (32.3)      | 17 (29.8)        | 14 (35.9)                   | 0.532   |
| o No           | 65 (67.7)      | 40 (70.2)        | 25 (64.1)                   |         |

Values given in parentheses are percentages. *Shows significance at \( P \leq 0.05 \).
averages than patients with no tooth wear, there were no significant differences between these groups. The right BA showed higher values in patients without tooth wear than in patients with tooth wear, however, the opposite result was found for the left BA values. The right and left ISS average values in patients with tooth wear were higher than patients without tooth wear. The average value of the left ISS was statistically significant between patients with and without tooth wear ($P = 0.04$).

### 4. Discussion

The goal of this study was to assess and compare the condylar movements by measuring the SCA, ISS, and BA with the aid of an electronic pantograph, among dentate and partially dentate, male and female, and Saudi and non-Saudi patients. Also, the study aimed to statistically analyze the correlation of the condylar movements with tooth loss and tooth wear. The results showed that there were significant differences between dentate and partially dentate groups in the left BA, Saudi and non-Saudi groups in the right SCA, and tooth wear and no tooth wear in the left ISS. Other variables showed insignificant differences in these groups, and also in the female and male groups and in the tooth loss types. Therefore, the null hypotheses were partially rejected.

ISS mean values when correlated to gender variation were found to be 0.2 mm in males and 0.07 mm in female patients with no significance between the two groups. In the study of Zakaria, a highly significant difference was reported between the mean ISS of male patients (1.68 mm) compared to that of female patients (0.80 mm). However, it could be noticed that ISS mean values in both studies were higher in male patients. Whereas in another research, which studied ISS

| Table 2 | Comparison of average condylar inclination between fully dentate versus partially dentate groups. |
|---------|--------------------------------------------------------------------------------------------------|
| Variables | Dentate (n = 57) | Partially Dentate (n = 39) | $P$-value |
| Age | 26.04 ± 5.56 | 35.33 ± 13.04 | 0.000 |
| Right SCA | 40.00 ± 11.67 | 41.46 ± 7.08 | 0.702 |
| Left SCA | 41.19 ± 8.25 | 37.75 ± 8.24 | 0.183 |
| Right BA | 7.45 ± 2.52 | 7.29 ± 3.10 | 0.409 |
| Left BA | 8.65 ± 4.03 | 6.92 ± 3.17 | 0.011* |
| Right ISS | 0.07 ± 0.13 | 0.10 ± 0.14 | 0.246 |
| Left ISS | 0.08 ± 0.15 | 0.07 ± 0.09 | 0.552 |
* Shows significance at $P \leq 0.05$.

| Table 3 | Comparison of average condylar inclination measurements between types of tooth loss. |
|---------|-----------------------------------------------------------------------------------|
| Condylar inclination measurements | Type of tooth loss | | $P$-value |
| | Anterior (n = 3) | Premolar (n = 17) | Molar (n = 35) |
| Right SCA | 46.67 ± 2.08 | 42.06 ± 5.40 | 42.18 ± 8.20 | 0.496 |
| Left SCA | 39.67 ± 9.24 | 38.47 ± 6.97 | 39.68 ± 9.80 | 0.900 |
| Right BA | 9.33 ± 5.86 | 9.24 ± 4.02 | 8.51 ± 4.17 | 0.820 |
| Left BA | 9.00 ± 6.93 | 6.63 ± 3.50 | 7.09 ± 3.89 | 0.484 |
| Right ISS | 0.20 ± 0.10 | 0.11 ± 0.16 | 0.11 ± 0.16 | 0.634 |
| Left ISS | 0.03 ± 0.06 | 0.06 ± 0.08 | 0.05 ± 0.07 | 0.778 |
Nonsignificant difference at $P \leq 0.05$.

| Table 4 | Comparison of average condylar inclination measurements between demographic characteristics. |
|---------|--------------------------------------------------------------------------------------------------|
| Condylar inclination measurements | Gender | | $P$-value |
| | Male (n = 24) | Female (n = 72) | |
| Right SCA | 41.50 ± 9.61 | 44.51 ± 8.83 | 0.175 |
| Left SCA | 41.14 ± 9.70 | 42.25 ± 9.40 | 0.633 |
| Right BA | 6.87 ± 2.78 | 8.51 ± 4.16 | 0.080 |
| Left BA | 9.09 ± 5.55 | 8.74 ± 4.77 | 0.774 |
| Right ISS | 0.14 ± 0.19 | 0.08 ± 0.14 | 0.088 |
| Left ISS | 0.06 ± 0.08 | 0.06 ± 0.12 | 0.856 |
| Gender | Male | Female | $P$-value |
| Nationality | Saudi (n = 78) | Non-Saudi (n = 18) | |
| Right SCA | 44.80 ± 8.17 | 39.35 ± 11.51 | 0.024* |
| Left SCA | 42.60 ± 9.21 | 39.13 ± 10.21 | 0.184 |
| Right BA | 8.23 ± 4.04 | 7.61 ± 3.43 | 0.547 |
| Left BA | 8.84 ± 4.88 | 8.77 ± 5.39 | 0.954 |
| Right ISS | 0.10 ± 0.16 | 0.07 ± 0.11 | 0.525 |
| Left ISS | 0.06 ± 0.12 | 0.05 ± 0.09 | 0.768 |
* Shows significance at $P \leq 0.05$.

| Table 5 | Correlation of average condylar inclination measurements with tooth wear. |
|---------|-----------------------------------------------------------------------------------|
| Condylar inclination measurements | Tooth wear | | $P$-value |
| | Yes (n = 31) | No (n = 65) | |
| Right SCA | 44.18 ± 8.51 | 38.64 ± 10.76 | 0.147 |
| Left SCA | 40.30 ± 10.63 | 39.78 ± 7.32 | 0.872 |
| Right BA | 7.19 ± 2.64 | 7.47 ± 2.82 | 0.669 |
| Left BA | 9.14 ± 5.13 | 7.63 ± 3.10 | 0.128 |
| Right ISS | 0.11 ± 0.17 | 0.07 ± 0.11 | 0.282 |
| Left ISS | 0.13 ± 0.16 | 0.06 ± 0.12 | 0.040* |
* Shows significance at $P \leq 0.05$. 

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during symmetric mandibular movements using computerized condylography, they found that ISS from the rest position to any direction, ranged from 1.0-3.5mm during opening and closing. They also found a significant increase in the ISS in the adult group when compared to the young group (Mito et al., 2009). These contrasting results could be due to many factors such as the hypertension of masticatory muscles and the strain of the TMJ area, or the variation of the sizes and shapes of regional muscle attachments Moreover, the stretch in the ligaments of the articular capsule of the working condyle may play a role.

Similar to the results of the current study, Alshali et al. noticed that the mean SCI value for men was 40.3° and for women was 43.6°, with no significant difference between the two groups (Alshali et al., 2013). Also, close results were obtained by J.A. Payne and H.C. Lundeen with a mean SCI of 42.7° and 45°, respectively (Payne, 1997; Lundeen, 1979). In addition, Alfredo I. Hernandez found no statistical significance between right and left SCI angles at 10mm condylotrack distance, 43.3 and 45.1 degrees, respectively (Hernandez et al., 2010). A similar study conducted to compare mandibular recordings by Cadiax Compact II with intraoral records using wax and additional silicon also found a significant difference between the two groups. Even the mean SCI value was higher in the use of Cadiax records (41.6 degrees), while intra-oral records showed a lower value (39.6 degrees) (Torabi et al., 2014). It is evident from the diverse results that SCI is highly variable. This variability could be related to the true variation in the population or due to the different techniques used by the researchers; for example, some studies relied on certain condylar track lengths (4, 5, or 10 mm), while others did not even mention the distance at which the SCI was measured (Alshali et al., 2013).

In the present study, there was an insignificant difference between dentate and partially dentate groups for the right BA, while there was a significant difference in relation to the left BA. Another study has evaluated BA in dentate patients and found that the mean BA value was 10.19 for the right side and 10.02 for the left condyle with a significant difference (Ghodsi and Rasaeipour, 2018). In the study of Celar A.G., however, which studied the accuracy of a 3D-digitizer in relation to the Cadiax Compact II in measuring the BA at 5 different articulator adjustments, it was found that the mean BA was 23.415 in the 3D-digitizer, which was significantly higher than the Cadiax Compact II’s mean of 10.67 (*P < 0.01) at a 10-mm condylotrack distance (Celar and Tamaki, 2002). In the study of Kianooosh Torabi, which compared the values of BA by using Cadiax record with intraoral records, cadiax record revealed a lower mean value (10.6 degrees), whereas intra-oral record showed a higher value (15.9 degrees) (Torabi et al., 2014). While in another study, it was found that the average BA is approximately 8 degrees (Cimic et al. (2016)).

In this study, it was found that significance in both BA and ISS are related to the left side in relation to tooth loss and tooth wear, respectively. Since no previous studies found a similar correlation, we believe that the reason behind this is related to the right side as the preferred chewing side, which is strongly supported by the study of B. Rovira-Lastra, who found that 77% of the unilateral chews prefer the right side (Rovira-Lastra et al., 2016). Therefore, having the working condyle most often on the right side could lead to higher values in the non-working condyle of the left side.

The sample size was adequate in the present study, which could make the results more reliable. However, the study has certain limitations, including that, given its cross-sectional design, it may not support cause and effect or directionality; furthermore, the ratio of male to female patients may have had an influence on the study results, and increasing the sample size could improve the reliability of the study results.

5. Conclusions

- The major impact of tooth loss based on comparing the condylar movements between dentate and partially dentate patients was in the left BA.
- Patients with tooth wear had a significantly increased ISS on the left side, while the other measurements of condylar movements were not significantly affected.
- Saudi patients had a substantial increase in the right SCA only, as compared with non-Saudi patients.
- The type of tooth loss, in anterior teeth, premolars, or molars, had no significant influence on the condylar movements.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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