Bohler’s Angle and Critical Angle of Gissane: Morphometry in Adult Indian Population

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ABSTRACT
Introduction: For the quantification of intra-articular fracture of the calcaneus, different types of angles have been mentioned in the literature. Of these, the Bohler’s angle (BA) and the critical angle of Gissane (CAG) are used in common practice. However, there is a great paucity of literature conducted on the Indian populace to find out the normal range of BA and CAG. In this article, our objective is to homologate and confirm the normal range of BA and the CAG in the Indian population and compare their values to the published international reference values.

Materials and methods: It is an observational cross-sectional study done between 2017 and 2019. X-rays were anonymized by hiding the identification data. The BA and CAG were measured together and by two authors simultaneously. Each angle was measured two times. Two-sample T-test was chosen to compare the means of the values and the p value <0.05 was considered significant.

Results: Three hundred and eighty-four (n=384) X-rays were studied. The average age of the patients was 41.73 years. The mean (°) of BA was 33.53 ± (SD) 6.78 (max = 46.35, min = 16.23) and the mean (°) of CAG was 115.90 ± (SD) 11.00 (max = 142.88, min = 90.22).

Conclusion: The distinct apprehension of the normal dispersion of Bohler’s angle and the CAG is utmost needed for the clinical practice in a population (racial) group. So, it is praiseworthy to conduct a multicenter study over a large Indian population (considering racial variation) with inter and intra-rater reliability.

Keywords: Ankle, Indian, Population.
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INTRODUCTION
Ascertaining of a normal range of Bohler’s angle (BA) and the critical angle of Gissane (CAG) is a prerequisite for determining the degree of deformity and quality of reduction of calcaneus which allows more predictive morbidity of a calcaneal fracture. Among the saga of diagnosis and quantification of intra-articular fracture of the calcaneus, various angles have been mentioned in the literature. But, the BA and CAG are predominantly used in the mass practice for the management of adult calcaneal fracture.

Since the chronicles of BA and the CAG amazingly there is a great paucity of literature conducted over the Indian populace to find out the normal range of BA and CAG. Furthermore, various works of literature have emphasized that the normal range of BA and CAG of the calcaneum is influenced by race. So, it becomes evident to set a reference value for the Indian race. Hitherto, due to the unavailability of standard parameters for our country, the Indian orthopedic surgeons have promulgated the available western reference value of calcaneal angles. Our objective was to homologate and confirm the normal range of BA and the CAG in the Indian population and juxtaposition to the international reference values. This article aimed to measure the BA and CAG in the Indian population to analyze their range of distribution and the influence of side (right or left) and sex.

MATERIALS AND METHODS
This study was carried out at one of the graceful medical colleges of central India. It is an observational cross-sectional study done, from January 2017 to June 2019. Digital radiograph of a lateral view of the ankle (either left or right) for either gender, who visited the hospital due to any ankle related problem, was included in the study. A specialized foot and ankle radiographer was employed to take the X-ray and only the standard lateral ankle X-ray was chosen to measure the angle. X-rays of the calcaneus with fused epiphysis only were included in the study.

Ankle X-ray showing the un-ossified calcaneum, fracture, structurally deformed, and pathological condition (i.e., arthritis) of calcaneum was abdicated.

The BA is formed by the intersection of the two lines. The first-line (A–B) is drawn from the top of the posterior articular surface to the most cephalic point of the calcaneal tuberosity. Then, the second-line (C–D) is drawn from the anterior process (that forms the articular process for the cuboid bone) of the calcaneus to the top of the posterior articular surface. The intersecting point (E) of both lines forms the angle AEC called BA (Fig. 1). For the measurement of CAG, the first-line (A–B) is drawn from the tarsal sinus toward the highest most point of the anterior surface (for the cuboid bone). Then, another line (C–B) is drawn from the tarsal sinus toward the posterior talar articular surface. Now the formed angle ACB is the CAG (Fig. 2).

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All the X-rays were anonymized by hiding the identification data (i.e., name, age, and sex) and arranged in a casual order. The BA and CAG were measured together and by two authors simultaneously at the workstation (IMAGE version 14.01, Evertech Software Private Limited Mumbai, India). Each angle was measured two times (at least at the interval of 24 hours in a random fashion) to minimize the errors and the mean was calculated. The statistical analysis was accomplished by Microsoft XL 2007 (data add-in functions were installed for data analysis). Data of the whole population as well as in the groups (male to female and right to left) were also analyzed. Two sample T-test was chosen to compare the means of the values and p value < 0.05 was considered significant.

**Results**

Three hundred and eighty-four (n = 384) X-rays were included in this study. The male and female ratio was 222 males and 162 females and the right and left distribution was 150 left (88 males and 62 female) 234 right (134 males and 100 female). The average age of the patients was 41.73 years (max = 80, min = 18). The analytic detail of the BA and CAG of overall patients is given in Table 1. The mean (°) of BA was 33.53 ± (SD) 6.78 (max = 46.35, min = 16.23) and the mean (°) of CAG was 115.90 ± (SD) 11.00 (max = 142.88, min = 90.22).

Gender (male and female) and side (left and right) specific statistical analyses were also done and depicted in Tables 2 and 3, respectively. Among male gender, BA value (°) was (mean ± SD) 33.41 ± 7.20 (p = 0.5, max = 40.32, min = 18.25) and CAG value (°) was 115.68 ± (SD) 6.95 (max = 45.18, min = 96.72). The BA value (°) for left side was 33.19 ± (SD) 6.81 (p = 0.5, max = 45.18, min = 18.25) and CAG value (°) was 116.94 ± (SD) 10.56 (p = 0.5, max = 142.88, min = 96.72). Moreover, the comparison of the values of BA and CAG in left and right as well as male and female side did not reveal any statistically significant differences.

Bohler proposed the normal tuber-joint angle of the calcaneum. The unanimously accepted range of normal BA is 25 to 40°. Bohler professed that the tuber-joint angle (now commonly known as BA) of the calcaneum is advantageous for the diagnosis of the compressive calcaneal fracture. Since long it has been assumed that the intra-articular fracture (tongue-type and joint-depression type) shows a reduction in the BA. But the BA is also decreased in other extra-articular fractures of calcaneum, so the role of the BA is significant in almost all types of a calcaneal fracture. The measurement of BA is easier, quick, accurate, and credible, even it can be used impromptu to diagnose the calcaneal fracture.
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Gissane noted that in the lateral view of the calcaneum there is a conspicuous angular cortical platform, which parallels the lateral process of the talus. This angular measurement by Gissane is widely accepted and called CAG and varies between 100 and 130°.8

Contrary to BA which decreases in both extra- and intra-articular fractures, the CAG is more specific but only deviates in intra-articular fractures of the calcaneum.

It is well evident that as the calcaneum grows with age, the morphology of calcaneum (BA and CAG) also varies with time. So, the measurement of BA and CAG will be varied due to ossification with the age. Some authors have advocated that the absolute measurement of an angle is meaningless in a pediatric age group.9,10 Thus, in this study, we did not include the pediatric calcaneal X-rays to maintain the homogeneity of values.

There is always a debate between comparative superiority between the cadaveric and radiological morphometric study. It is conceded that the cadaveric group tends to be comprised of a relatively older (non-homogeneous age distribution) population and has the difficulty in sex determination, wear and tear of bone and there are higher chances to include the pathologic bone in the study due to unknown history.11 So, due to the non-homogeneity of the sample population, the morphometric values may be deranged. Kim et al. in their study found that there was no significant statistical difference between the cadaveric and radiological morphometric values of BA and CAG, although they noticed that mean values of BA and CAG were higher in the radiological group.12 It is the most controversial point that how to interpret the cadaveric morphometric values in clinical practice where the restoration of BA and CAG is mainly assessed by a radiological method. Thus, radiologically measured morphometric values of BA and CAG are more valid and authenticated than cadaveric study.

Calcaneus fracture is the most common entity (75% of all foot fractures) among the tarsal bones and it accounts for 2% of all fractures.13 It is more common in males because males are supposed to be more outgoing as well as more engaged in industrial work in comparison to females. So, the importance of calcaneal fractures can be assumed in such a way that, male laborer sustaining bilateral intra-articular fractures has the support of compensation because of below-par outcome.14 Outcome of calcaneal fractures also correlates with the socioeconomic impact of injury over the patient. The preoperative value of these calcaneal angles substantially correlated to the severity of the injury and the postoperative value has a strong correlation to predict the functional outcome and anticipation of subtalar fusion.15,16 So, there is evidential manifest that the precise (normal range) knowledge of BA and CAG has the imperative necessity for the evaluation and the management (anatomical alignment) of calcaneal fracture, particularly in the concern of bilateral calcaneal fracture.

Table 4 depicts the comparative values of BA and CAG of our study with the unanimously accepted reference value. Chen et al. in their study found that if the lower limit of BA is reduced from 28° to 18° (mean—2 SD), it reduces the (from 31% to up to 1%) false-positive abnormal values. So, it is obvious that the lower limit of BA and CAG is of greater interest. Our study (Table 4) shows the lower value for a lower limit of BA and CAG in comparison to an accepted reference value, which complies with Chen et al.’s study.17 The diagnosis making of the calcaneal fracture using the BA and CAG poses a difficulty, because there is no agreed cutoff angle to rule in or rule out the fracture. So, the calcaneal fracture can be ascertained by obtaining and comparing the X-ray of the opposite side. But it is not the same for the case of a bilateral calcaneal fracture. In such circumstances, the importance of the cutoff value of BA and CAG is of great value. So, the lower cutoff angle (BA and CAG) of a particular race (i.e., Indian) has practical implications in the field of orthopedic practice. Our study includes a quite bigger population than other study and our study also has the lowest value of BA and CAG among the discussed works of literature. So, it can be conceded as a reference parameter (of BA and CAG) for the management of calcaneal fracture in the Indian population.

Since few schools of thought do not consent to use the existing population as standard reference values, we also compared the contralateral calcaneal parameters, which were statistically insignificant (Table 3). This statistical insignificance difference (between right and left feet) of BA and CAG, is in correlation with the racial study done over the Egyptian and Saudi Arabian population.18,19 So, it is commendable here to use the contralateral morphometric parameters (reference value) for the management of calcaneal fracture, rather than existing (racial) population data. Our study is also in correlation to a finding of Seyahi et al., which could not find any statistically significant difference in BA and CAG (between male and female population) of Turkey.20

Our study was completed with a few limitations. It was conducted at a single center with a relatively small adult population, so these morphometric values cannot be applied in children. And, the dissimilar distribution of gender (male or female) and side (right or left) in the study could have been another factor to affect the comparisons of values. So, for homogeneity, a multicenter study with similar distribution should be carried out over a large population. Furthermore, in this study, we did not statistically enumerate the inter-rater as well as intra-rater reliability, which could have improved our study.

**Conclusion**

The range of normal limits and the distribution of the BA and the CAG are broad and different for each population. For that reason, the normal limits and the distribution of BA and CAG should be defending the corresponding population cohort. Our data can be used as reference data for the anatomical alignment in the management of the calcaneal fracture. So, it is praiseworthy to conduct a multicenter study over a large Indian population (considering racial variation) with inter and intra-rater reliability.

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