"COMPARATIVE EVALUATION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"

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CERTIFICATE

This is to certify that thesis entitled **"COMPARATIVE EVALUATION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"** is an original work of **Dr. R. Baskar** carried out under our direct supervision and guidance at Department of Dentistry, All India Institute of Medical Sciences, Jodhpur.

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DECLARATION

I, hereby declare that the work reported in the thesis entitled **"Comparative evaluation of morphological differences in temporomandibular joint (TMJ) in patients with posterior crossbite"** embodies the result of original research work carried out by me in the Department of Dentistry – Orthodontics and Dentofacial Orthopaedics, All India Institute of Medical Sciences, Jodhpur.

I further state that no part of the thesis has been submitted either in part or in full for any other degree of All India Institute of Medical Sciences or any other Institution/ University.

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LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL FORM
PCB	Posterior crossbite
UPCB	Unilateral posterior crossbite
FUPCB	Functional unilateral posterior crossbite
CO	Centric occlusion
CR	Centric relation
CT	Computed tomography
CBCT	Cone beam computed tomography
TMJ	Temporomandibular joint
TMD	Temporomandibular disorder
RME	Rapid maxillary expansion
EMG	Electromyography
RCT	Randomized control trial
DICOM	Digital imaging and communication in medicine
FHP	Frankfort horizontal plane
CG	Control group
MSP	Mid sagittal plan
LCP	Left condylar process
RCP	Right condylar process
MDCD	Mesio-distal condylar diameter
APCD	Antero-posterior condylar diameter
CI	Condylar inclination
CD	Condylar distance
WGF	Width of the glenoid fossa
DGF	Depth of the glenoid fossa
AJS	Anterior joint space
SJS	Superior joint space
PJS	Posterior joint space
MxMI	Maxillary molar inclination
MnMI	Mandibular molar inclination
MBT	Maxillary buccal bone thickness
MBH	Maxillary buccal bone height
SD	Standard Deviation

CI	Confidence Interval
ANOVA	Analysis of Variance
ICC	Intra-class correlation coefficients
P-value	Probability value

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INTRODUCTION

Temporomandibular joint is one of the complex joints in the body and it is the area where craniomandibular articulation occurs. It is formed by the mandibular condyle articulating with the mandibular fossa of the temporal bone. Articular disc separates these two bones from direct articulation is the form of compound joint. It divides the joint into upper and lower compartments. While upper compartment permits only gliding movements, lower compartment permits gliding as well as rotatory movements. This articulation is closely associated with transverse relationship of maxillary and mandibular teeth. Normal transverse posterior relationship of maxillary and mandibular teeth is in which, mesiopalatal cusp of maxillary first molar occluding with the central fossa of mandibular first molar.

It is observed that normally teeth tend to erupt throughout life until sufficient occlusal or soft tissue load prevents further eruption. Teeth tends to erupt along their long axis, but their bucco-lingual direction is influenced by the soft tissue envelope (tongue-cheeks-lips) in order to bring them into occlusion with teeth from the opposing jaw. In the presence of a hypoplastic maxilla, the tongue will tend to tip the maxillary molar buccally, and cheek will tend to tip the mandibular molars lingually (transverse compensations) (1). Any deviation from this will result in posterior crossbite.

Posterior crossbite (PCB) has been identified as a lingual inversion of the normal transverse relationship between the upper and lower dental arches, characterized by the buccal cusps of the maxillary teeth occluding lingually to the buccal cusps of the corresponding mandibular teeth. It is one of the most prevalent malocclusions which has been reported between 8-23% in the primary and mixed dentition with less than 16% of incidence for self-correction. The prevalence of crossbite in permanent dentition has been reported up to 15.6% where in prevalence of bilateral posterior crossbite is up to 6.2% and unilateral posterior crossbite is up to 5.9% on the right side and 3.6% on the left side (2-4).

The etiology of posterior crossbite can include any combination of dental, skeletal, and neuromuscular functional components, but the most frequent cause is reduction in width of the maxillary dental arch. A small maxilla to mandible width ratio may arise from genetic or environmental factors. Upper airway obstruction in the form of hypertrophied adenoids or tonsils and allergic rhinitis can result in mouth breathing and are often correlated with the development of posterior crossbites (5-7). Those who have been intubated during infancy also have a significantly higher prevalence of posterior crossbites (8). Non-nutritive sucking habits are also associated with development of posterior crossbite. In 2- to 5-year-old children, a significantly higher prevalence of posterior crossbite is seen when a pacifier had been used. Both pacifiers and prolonged digit sucking, particularly if extended beyond age 4, are strongly associated with the development of posterior crossbites (9-13). Since spontaneous correction is rare, posterior crossbite is believed to be transferred from primary to permanent dentition, with long-term effects on the growth and development of the stomatognathic system (14-15).

Unilateral posterior crossbite (UPCB) is an asymmetric malocclusion characterized by an inverted transverse relationship between posterior upper and lower teeth restricted to either the left or right side and may affect one or more teeth. In most cases, a mandible shift occurs accompanied by a deviation of the lower midline and it is known as functional unilateral posterior crossbite (FUPCB) (16-18). The most common form is a unilateral presentation with a functional shift of the mandible toward the crossbite side, which occurs in 80% to 97% of cases. The prevalence of functional unilateral posterior crossbite (FUPCB) is 8.4% in the primary dentition and 7.2% in the mixed dentition (19-20). A centric occlusion (CO) to centric relation (CR) discrepancy is evident in a FUPCB, whereas CO and CR are usually coincident in a true unilateral crossbite. A bilateral crossbite due to skeletal imbalance between maxillary and mandibular transverse dimensions differs from a FUPCB only in degree of severity, the maxillary to mandibular width discrepancy is less with FUPCB (21).

Lateral shift of the mandible in a FUPCB results in a mandibular skeletal midline deflection to the crossbite side. The maxillary arch is usually symmetrical with coincident maxillary dental and skeletal midlines. The maxilla is transversely constricted in a FUPCB with marginal ridges of maxillary and mandibular teeth in line and absence of simple dental crossbite. Because of this transverse maxillary deficiency, crowding is seen more frequently in the maxilla than in the mandible. The crossbite side in a FUPCB often shows a partial or full Class II molar relationship, while the non-crossbite side shows a Class I relationship due to rotational closure of the mandible (22).

Posterior unilateral crossbite with postural alterations in mandibular morphology can result in asymmetrical growth and function of the skeletal and muscle structures. It has been suggested that an altered morphological relationship between the upper and lower dentition is associated with right-to-left-side changes in the glenoid fossa (23).

Electromyographic studies have reported asymmetry in masticatory muscle activity during dynamic occlusion and asymmetric muscular potential in the postural position of the mandible in patients with posterior unilateral crossbite. Subsequent adaptation of the neuromusculature to the acquired mandibular position can cause asymmetric mandibular growth, facial disharmony, and several functional changes in the masticatory muscles and temporomandibular joint (24). Studies indicate that patients with unilateral posterior crossbite have altered mandibular kinematics – reverse sequencing chewing patterns and changes in the bite force (25-27).

The condyles on the crossbite side are positioned relatively more superiorly and posteriorly in the glenoid fossa than those on the non-crossbite side. Since skeletal remodeling of the temporomandibular joint can occur over time, the condyles become more symmetrically positioned in their fossa, but facial asymmetry with mandibular midline deviation toward the crossbite side might persist (28).

Vitral et al. (29) investigated the condyle-fossa relationship, the position of the condyles and the dimensional and positional symmetries between the right and left condyles in a sample with normal occlusion. He found that the largest mesio-lateral diameter of the mandibular condylar processes and the posterior joint spaces showed a statistically significant difference between the right and left sides. Evaluation of the concentric position of the condyles in their respective mandibular fossae showed a non-centralized position for the right and left sides. Another study conducted by Pittman et al. (30) on condylar changes in patients with unilateral posterior crossbite with a functional shift, significant differences were found between the molar inclinations, condylar width, angulation and joint space measurements between the two groups.

The use of computed tomography (CT) scans in TMJ studies is a significant advancement in the research to study the morphology of these structures and the diagnosis of pathologies that are difficult to identify by conventional radiographs. CT technology makes it possible to create anatomically true (1:1 in size) images devoid of magnification and superimposition. These scans are closer to anatomic measurement and give a three-dimensional view of the condyle-glenoid fossa relationship.

Routine orthodontic treatment can be enhanced by the ability to diagnose and plan treatment in three dimensions of space. However, comprehensive orthodontic treatment planning has not been possible because of the lack of craniofacial normative values (31). Enlow (32) reported that, the near-future will be based on the actual biology of an individual's own craniofacial growth and development, and it will be determined by a 3D evaluation based on that person's actual morphogenic characteristics, not simply developmentally irrelevant radiographic landmarks.

Since the previous studies have showed quite conflicting in TMJ morphology and position between different posterior transverse bite patients results, more studies are required to evaluate temporomandibular joint morphology in crossbite patients. Therefore, the purpose of this study was to analyze condylar morphology and glenoid fossa dimensions in patients with posterior crossbite using computerized tomography.

AIMS AND OBJECTIVES

Aim:

To analyze condylar morphology and glenoid fossa dimensions in patients with posterior crossbite using computerized tomography.

Objective:

Primary Objective:

- To compare condylar morphology and glenoid fossa dimensions in patients with normal posterior bite (control) and posterior crossbite.

Secondary Objectives:

- To compare in molar inclination, buccal alveolar bone thickness and buccal alveolar bone height in patients with normal posterior bite (control) and posterior crossbite.

REVIEW OF LITERATURE

- **O'Byrn et al**. (24) in 1995 conducted a retrospective study to determine whether mandibular symmetry in adults with untreated unilateral posterior crossbite was different from that adults with untreated Class I malocclusions. Thirty adults with a unilateral posterior crossbite were compared with thirty adults exhibiting Angle Class I malocclusions. Skeletal and dental symmetry were assessed with submentovertex (SMV) radiographs, whereas condylar position within the glenoid fossa was analyzed with horizontally corrected tomograms. The mandible in adults with unilateral posterior crossbite was rotated relatively posteriorly on the crossbite side as related to the cranial floor. Also, the molars were positioned relatively posterolaterally on the crossbite side. Because of a lack of demonstrable difference in both mandibular skeletal asymmetry and condylar position within the fossa between the two groups, it was assumed that the glenoid fossa through remodelling was also located relatively posteriorly on the crossbite side.

- **Hesse et al**. (22) in 1997 did study to confirm that correction of functional posterior crossbite through maxillary expansion is associated with a change in condylar position and occlusal relationships, and to determine whether maxillary expansion is associated with autonomous increase in mandibular arch width. Pretreatment and posttreatment tomographic evaluation revealed that the condyles moved posteriorly and superiorly on the non-crossbite side from before to after treatment. No differences were observed on the crossbite side. Superior joint space was greatest on the non-crossbite side before treatment, whereas, conversely, it was greatest on the crossbite side after treatment. Relative condylar position was more anterior on the non-crossbite side before treatment, but similar on both sides after treatment. Molar and canine relationships were more Class II on the crossbite side before treatment and similar on both sides after treatment. A significant reduction in midline deviation was seen from before to after treatment. A small, but significant autonomous increase in mandibular intermolar width occurred concomitant with the maxillary expansion.

- **Nerder et al.** (33) in 1999 studied changes in the functional shift of the mandibular midline and condyle during treatment of unilateral posterior crossbite in six children, aged 7-11 years. An expansion plate with covered occlusal surfaces was used as a reflex- releasing stabilizing splint during an initial diagnostic phase(I) in order to determine the structural (i.e. non guided) position of the mandible. The same plate was used for expansion and retention (phase II), followed by a post-retention phase (III) without the appliance. Transverse mandibular position was recorded on cephalometric radiograph. Prior to phase I, the mandibular midline deviated more than 2mm and, in occlusion (ICP), the condyle showed normally centred position in the sagittal plane. With the splint, the condyle on the crossbite side was displaced 2.4mm forwards compared with the ICP, while the position of the condyle on the non-crossbite side was unaltered. After phase III, the deviation of the midline had been eliminated. These finding suggest that the TMJs adapted to displacement of the mandible by condylar growth or surface remodeling of the fossa. The rest position remained directly caudal to the ICP during treatment. Thus, the splint position, rather than the rest position should be used to determine the therapeutic position of the mandible.

- **Pinto et al**. (34) in 2001 evaluated the morphological and positional mandibular asymmetry of 15 young patients with functional unilateral posterior crossbite. Patients were evaluated at the initiation of treatment and approximately 6 months after the retention phase. A bonded palatal expansion appliance was used to rapidly expand the maxilla (1 month) and retain the treatment changes (6 months). Zonograms were used to assess articular joint spaces, and submental vertex radiographs were used to assess morphological and positional asymmetry. The results showed that the mandible was significantly longer on the non-crossbite side than it was on the crossbite side. The asymmetry was most evident for the ramus and involved both the condylar and the coronoid processes. The posterior and superior joint spaces were larger on the non-crossbite side than they were on the crossbite side. After treatment and retention, the mandible showed no significant morphological asymmetries. Mandibular growth was greater on the crossbite side than non-crossbite side, and the mandible had been repositioned. The crossbite side had rotated forward and medially toward the non-crossbite side. They concluded that unilateral posterior crossbites produce morphological and positional asymmetries of the mandible in young children, and that these asymmetries can be largely eliminated with early expansion therapy.

- **Petren et al.** (35) in 2003 assessed the orthodontic treatment effects on unilateral posterior crossbite in the primary and early mixed dentition by systematically reviewing the literature. The inclusion criteria were primary and early mixed dentition with unilateral posterior crossbite, randomized controlled trials (RCT), prospective and retrospective studies with concurrent untreated as well as normal controls, and clinical trials comparing at least two treatment strategies without any untreated or normal group involved. They concluded that there is no scientific evidence available to show which of the treatment modalities, grinding, quad-helix, expansion plates, or rapid maxillary expansion, is the most effective. Most of the studies have serious problems of lack of power because of small sample size, bias and confounding variables, lack of method error analysis, blinding in measurements, and deficient or lack of statistical methods. To obtain reliable scientific evidence, better-controlled RCTs with sufficient sample sizes are needed to determine which treatment is the most effective for early correction of unilateral posterior crossbite.

- **Kiki et al.** (36) in 2007 investigated whether patients with bilateral posterior crossbite have asymmetrically developed condyles. The study group consisted of 75 patients with bilateral posterior crossbite, and a control group of 75 subjects with normal occlusion. Condylar, ramal, and condylar plus ramal asymmetry values were computed for all of the subjects on orthopantomograms. The patients with bilateral posterior crossbite had more asymmetrical condyles relative to the controls. However, there were no statistically significant differences in condylar, ramal, or condylar plus ramal heights between left and right sides in both the control and crossbite groups. Patients with bilateral posterior crossbite can have asymmetrical condyles and might be at risk for the development of future skeletal mandibular asymmetries.

- **Kilic et al.** (37) in 2008 investigated condylar and ramal asymmetries in 81 patients with unilateral posterior crossbite and 75 patients with normal occlusion. Condylar, ramal, and condylar-plus-ramal asymmetry values were computed for all subjects on panoramic radiographs. They found the patients with unilateral posterior crossbite had more asymmetric condyles than the controls. In addition, condylar, ramal, and condylar-plus-ramal heights on the crossbite side were smaller than those on the noncrossbite side.

- **Lippold et al.** (38) in 2008 analysed potential discrepancies in condyle position among different occlusal relations (centric relation and maximum intercuspation) in children with unilateral posterior crossbite. They employed alternative procedure for the assessment of condylar deviations was ARCUS®digma, a measuring system based on ultrasound technology, to record condylar differences occurring in 65 children (6.9 ± 2.0 years of age) with functional unilateral posterior crossbite in late deciduous and early mixed dentition. After randomization, 31 patients underwent early orthodontic treatment (bonded palatal expansion appliance and U-bow activator), whereas 34 patients remained untreated. Examinations were carried out at the beginning (T1) and after 12 months of treatment (T2). A three-dimensional (3D) assessment of deviations between maximum intercuspation and centric position was carried out. A mean condylar deviation of > 2 mm was noted at T1 in the sagittal, frontal and transversal planes for crossbite and the non-crossbite sides. This difference was reduced in the therapy group, a finding that proved statistically highly significant and also observed a highly significant difference between the control and therapy groups at T2. So, they recommended early treatment for unilateral crossbite patients.

- **Andrade et al.** (39) in 2009 assessed by systematically reviewing the literature, the functional changes of the masticatory muscles associated with posterior crossbite in the primary and mixed dentition. They concluded that children with posterior crossbite can have reduced bite force and asymmetrical muscle function during chewing or clenching, in which the anterior temporalis is more active and the masseter less active on the crossbite side than the non-crossbite side. Moreover, there is a significant association between posterior crossbite and TMD symptomatology. The consequences of the functional changes for the growth and development of the stomatognathic system deserves further investigation.

- **Uysal et al.** (40) in 2009 evaluated the condylar, ramal, and condylar-plus-ramal mandibular vertical asymmetry in a group of adolescent subjects with normal occlusion and unilateral and bilateral posterior crossbite malocclusions. Mandibular asymmetry index measurements (condylar, ramal, and condylar-plus-ramal) were made on the panoramic radiographs of 126 subjects. The study groups consisted of 46 unilateral and 40 bilateral posterior crossbite patients and a group of 40 subjects with normal occlusion. No group showed statistically significant sex- or side-specific differences for posterior vertical height measurements. Asymmetry indexes (condylar, ramal, and condylar-plus-ramal) were similar, and no statistically significant differences were found among the unilateral and bilateral posterior crossbite groups and the normal occlusion sample.

- **Vitral et al.** (29) in 2011 conducted a study on thirty subjects from 15 to 32 years of age with normal occlusion with computed tomography scans of their temporomandibular joints. The images obtained from the axial slices were evaluated for possible asymmetries in size and position between the condylar processes. The images obtained from the sagittal slices were used to assess the depth of the mandibular fossa, the condyle-fossa relationship, and the centralization of the condyles in their respective mandibular fossae. He concluded that no singular characteristic in the temporomandibular joint of the normal posterior bite group was verified. The largest mesiolateral diameter of the mandibular condylar processes and the posterior joint spaces showed a statistically significant difference between the right and left sides. Evaluation of the concentric position of the condyles in their respective mandibular fossae showed a non-centralized position for the right and left sides.

- **Veli et al.** (41) in 2011 tested the hypotheses that (1) there is no difference in mandibular asymmetry between the crossbite and normal side in a unilateral crossbite group and between the right and left sides in a bilateral crossbite group and a control group and (2) there is no significant difference in mandibular asymmetry among crossbite groups and control group. The cone-beam computed tomography scans of three groups were studied: 15 patients with unilateral posterior crossbite, 15 patients with bilateral posterior crossbite and

15 patients as a control group. Fourteen parameters (eight linear, three surface, and three volumetric) were measured. According to side comparisons, no statistically significant difference was found in the unilateral crossbite group. There were statistically significant differences in hemimandibular and ramal volumes for the bilateral crossbite group and in ramal height and body length for the control group. Intergroup comparisons revealed significant differences in hemimandibular and body volume for the normal side of the unilateral crossbite group and left sides of the other groups, and in angular unit length and condylar width for the crossbite side of the unilateral crossbite group and the right sides of the other groups. Skeletal components of the mandible have significant asymmetry among the crossbite groups and the control group.

- **Leonardi et al.** (42) in 2012 investigated condylar symmetry and condyle fossa relationships in subjects with functional posterior crossbite comparing findings before and after rapid maxillary expansion (RME) treatment through low-dose computed tomography (CT). Twenty-six patients (mean age 9.6 ± 1.4 years) with functional posterior crossbite diagnosis underwent rapid palatal expansion with a Hyrax appliance. Patients' temporomandibular joints (TMJ) underwent multislice CT scans before rapid palatal expansion (T0) and after (T1). Joint spaces were compared with those of a control sample of 13 subjects Anterior space (AS), superior space (SS), and posterior space (PS) joint space measurements at T0 between the functional posterior crossbite side and contralateral side demonstrated no statistically significant differences. After RME treatment (T1), all three joint spaces increased on both the functional posterior crossbite side and the non-crossbite side. There were no statistically significant differences in condyle position within the glenoid fossa between the functional posterior crossbite side and non-crossbite side before treatment. Increases in joint spaces were observed after treatment with RME on both sides.

- **Talapaneni et al.** (43) in 2012 evaluated the association between posterior unilateral crossbite and craniomandibular asymmetry in children, adolescents and adults through a systematic review of the literature. Prospective and retrospective studies with untreated, as well as normal controls and clinical trials comparing at least two treatment strategies were also identified. After data extraction and detailed evaluation 4 studies were deemed to have a high risk of bias due to low sample size and hence were excluded from the review. The majority of studies suggested a possible association between posterior unilateral crossbite and positional mandibular asymmetry. An evidence-based conclusion could not be drawn due to the low quality level of the retrieved studies and future study designs incorporating three-dimensional evaluation techniques are recommended.

- **Miner et al.** (44) in 2012 conducted study on CBCT scans of two hundred forty one patients with and without crossbite to assess the width of the jaws and the inclination of the first molars. The dental and skeletal measurements were compared between the non-crossbite and the crossbite groups. The non-crossbite group included patients who had apparently normal transverse relationships, but also a surprising number of patients with an obvious skeletal transverse discrepancy masked by dental compensation. The obvious unilateral crossbite patient's demonstrated dental compensation in the maxillary first molar on the non-crossbite side, whereas the obvious bilateral crossbite patients had normal dental inclinations. They concluded skeletally, both the bilateral and unilateral crossbite groups had narrower maxillary widths than did the controls, but also wider mandibles, with more severe bilateral crossbites.

- **Paknahad et al**. (45) in 2016 conducted a study to find a relationship between temporomandibular joint morphology and the incidence of temporomandibular dysfunction. The CBCT data of bilateral temporomandibular joint of forty patients with temporomandibular dysfunction and twenty three symptom-free cases were evaluated. The articular eminence angulation, as well as the glenoid fossa depth and width of the mandibular fossa were measured. They concluded that the articular eminence angulation was steeper and glenoid fossa width and depth were higher in patients with temporomandibular dysfunction than in the control group.

- **Iodice et al.** (27) in 2016 concluded a systematic review to find the association between unilateral posterior crossbite and morphological and/or functional asymmetries (i.e. skeletal, masticatory muscle electromyographic (EMG) performance, bite force, muscle thickness, and chewing cycle asymmetries). They reported that EMG activity of masticatory muscles is different between crossbite and non-crossbite sides and subjects with UPCB show smaller bite force than non-crossbite subjects. There is no consistency of studies reporting masticatory muscle thickness asymmetry in UPCB subjects. UPCB is associated to an increase in the reverse chewing cycle. They concluded that the literature available on the subject is of medium–low scientific and methodological quality, irrespective of the association reported.

- **Tsanidis et al.** (46) in 2016 investigated whether oral functional asymmetry in children treated for unilateral functional posterior cross-bite disappears after orthodontic treatment with a resulting normalisation of oral functions. They concluded that although there was a lack of high-quality prospective studies, based on the available evidence, results suggest that the abnormal masticatory cycle associated with functional posterior unilateral cross-bite tends to normalise following early cross-bite treatment. Masticatory muscle activity shows an increase after early functional unilateral posterior cross-bite treatment, and this activity approaches normal levels. Insufficient evidence was available to conclude on maximal molar bite force or masticatory muscle thickness changes following early treatment of functional unilateral posterior cross-bite.

- **Alkhatib et al.** (47) in 2017 conducted a CBCT study on 59 patients (14 males and 45 females) to evaluate the buccolingual inclinations of maxillary and mandibular first molars in untreated adults. They measured the angle from the long axis of each maxillary and mandibular first molar to a vertical reference line that was perpendicular to the horizontal reference line. They concluded there is a curvature to the inclinations of first molars in untreated adults, where the maxillary molars have a slight buccal inclination and mandibular molars have a slight lingual inclination.

- **Lopatiene et al.** (48) in 2018 evaluated the relationship of mandibular condylar and ramal symmetry with unilateral posterior crossbite during late adolescence in 120 pre-orthodontic patients. Panoramic radiographs database were analyzed, mandibular condylar and ramal height, and asymmetry index were analysed. In the study group the mandibular condylar height, ramal height, and ramal plus condylar height on the crossbite side were statistically significantly lower than those on the noncrossbite side. They found that asymmetry indices were statistically significantly higher in the group with unilateral posterior crossbite than those in the control group.

- **Ellabban et al.** (49) in 2018 elucidated the positional and dimensional temporomandibular joint (TMJ) changes after correction of posterior crossbite in growing patients. Only two articles were finally eligible to be included in the qualitative analysis. Both studies were RCTs and were assessed as having unclear risk of bias. One study reported significant reduction in the condylar positional difference between centric and habitual occlusion in the treatment group, while no spontaneous correction of condylar asymmetric position occurred in the control group. The other study reported minor changes of condylar position in both treatment and control groups. They concluded that the current available data provide insufficient and weak evidence to form a solid and firm conclusion. There is poor, very low-quality evidence regarding the positional and dimensional effects of posterior crossbite correction on the TMJs.

- **Pittman et al. (30)** in 2019 conducted study on CT scans of sixty patients with an average age of 9.6 years. The study group consisted of twenty nine patients with a functional unilateral posterior cross bite and the control group had thirty two patients with no posterior crossbite. Transverse widths, Molar inclination, condylar angulations, condylar anterior joint space, superior joint space, and posterior joint space were measured. For dentoalveolar measurements of transverse width, the maxillomandibular difference for the study group was -8.2mm and for the control group was -4.0 mm. No significant differences were found between the molar inclinations, condylar width, angulation, or any joint space measurements between the two groups. A total of 61.3% of the subjects in the control group and 72.4% in the study group had a radiographic sign of joint disease. The lack of condylar positional differences between the control and crossbite groups suggests that temporomandibular joint signs and symptoms in the study group may be related to remodeling in the temporomandibular joint instead.

- **Cardinal et al.** (50) in 2019 evaluated if there is a true skeletal asymmetry of the condylar and coronoid processes of the mandible in growing individuals with unilateral posterior crossbite (UPC) either functional or not. This cross-sectional study screened 20 CBCT images of individuals with UPC and 19 CBCT images of individuals without transverse malocclusion. The lengths of the condylar and coronoid processes were measured to evaluate asymmetry, as well as the magnitude of the mandibular lateral deviation in the UPC group. They found that there was a significant difference between the lengths of the affected and non-affected sides of the coronoid processes in the UPC group. The same was not observed in the condyle in the UPC group. They suggested no differences in the condyle were observed, the coronoid process was asymmetric in individuals with UPC. However, this asymmetry was not considered to be clinically significant.

- **Sollenius et al.** (51) in 2020 assessed the three-dimensional treatment changes (palatal surface area and volume) of forced unilateral posterior crossbite correction using either quad-helix or removable expansion plate appliances in the mixed dentition. They also compared than with untreated unilateral posterior crossbite patients as well as in subjects with normal occlusion and with no or mild orthodontic treatment need. The patients were randomized into the following five groups: quad-helix treatments in specialist orthodontic clinics (QHS), quadhelix treatments in general dentistry (QHG), removable expansion plate treatments in specialist orthodontic clinics (EPS), removable expansion plate treatments in general dentistry (EPG), and untreated crossbite (UC). Twenty-five patients with normal occlusion who served as normal controls were also included in the trial data on all children were evaluated on an intention-to-treat basis, regarding 3D palatal surface area, palatal projection area, and palatal shell volume; two-dimensional linear measurements were registered at the same time. After treatment, the surface and projection area and shell volume increased in the four treatment groups (QHS, QHG, EPS, and EPG). QHS increased significantly more than EPG for the surface and projection area. The QHS and EPS had significantly higher mean difference for shell volume.

- **Moon et al.** (52) in 2020 in a study on 48 patients evaluated the inclination and skeletal and alveolar bone changes when comparing tooth bone-borne (MSE) and tissue bone-borne type maxillary expanders (C-expander) using cone-beam computed tomography (CBCT) in late adolescence. Transverse skeletal and dental expansion, alveolar inclination, tooth axis, buccal alveolar bone height, thickness, dehiscence, and fenestration were evaluated on the maxillary first molar. They found that the MSE group produced greater dental expansion whereas skeletal expansion was similar in both groups. The C expander group had more alveolar bone angulation change, and the MSE group had more buccal tipping of the anchorage teeth. Buccal alveolar bone height loss and thickness changes were greater in the MSE group. For patients in late adolescence, tissue bone-borne expanders offer comparable skeletal effects to tooth bone-borne expanders, with fewer dentoalveolar side effects.

- **Leonardi et al.** (53) in 2020 investigated mandibular morphology in 38 adults affected by posterior unilateral crossbite (PUXB) and evaluated the hemi mandibular volumes from the crossbite (CB) and non-CB sides of the same patients. They found that total mandibular volume showed a difference of 2.46 cm^3 between patients and controls, which was not statistically significant. A mean difference of 1.53 cm^3 was found comparing the hemi mandibular volumes from the CB and non-CB sides of PUXB patients, this difference was statistically significant. They concluded adult patients affected by PUXB show a greater mandibular structural asymmetry compared to controls because of a lower matching percentage obtained from the surface-to surface matching technique.

- **Evangeslista et al.** (54) in 2020 evaluated the morphologic and positional features of the mandible in children, adolescents, and adults with skeletal Class I and unilateral posterior crossbite. Condylar and mandibular linear distances and angles were performed using a mirrored 3-dimensional overlapped model. Intragroup asymmetries were determined by a comparison between crossbite and no crossbite sides. The differences between both sides of all measurements were compared among groups and correlated to mandibular horizontal rotation (yaw) and age. The crossbite side showed shorter distances in the condyle and mandibular regions. Asymmetries were slightly but significantly greater in adults, as expressed by the lateromedial condylar distance, total ramus height, and mandibular length with an average 0.7 mm, 2.0 mm, and 1.5 mm, respectively. The mandibular yaw rotation was not correlated to age but moderately associated to asymmetry in mandibular length and total ramus height.

- **Muraglie et al.** (55) in 2020 compared, using surface-to-surface (StS) matching, any shape differences between the crossbite and noncrossbite side of the glenoid fossa and articular eminence in adult patients affected by posterior unilateral crossbite (PUXB) and compare them with unaffected controls. A mean difference of >11% was found between the study group and controls when comparing the matching percentages of the two sides of the glenoid fossa and articular eminence at all three levels of tolerance selected for this study. These differences were found to be highly statistically significant. According to the shape analysis findings, adult PUXB patients exhibit a higher degree of glenoid fossa and articular eminence shape differences compared to unaffected controls.

- **Wang et al.** (56) in 2020 the systematic review assessed the association between maxillary expansion (ME) and changes in condylar position in growing patients, including patients with functional unilateral posterior crossbite (FUPC), patients with bilateral posterior crossbite (BPC) and patients who have maxillary transverse deficiency (MTD) without posterior crossbite (PC). Eleven clinical studies were selected for data extraction. In 3 studies, significant changes in condylar position were observed bilaterally with ME in patients with FUPC. One study showed significant changes in condylar position with ME only in the non-crossbite sides; and 2 studies found no significant changes in condylar position with ME in patients with FUPC. One study reported significant changes in condylar position in both sides with ME in patients with bilateral PC. In patients without PC, 1 study showed significant changes in condylar position bilaterally with ME; and 2 studies reported no significant changes in condylar position. The mean MINORS score was 13.8 _ 2.89 (out of 24).The association between ME and changes in condylar position in growing patients remains debatable.

- **Almaqrami et al.** (57) in 2021 evaluated the morphological and positional features of the temporomandibular joint (TMJ) in adults with unilateral and bilateral posterior crossbite compared with aligned control subjects. The CBCT images of 90 adult subjects' divided into three equal groups: bilateral posterior crossbite (BCG), unilateral posterior crossbite (UCG) and control group (CG). 3D measurements of the TMJ included the following: (a) position, angulation and inclination of the mandibular condyles; (b) centralisation of the condyles in their respective mandibular fossae; and (c) volumetric measurements of the TMJ spaces. They found significant differences in the anteroposterior condylar inclination, medial condylar position, condylar width and height, anterior, posterior, superior and volumetric joint spaces, and anteroposterior condylar joint position between the crossbite side of the UCG and the right sides of the other groups.

MATERIALS AND METHODS

SETTING AND LOCATION

The study was conducted in the Department of Dentistry, All India Institute of Medical Sciences, Jodhpur. Ethical approval was obtained from the Institutional Ethics Committee, AIIMS Jodhpur (AIIMS/IEC/2019-20/976), Rajasthan, India. After attaining information about the study, either the patient or the guardian reviewed and signed the informed consent.

STUDY DESIGN

The present study is an observational study in which orthodontic patients were recruited based on pre-determined inclusion criteria.

STUDY POPULATION

Patients of both sexes, with an age group 15 and 30 years (22.7 ±4.6 years) were recruited in the present study.

PARTICIPANTS

The CT scans of the subjects was included on the basis of following criteria:

INCLUSION CRITERIA:

1. An age group 15-30 years
2. Presence of maxillary transverse deficiency with posterior crossbite (involving greater than one tooth)
3. No history of previous orthodontic treatment
4. No history of trauma in maxilla-facial region or any plastic surgery

EXCLUSION CRITERIA:

1. Presence of anterior crossbite
2. Presence of any complete or partial crown coverage or cuspal restoration

3. Developmental or acquired craniofacial deformity with or without mandibular/condylar involvement
4. Presence of any image artifacts in CT scans
5. History or clinical signs of TMJ disorders

METHODOLOGY

Thirty-six CT scans was selected according to inclusion and exclusion criteria. After selection, the sample was divided into three groups based on transverse posterior occlusion.

1. Group 1 – Normal posterior bite
2. Group II – Unilateral posterior cross bite (Involving greater than one tooth on one side)
3. Group III – Bilateral posterior cross bite (Involving greater than one tooth on both side)

1. ACQUISITION AND STANDARDIZATION OF CT:

The helicoidal, multislice CT scan was performed with a Somaton Spirit device (Siemens, Xangai, China) at 120 kV and 160 mA. We obtained 1-mm thick tomographic imaging slices spaced at 1-mm interval, using the helicoidal technique. All the images were exported as Digital Imaging and Communication in Medicine (DICOM) files. The patient's heads were oriented by adjusting the Frankfort and midsagittal panes were perpendicular to the floor, and the CT scans were taken while the patients bit into maximum intercuspation. The scans were recorded and patient positioning was done by the same investigator.

2. COMPUTED TOMOGRAPHY ORIENTATION

CT images was imported into Dolphin Imaging Software (version 11.95; Dolphin Imaging and Management Solutions, Chatsworth, Calif). The CT images were reoriented with different reference planes to standardize the measurements and minimize errors.

a) The mid-sagittal plane was oriented through anterior nasal spine and nasion.

b) The Frankfort horizontal (FH) plane (Axial plane) oriented to porion and orbitale and the coronal plane was oriented so that it passes through both the left and the right mesiobuccal cusp tip of first molars.

c) The transverse view was constructed via mid-sagittal plane at level of plane passing from crista galli and basion.

3) After CT orientation, various measurements of TMJ complex and transverse discrepancy were made upto 1/10th of mm using measurement tool of dolphin imaging software. (Table 1)

S.No	Measurements	Definition
1. CONDYLAR MORPHOLOGY MEASUREMENTS (AXIAL PLANE).		
1.1	**Antero-posterior condylar diameter**	The largest anteroposterior diameter of the mandibular condylar process was evaluated. (Fig:1A)
1.2	**Mesio-distal condylar diameter**	The largest mediolateral diameter of the mandibular condylar process was evaluated. (Fig:1B)
1.3	**Condylar angulation**	The angle between the long axis of the mandibular condylar process and the midsagittal plane. (Fig:1C)
1.4	**Condylar distance**	The distance between the geometric centers of the condylar processes and the midsagittal plane. (Fig:2A)
1.5	**Condylar difference**	The anteroposterior difference between the geometric center of the right and left condylar process as reflected on the mid-sagittal plane. (Fig:2B) The point representing the geometric center of the right condylar process was the 0 point. The variations on the left side were measured from this point. The geometric centers situated anterior to the 0 point were considered positive, and those posterior to it were considered negative.
2. GLENOID FOSSA MEASUREMENTS (SAGITTAL PLANE).		
2.1	**Width of the glenoid fossa**	The distance between the anterior border of condylar fossa and posterior border of condylar fossa on the plane formed by the most inferior

		point of the articular tubercle and the most inferior point of the auditory meatus. (Fig:3A)
2.2	**Depth of the glenoid fossa**	The most superior point of the glenoid fossa to the plane formed by the most inferior point of the articular tubercle and the most inferior point of the auditory meatus. (Fig:3B)
3. TEMPOROMANDIBULAR JOINT SPACE MEASUREMENTS (SAGITTAL PLANE).		
3.1	**Anterior joint space**	The shortest distance between the most anterior point of the condyle and the posterior wall of the articular tubercle. (Fig:4A)
3.2	**Superior joint space**	The shortest distance between the most superior point of the condyle and the most superior point of the mandibular fossa. (Fig:4B)
3.3	**Posterior joint space**	The shortest distance between the most posterior point of the condyle and the posterior wall of the mandibular fossa. (Fig:4C)
4. TRANSVERSE DISCREPANCY MEASUREMENTS.		
4.1	**Maxillary molar inclination** (Coronal section)	The angle outlined between the palatal long axis of the tooth (the line joining the mesiopalatal cusp tip with the palatal root apex) with the tangent to the inferior border of the nasal cavity. (Fig:5)
4.2	**Mandibular molar inclination** (Coronal section)	The angle formed between the long axis of the tooth (the line connecting the central groove with the apex of the mesial root) to the tangent to the inferior border of the mandible. (Fig: 6)
4.3	**Maxillary buccal bone thickness** (Axial section)	The measurement was made from the outer point on buccal bone to the mesio buccal roots at the level of the furcation point of maxillary first molar. (Fig:7)
4.4	**Maxillary buccal alveolar bone height** (Coronal section)	This measurement was made from alveolar crest to cement enamel junction of maxillary first molar at the level of mesiobuccal root. (Fig:8)

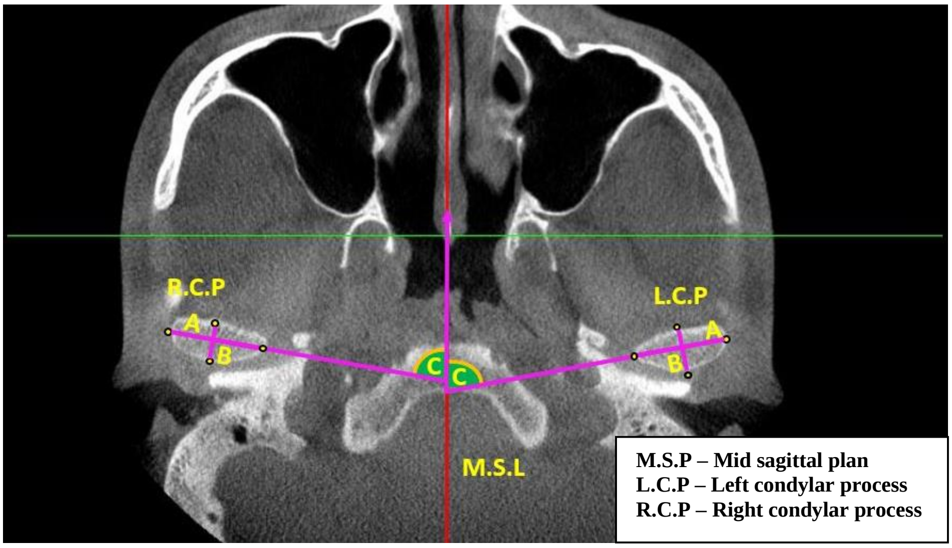

Figure 1: Condylar morphology measurements (A) Antero – posterior condylar diameter, (B) Mesio – distal condylar diameter, (C) Condylar angulation.

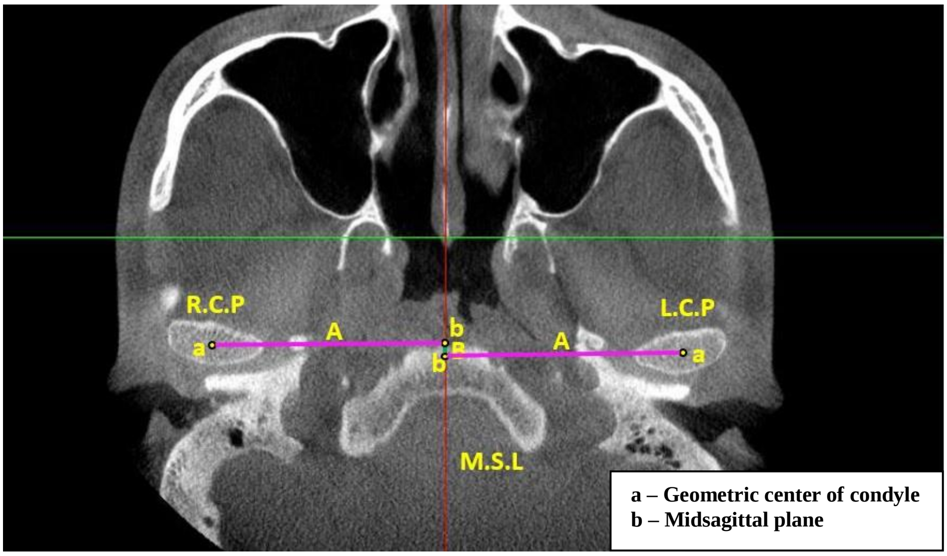

Figure 2: Condylar morphology measurements (A) Condylar distance, (B) Condylar difference.

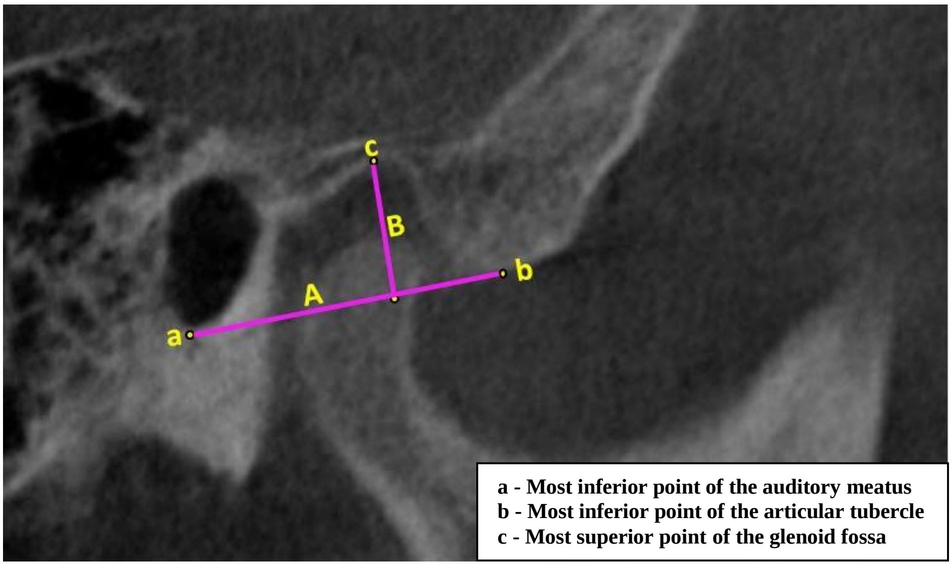

Figure 3: Glenoid fossa measurements (A) Width of the glenoid fossa, (B) Depth of the glenoid fossa.

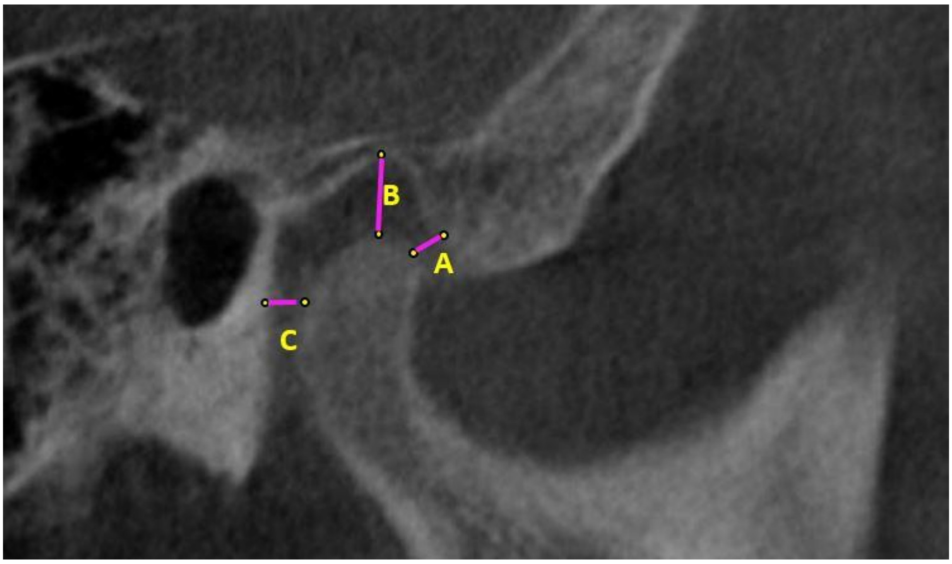

Figure 4: Temporomandibular joint space measurements (A) Anterior joint space, (B) Superior joint space, (C) Posterior joint space.

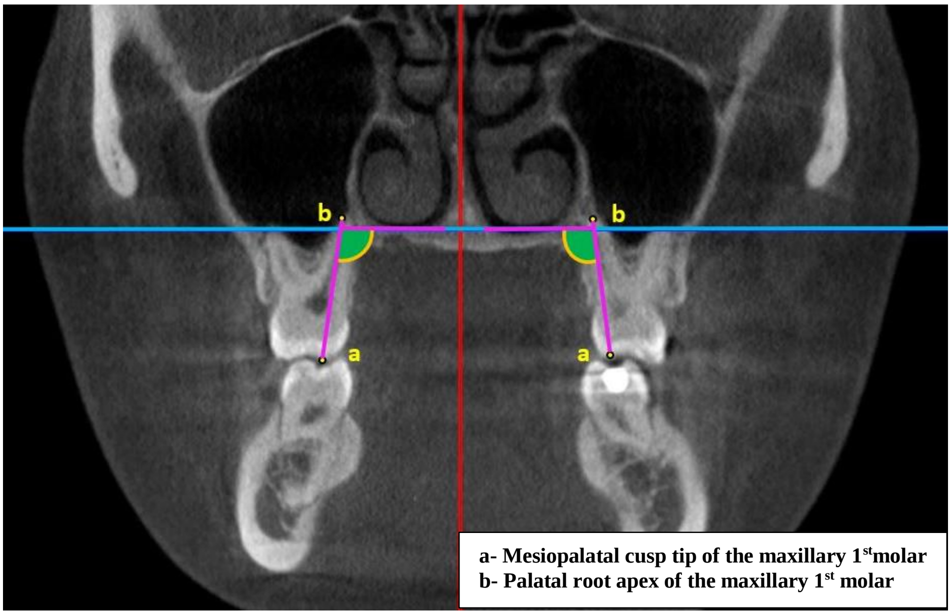

Figure 5: Maxillary molar inclination measurement

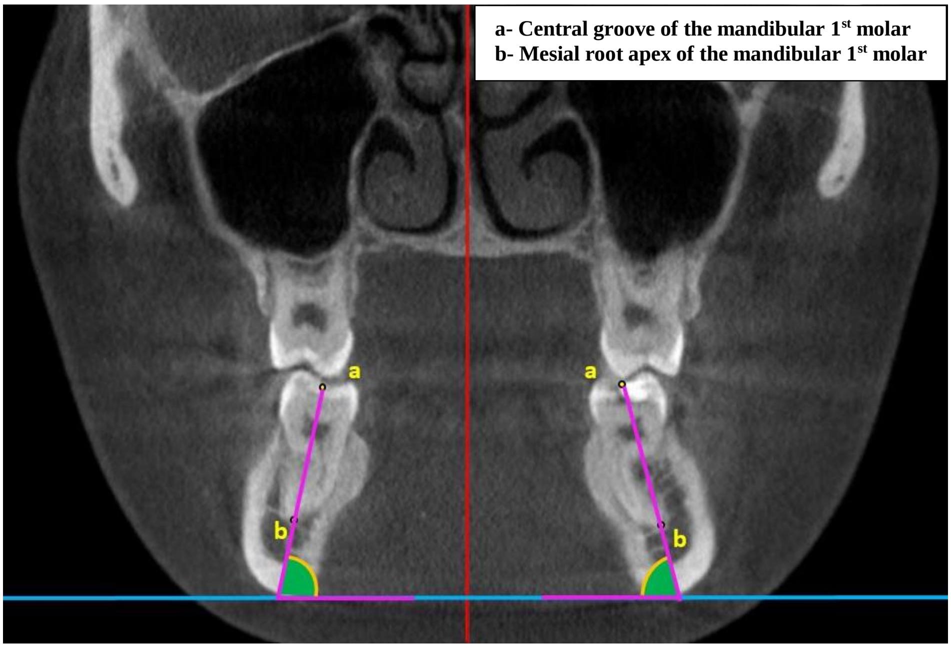

Figure 6: Mandibular molar inclination measurement

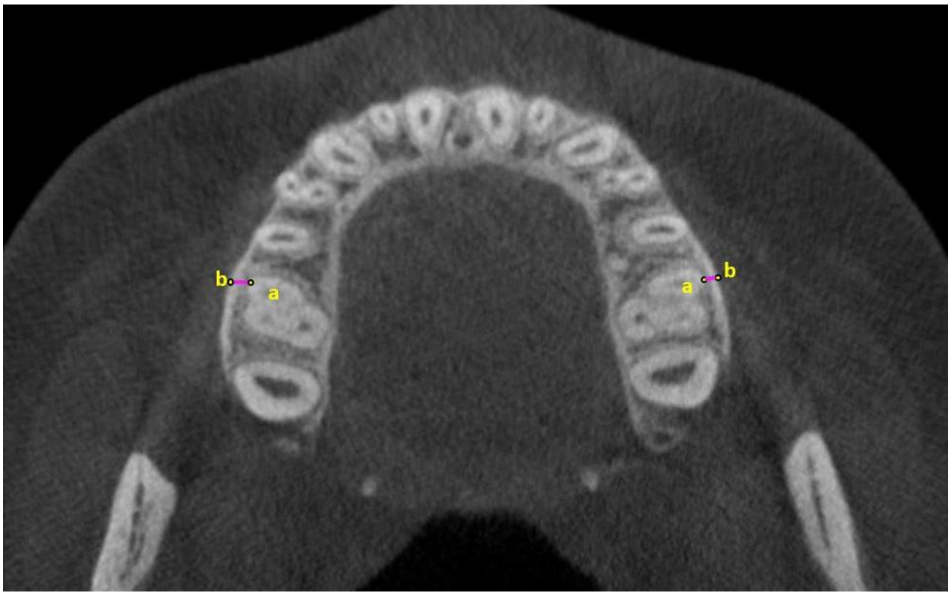

Figure 7: Maxillary buccal bone thickness measurement a- outer point on the mesio buccal roots at the level of the furcation point of maxillary first molar, b- outer point on buccal bone at the level of the furcation point of maxillary first molar.

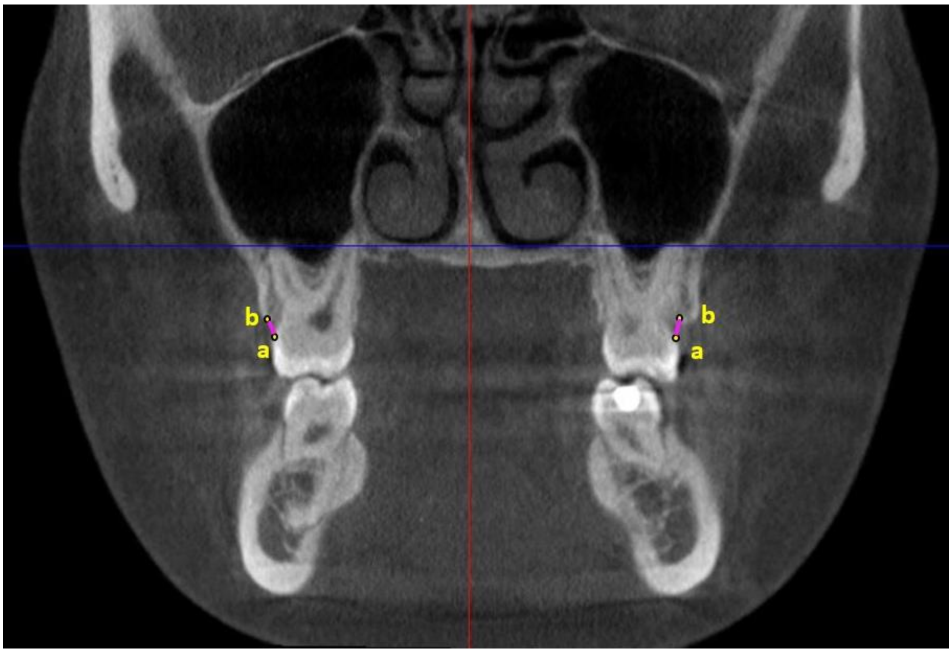

Figure 8: Maxillary buccal bone height measurement a- cement enamel junction of maxillary first molar at the level of mesiobuccal root, b- alveolar crest of maxillary first molar at the level of mesiobuccal root.

Data so obtained from the above measurements was subjected to statistical evaluation.

SAMPLE SIZE CALCULATION

The sample size was calculated based on previously published study done by Miner et al. (44) Assuming a standard deviation of 2.56 in study group and 4.24 in control group with effect size of 0.88 and clinically meaningful mean difference of 3˚ inclination in three different groups the sample size was estimated to be 21 per treatment group. The sample size was calculated with 80% power and 5 percent error. Total sample size for 3 groups was estimated to be 63. Keeping in view of COVID-19, we have kept the of convenient sampling. i.e., number of patients has to be recruited till the completion of study duration. Therefore, due to COVID-19 and as per convenient sampling we were able to recruit 12 patients per treatment group.

STATISTICAL ANALYSIS

Data was analysed using statistical package for Social Sciences for Windows version 23.0 (Armonk, NY: IBM Corp). Intra-examiner repeatability (repeated after two weeks) and inter-examiner reproducibility was assessed using Intra-class correlation coefficients (ICC) (Cronbach's alphas). Intragroup analysis of right and left for assessing differences in different transverse posterior bite group was done using Student's t- test. One-way Analysis of Variance (ANOVA) followed by Post-hoc Scheffe test was used to find differences between the groups.

RESULTS

A total of 36 patients (18 males and 18 females) who fulfilled the inclusion criteria were enrolled in the study. The subjects were divided into three groups based on transverse posterior occlusion. For each participant CT scans were taken while the patient bit into maximum intercuspation. Condylar morphology, glenoid fossa, temporomandibular joint space, transverse discrepancy variables were tabulated in all the three groups and data so obtained was subjected to statistical analysis. (Fig: 9)

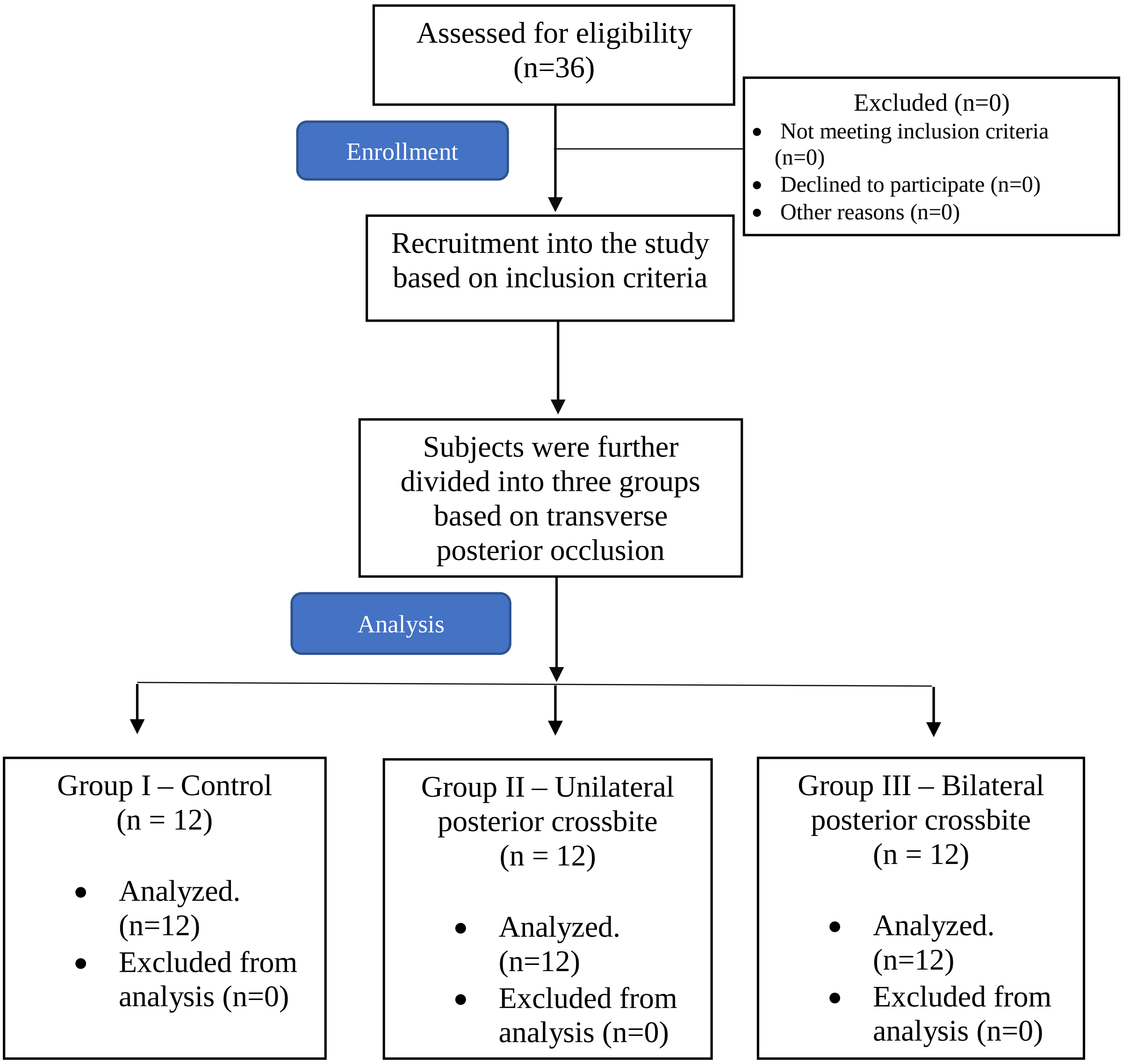

Figure 9: Distribution of the sample.

Table 2: Distribution of participants in each group.

Groups	Male		Female		Total		Age (years)
	N	%	N	%	N	%	Mean (±SD)
Group I (Control)	8	66.7%	4	33.3%	12	100%	22.5±4.6
Group II (Unilateral posterior crossbite)	6	50%	6	50%	12	100%	23.2±4.4
Group III (Bilateral posterior crossbite)	4	33.3%	8	66.7%	12	100%	22.3±5.0
Total	18	50%	18	50%	36	100%	22.7±4.6
p – value	0.281						0.887

N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using one-way ANOVA; NS= Non Significant,*=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 2 describes the sample distribution according to gender. Group I consisted of 8 (66.7%) males and 4 (33.3%) females. Group II consisted of 6 (50%) males and 6 (50%) females. Group III consisted of 4 (33.3%) males and 8 (66.7%) females. In the total sample of 36 subjects, 18 (50%) were males and 18 (50%) were females. There was no significant difference in the number of male and female patients between three groups. The mean age of subjects at the baseline was 22.5±4.6years, 23.2±4.4years and 22.7±4.6years in Group I (Control), Group II (Unilateral posterior crossbite) and Group III (Bilateral posterior crossbite), respectively. There was no significant difference in age of the patients between three groups.

Table 3. Intra-class correlation coefficients for intra-examiner repeatability

S.No		ICC (95% CI)	P-value
Condylar morphology variables			
1.	Mesio-distal condylar diameter (mm)	0.784 (0.358 – 0.935)	<0.001*
2.	Antero-posterior condylar diameter (mm)	0.781 (0.406 – 0.932)	<0.001*
3.	Condylar inclination (°)	0.973 (0.913 – 0.992)	<0.001*
4.	Condylar distance (mm)	0.843 (0.537 – 0.952)	<0.001*
Condylar morphology variables – Condylar difference			
1.	Antero-posterior difference of condylar process (mm)	0.974 (0.914 – 0.992)	<0.001*
Glenoid fossa variables			
1.	Width of the glenoid fossa (mm)	0.820 (0.498 – 0.944)	<0.001*
2.	Depth of the glenoid fossa (mm)	0.869 (0.605 – 0.960)	<0.001*
Temporomandibular joint space variables			
1.	Anterior joint space (mm)	0.446 (-0.064 – 0.792)	<0.001*
2.	Superior joint space (mm)	0.710 (-0.550 – 0.561)	0.007*
3.	Posterior joint space (mm)	0.744 (0.310 – 0.920)	<0.001*
Transverse discrepancy variables			
1.	Maxillary molar inclination (°)	0.966 (0.889 – 0.990)	<0.001*
2.	Mandibular molar inclination (°)	0.939 (0.810 – 0.982)	<0.001*
3.	Maxillary buccal bone thickness (mm)	0.798 (0.439 – 0.937)	<0.001*
4.	Maxillary buccal bone height (mm)	0.747 (0.336 – 0.920)	0.002*

*P-value <0.05 is considered as significant; ICC – Intra-class Correlation Coefficient; ICC correlation was analyzed using two-way mixed effect model with absolute agreement.

To test the intra examiner reliability each CT was measured twice within 2 weeks interval by same examiner (R.B) using Dolphin Imaging Software (version 11.95; Dolphin Imaging and Management Solutions, Chatsworth, Calif).

Table 3 shows repeatability of the main examiner (R.B) was excellent for condylar morphology variables: Mesio-distal condylar diameter [ICC value, intra-examiner: 0.784 (0.358 – 0.935)], Antero-posterior condylar diameter [ICC value, intra-examiner: 0.781 (0.406 – 0.932)], Condylar inclination [ICC value, intra-examiner: 0.973 (0.913 – 0.992)], Condylar distance [ICC value, intra-examiner: 0.843 (0.537 – 0.952)], respectively. Condylar difference - Antero-posterior difference of condylar process [ICC value, intra-examiner: 0.974 (0.914 – 0.992)] respectively.

The repeatability of the main examiner (R.B) was excellent for glenoid fossa variables: Width of the glenoid fossa [ICC value, intra-examiner: 0.820 (0.498 – 0.944)], Depth of the glenoid fossa [ICC value, intra-examiner: 0.869 (0.605 – 0.960)], respectively.

The repeatability of the main examiner (R.B) was excellent for temporomandibular joint space variables: Anterior joint space [ICC value, intra-examiner: 0.446 (-0.064 – 0.792), Superior joint space [ICC value, intra-examiner: 0.710 (-0.550 – 0.561)], Posterior joint space [ICC value, intra-examiner: 0.744 (0.310 – 0.920)], respectively.

The repeatability of the main examiner (R.B) was also excellent for transverse discrepancy variables: Maxillary molar inclination [ICC value, intra-examiner: 0.966 (0.889 – 0.990)], Mandibular molar inclination [ICC value, intra-examiner: 0.939 (0.810 – 0.982)], Maxillary buccal bone thickness [ICC value, intra-examiner: 0.798 (0.439 – 0.937)], Maxillary buccal bone height [ICC value, intra-examiner: 0.747 (0.336 – 0.920)], respectively.

Table 4. Intra-class correlation coefficients for inter-examiner reproducibility

S.No		ICC (95% CI)	P-value
Condylar morphology variables			
1.	Mesio-distal condylar diameter (mm)	0.528 (-0.077 – 0.846)	0.004*
2.	Antero-posterior condylar diameter(mm)	0.647 (0.117 – 0.886)	0.003*
3.	Condylar inclination (°)	0.959 (0.740 – 0.990)	<0.001*
4.	Condylar distance (mm)	0.712 (0.266 – 0.907)	0.001*
Condylar morphology variables – Condylar difference			
1.	Antero-posterior difference of condylar process (mm)	-0.035 (-0.558 – 0.522)	0.546
Glenoid fossa variables			
1.	Width of the glenoid fossa (mm)	0.690 (0.089 – 0.908)	0.001*
2.	Depth of the glenoid fossa (mm)	0.704 (0.225 – 0.906)	0.001*
Temporomandibular joint space variables			
1.	Anterior joint space (mm)	0.375 (-0.109 – 0.752)	0.051*
2.	Superior joint space (mm)	0.002 (-0.557 – 0.556)	0.497
3.	Posterior joint space (mm)	0.523 (0.015 – 0.829)	0.019*
Transverse discrepancy variables			
1.	Maxillary molar inclination (°)	0.553 (0.042 – 0.843)	0.012*
2.	Mandibular molar inclination (°)	0.797 (0.455 – 0.936)	0.001*
3.	Maxillary buccal bone thickness (mm)	0.559 (0.056 – 0.845)	0.013*
4.	Maxillary buccal bone height (mm)	0.699 (0.261 – 0.902)	0.002*

*P-value <0.05 is considered as significant; ICC – Intra-class Correlation Coefficient; ICC correlation was analyzed using two-way mixed effect model with absolute agreement.

To test the inter-examiner reliability two independent examiners (R.B and P.M) made the measurement in CT using Dolphin Imaging Software (version 11.95; Dolphin Imaging and Management Solutions, Chatsworth, Calif). The measurements were repeated after an interval of two weeks.

Table 4 shows reproducibility of the inter-examiner agreement (R.B and P.M) was excellent for condylar morphology variables: Mesio-distal condylar diameter [ICC value, inter examiner: 0.528 (-0.077 – 0.846)], Antero-posterior condylar diameter [ICC value, inter-examiner: 0.647 (0.117 – 0.886)], Condylar inclination [ICC value, inter-examiner: 0.959 (0.740 – 0.990)], Condylar distance [ICC value, inter-examiner: 0.712 (0.266 – 0.907)], respectively. Condylar difference - Antero-posterior difference of condylar process [ICC value, inter-examiner: -0.035 (-0.558 – 0.522)] respectively.

The reproducibility of the inter-examiner agreement (R.B and P.M) was excellent for glenoid fossa variables: Width of the glenoid fossa [ICC value, inter-examiner: 0.690 (0.089 – 0.908)], Depth of the glenoid fossa [ICC value, inter-examiner: 0.704 (0.225 – 0.906)], respectively.

The reproducibility of the inter-examiner agreement (R.B and P.M) was excellent for temporomandibular joint space variables: Anterior joint space [ICC value, inter-examiner: 0.375 (-0.109 – 0.752)], Superior joint space [ICC value, inter-examiner: 0.002 (-0.557 – 0.556)], Posterior joint space [ICC value, inter-examiner: 0.523 (0.015 – 0.829)], respectively.

The reproducibility of the inter-examiner agreement (R.B and P.M) was also excellent for transverse discrepancy variables: Maxillary molar inclination [ICC value, inter-examiner: 0.553 (0.042 – 0.843)], Mandibular molar inclination [ICC value, inter-examiner: 0.797 (0.455 – 0.936)], Maxillary buccal bone thickness [ICC value, inter-examiner: 0.559 (0.056 – 0.845)], Maxillary buccal bone height [ICC value, inter-examiner: 0.699 (0.261 – 0.902)], respectively.

Table 5: Descriptive statistics and comparison of condylar morphology variables within control groups using paired t-test.

S.No		Right side	Left side	P-value
		Mean ± SD		
Condylar morphology variables				
1.	Mesio-distal condylar diameter (mm)	17.20±1.89	17.24±2.09	0.912
2.	Antero-posterior condylar diameter (mm)	6.80±1.06	6.96±0.93	0.282
3.	Condylar inclination (°)	71.47±4.99	70.21±5.28	0.342
4.	Condylar distance (mm)	48.32±3.03	48.50±3.14	0.126
Glenoid fossa variables				
1.	Width of the glenoid fossa (mm)	21.38±1.73	21.48±1.76	0.751
2.	Depth of the glenoid fossa (mm)	8.30±0.92	8.19±0.89	0.523
Temporomandibular joint space variables				
1.	Anterior joint space (mm)	2.10±0.76	2.01±0.51	0.497
2.	Superior joint space (mm)	3.65±0.63	3.52±0.83	0.343
3.	Posterior joint space (mm)	2.61±0.53	2.47±0.47	0.334
Transverse discrepancy variables				
1.	Maxillary molar inclination (°)	98.30±3.97	97.89±2.89	0.645
2.	Mandibular molar inclination (°)	79.19±3.77	78.24±2.63	0.134
3.	Maxillary buccal bone thickness (mm)	1.20±0.70	1.00±0.40	0.146
4.	Maxillary buccal bone height (mm)	2.86±0.69	2.77±0.70	0.243

*P-value <0.05 is considered as significant.

Table 5 shows comparison of mean values of the condylar morphology variables within control groups using paired t-test. There was no statistically significant difference in condylar morphology variables, glenoid fossa variables, temporomandibular joint variables and transverse discrepancy variables in between right and left side among the within control groups.

Table 6: Descriptive statistics and comparison of condylar morphology variables within unilateral posterior crossbite groups using paired t-test.

S.No		Crossbite side	Non-crossbite side	P-value
		Mean±SD		
Condylar morphology variables				
1.	Mesio-distal condylar diameter (mm)	18.21±2.28	18.42±1.91	0.531
2.	Antero-posterior condylar diameter (mm)	7.25±1.45	7.54±1.48	0.134
3.	Condylar inclination (°)	65.30±4.35	69.53±5.82	0.019*
4.	Condylar distance (mm)	49.71±3.21	48.28±2.58	0.010*
Glenoid fossa variables				
1.	Width of the glenoid fossa (mm)	23.76±1.70	23.99±2.09	0.348
2.	Depth of the glenoid fossa (mm)	8.90±1.03	8.77±0.91	0.691
Temporomandibular joint space variables				
1.	Anterior joint space (mm)	2.09±1.03	1.58±0.71	0.056
2.	Superior joint space (mm)	2.80±0.82	2.65±1.06	0.600
3.	Posterior joint space (mm)	2.44±0.91	2.88±1.03	0.055
Transverse discrepancy variables				
1.	Maxillary molar inclination (°)	97.25±3.49	102.79±7.98	0.062
2.	Mandibular molar inclination (°)	83.06±4.39	78.97±8.28	0.023*
3.	Maxillary buccal bone thickness (mm)	0.89±0.61	0.80±0.58	0.410
4.	Maxillary buccal bone height (mm)	3.13±0.48	3.15±0.53	0.801

*P-value <0.05 is considered as significant

Table 6 shows comparison of mean values of the condylar morphology variables within unilateral posterior crossbite groups using paired t-test. A statistically significant difference was found in condylar inclination ($P<0.05$), condylar distance ($P<0.05$) and mandibular molar inclination ($P<0.05$) in between right and left side among the within unilateral posterior crossbite groups.

Table 7: Descriptive statistics and comparison of condylar morphology variables within bilateral posterior crossbite groups using paired t-test.

S.No		Right side	Left side	P-value
		Mean±SD		
Condylar morphology variables				
1.	Mesio-distal condylar diameter (mm)	14.93±2.40	14.45±2.64	0.114
2.	Antero-posterior condylar diameter (mm)	7.55±0.87	7.09±1.25	0.042*
3.	Condylar inclination (°)	71.30±7.29	66.1±6.56	0.006*
4.	Condylar distance(mm)	47.17±4.18	47.06±3.56	0.879
Glenoid fossa variables				
1.	Width of the glenoid fossa (mm)	23.52±1.52	23.44±1.35	0.781
2.	Depth of the glenoid fossa (mm)	8.22±1.06	8.15±1.09	0.755
Temporomandibular joint space variables				
1.	Anterior joint space (mm)	1.64±0.45	1.84±0.53	0.120
2.	Superior joint space (mm)	2.48±0.78	2.48±0.89	1.000
3.	Posterior joint space (mm)	2.20±0.72	2.17±0.54	0.851
Transverse discrepancy variables				
1.	Maxillary molar inclination (°)	94.15±4.92	95.08±4.17	0.667
2.	Mandibular molar inclination (°)	84.75±4.22	83.69±4.59	0.451
3.	Maxillary buccal bone thickness (mm)	0.95±0.71	0.89±0.76	0.526
4.	Maxillary buccal bone height (mm)	2.98±0.61	2.78±0.59	0.049*

*P-value <0.05 is considered as significant

Table 7 shows comparison of mean values of the condylar morphology variables within bilateral posterior crossbite groups using paired t-test. A statistically significant difference was found in antero-posterior condylar diameter ($P<0.05$), condylar inclination ($P<0.01$), and maxillary molar buccal alveolar bone height ($P<0.05$) in between right and left side among the within bilateral posterior crossbite groups.

Table 8: Descriptive statistics and comparison of condylar morphology variables between different transverse posterior bite groups using one way ANOVA.

S.No	Condylar morphology variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value
		Mean ±S. D			
Right side					
1.	Mesio-distal condylar diameter (mm)	17.2±1.8	18.2±2.2	16.7±2.5	0.003**
2.	Antero-posterior condylar diameter (mm)	6.8±1.0	7.2±1.4	7.5±0.8	0.285
3.	Condylar inclination (°)	71.4±4.9	65.3±4.3	71.3±7.2	0.018*
4.	Condylar distance (mm)	48.3±3.0	49.7±3.2	47.1±4.1	0.222
Left side					
1.	Mesio-distal condylar diameter (mm)	17.2±2.0	18.4±1.9	14.4±2.6	<.001***
2.	Antero-posterior condylar diameter (mm)	6.9±0.9	7.5±1.4	7.0±1.2	0.501
3.	Condylar inclination (°)	70.2±5.2	69.5±5.8	66.1±6.5	0.209
4.	Condylar distance (mm)	47.5±3.1	48.2±2.5	47.0±3.5	0.630
Condylar difference					
1.	Antero-posterior difference of condylar process (mm)	1.0±0.6	1.7±0.9	1.4±0.7	0.155

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using one-way ANOVA; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 8 shows comparison of mean values of the condylar morphology variables between different transverse posterior bite groups using one way ANOVA test. A statistically significant difference was found in medio-distal condylar diameter on both right and left side (P <0.01, P <0.001 respectively) and condylar inclination on right side (P <0.05) among the different transverse posterior bite groups. The mean mesio-distal condylar diameter on both right and left side was found to be maximum in Group II (Unilateral posterior crossbite) followed by Group I (Control) and minimum in Group III (Bilateral posterior crossbite). The mean condylar inclination right side was found to be maximum in Group I (Control) followed by Group III (Bilateral posterior crossbite) and minimum in Group II (Unilateral posterior crossbite).

No statistically significant differences (P > 0.05) were found in antero-posterior condylar diameter on both right and left side, condylar inclination on left side, condylar distance on both right and left side and condylar difference in different transverse posterior bite groups. (Fig:10)

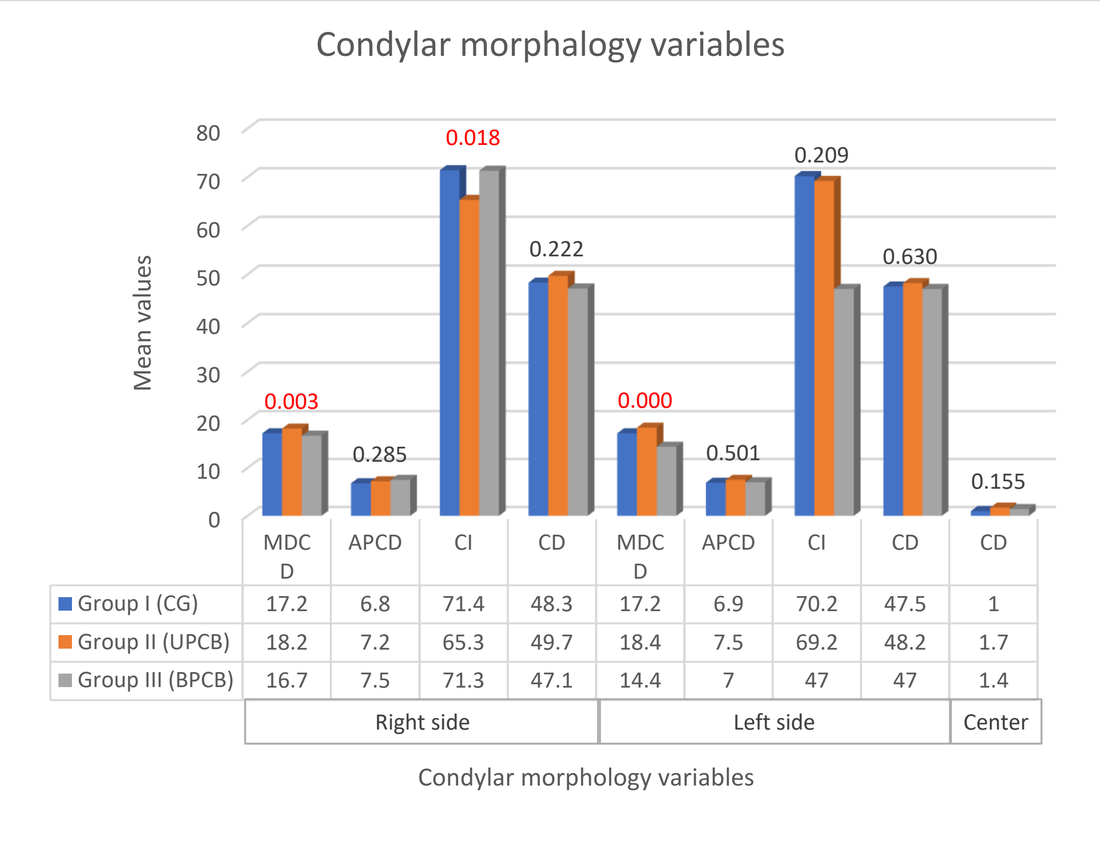

Figure 10. Plot of comparison of condylar morphology variables between different transverse posterior bite groups. For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. P-value labeled above the graph.

Table 9: Descriptive statistics and comparison of glenoid fossa variables between different transverse posterior bite groups using one way ANOVA.

S.No	Glenoid fossa variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value
		Mean ±S. D			
Right side					
1.	Width of the glenoid fossa (mm)	21.3±1.7	23.7±1.7	23.5±1.5	0.002**
2.	Depth of the glenoid fossa (mm)	8.3±0.9	8.9±1.0	8.2±1.0	0.219
Left side					
1.	Width of the glenoid fossa (mm)	21.4±1.7	23.9±2.0	23.4±1.3	0.004**
2.	Depth of the glenoid fossa (mm)	8.1±0.8	8.7±0.9	8.1±1.0	0.228

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using one-way ANOVA; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001).

Table 9 shows comparison of mean values of the glenoid fossa variables between different transverse posterior bite groups using one way ANOVA test. A statistically significant difference was found in width of the glenoid fossa on both right and left side (P <0.01) among the different transverse posterior bite groups. The mean width of the glenoid fossa right side was found to be maximum in Group II (Unilateral posterior crossbite) followed by Group III (Bilateral posterior crossbite) and minimum in Group I (Control). The mean width of the glenoid fossa left side was found to be maximum in Group II (Unilateral posterior crossbite) followed by Group III (Bilateral posterior crossbite) and minimum in Group I (Control).

No statistically significant differences (P > 0.05) were found in depth of the glenoid fossa on both right and left side in different transverse posterior bite groups. (Fig:11)

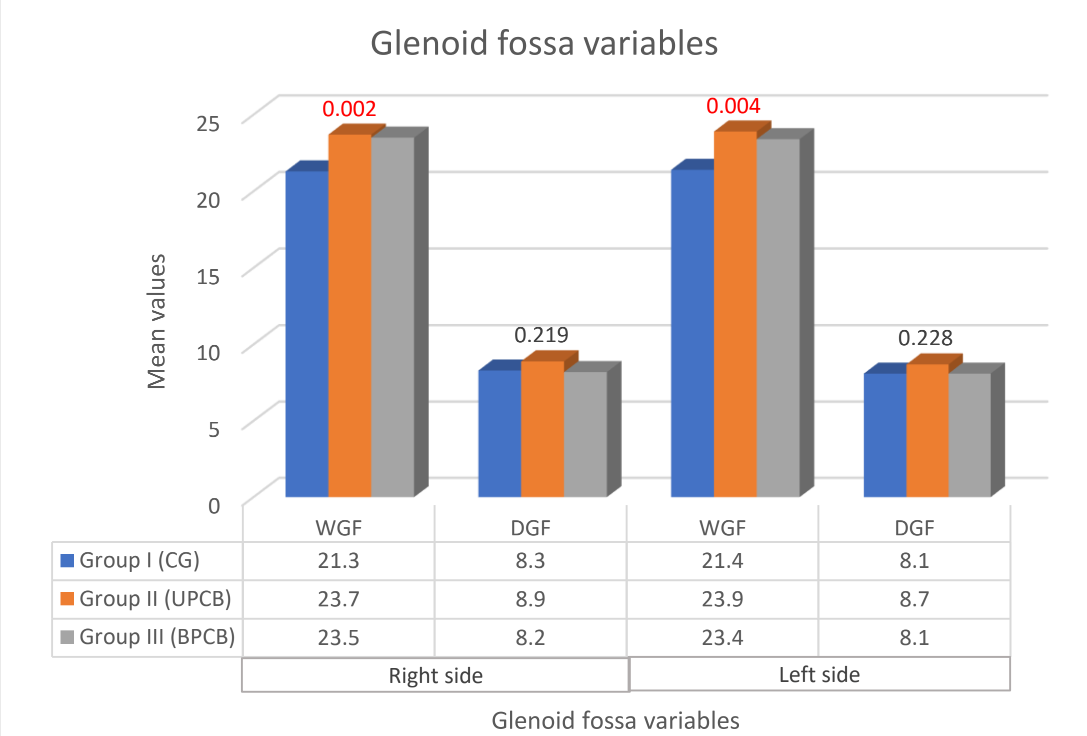

Figure 11: Plot of comparison of glenoid fossa variables between different transverse posterior bite groups. For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. P-value labeled above the graph.

Table 10: Descriptive statistics and comparison of temporomandibular joint space variables between different transverse posterior bite groups using one way ANOVA.

S.No	Temporomandibular joint space variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value
		Mean ±S. D			
Right side					
1.	Anterior joint space (mm)	2.1±0.7	2.0±1.0	1.6±0.4	0.275
2.	Superior joint space (mm)	3.6±0.6	2.8±0.8	2.4±0.7	0.179
3.	Posterior joint space(mm)	2.6±0.5	2.4±0.9	2.2±0.7	0.394
Left side					
1.	Anterior joint space (mm)	2.0±0.5	1.5±0.7	1.8±0.5	0.219
2.	Superior joint space (mm)	3.5±0.8	2.6±1.0	2.4±0.8	0.022*
3.	Posterior joint space(mm)	2.4±0.4	2.8±1.0	2.1±0.5	0.071

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using one-way ANOVA; NS=Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 10 shows comparison of mean values of the temporomandibular joint space variables between different transverse posterior bite groups using one way ANOVA test. A statistically significant difference was found in superior joint space on left side (P <0.05) among the different different transverse posterior bite groups. The mean superior joint space on left side was found to be maximum in Group I (Control) followed by Group II (Unilateral posterior crossbite) and minimum in Group III (Bilateral posterior crossbite).

No statistically significant differences (P > 0.05) were found in anterior joint space on both right and left side, superior joint space on right side, posterior joint space on both right and left side in different transverse posterior bite groups. (Fig:12)

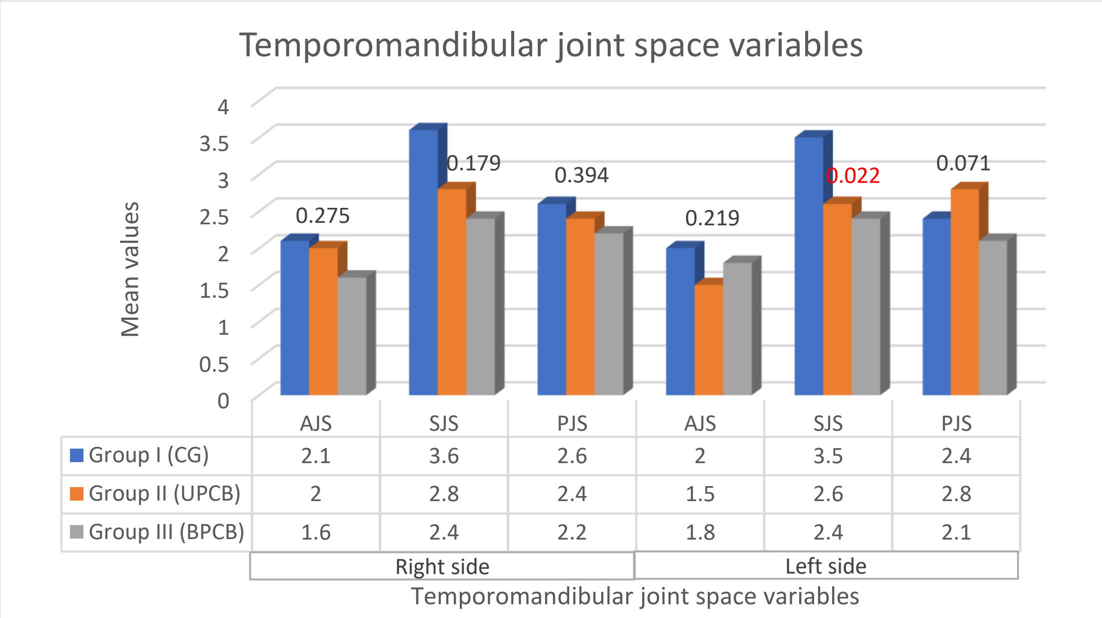

Figure 12. Plot of comparison of temporomandibular joint space variables between different transverse posterior bite groups. For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. P-value labeled above the graph.

Table 11: Descriptive statistics and comparison of transverse discrepancy variables between different transverse posterior bite groups using one way ANOVA.

S.No	Transverse discrepancy variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value
		Mean ±S. D			
Right side					
1.	Maxillary molar inclination (°)	98.3±3.9	97.2±3.4	94.1±4.9	0.053
2.	Mandibular molar inclination (°)	79.1±3.7	83.0±4.3	84.7±4.2	0.008**
3.	Maxillary buccal bone thickness (mm)	1.2±0.7	0.8±0.6	0.9±0.7	0.504
4.	Maxillary buccal bone height (mm)	2.8±0.6	3.1±0.4	2.9±0.6	0.560
Left side					
1.	Maxillary molar inclination (°)	97.8±2.8	102.7±7.9	95±4.1	0.005**
2.	Mandibular molar inclination (°)	77.2±2.6	78.9±8.2	83.6±4.5	0.025*
3.	Maxillary buccal bone thickness (mm)	1.0±0.4	0.8±0.5	0.8±0.7	0.720
4.	Maxillary buccal bone height (mm)	2.7±0.7	3.1±0.5	2.7±0.5	0.234

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using one-way ANOVA; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001).

Table 11 shows comparison of mean values of the transverse discrepancy variables between different transverse posterior bite groups using one way ANOVA test. A statistically significant difference was found in maxillary molar inclination on left side (P <0.01), mandibular molar inclination on both right and left side (P <0.01, P <0.05 respectively) among the different transverse posterior bite groups. The mean maxillary molar inclination on left side was found to be maximum in Group II (Unilateral posterior crossbite) followed by Group I (Control) and minimum in Group III (Bilateral posterior crossbite). The mean mandibular molar inclination on both right and left side was found to be maximum in Group III (Bilateral posterior crossbite) followed by Group II (Unilateral posterior crossbite) and minimum in Group I (Control).

No statistically significant differences (P > 0.05) were found in maxillary molar inclination on right, maxillary buccal bone thickness on both right and left side, maxillary buccal bone height on both right and left side in different transverse posterior bite groups. (Fig:13)

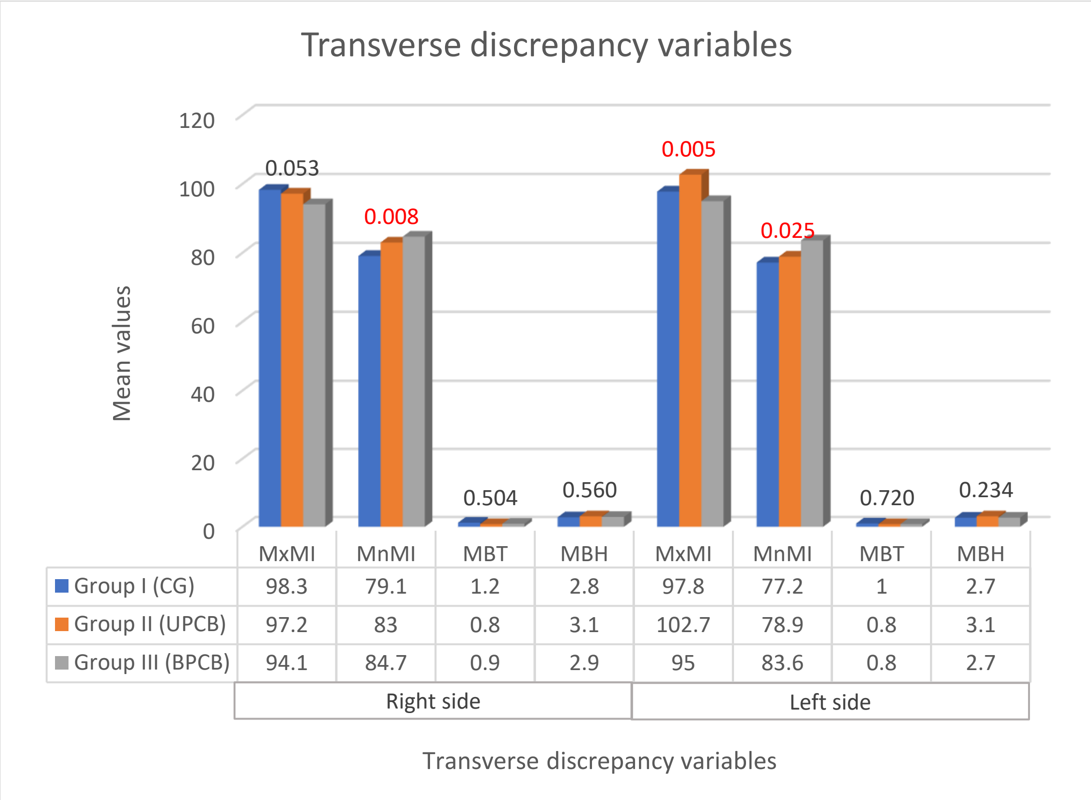

Figure 13: Plot of comparison of transverse discrepancy variables between different transverse posterior bite groups. For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. P-value labeled above the graph.

Table 12. Multiple comparison of condylar morphology variables between different transverse posterior bite groups using post hoc scheffe test.

S.No	Condylar morphology variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value		
		Mean ±S. D			CG vs UPCP	CG vs BPCB	UPCB vs BPCB
Right side							
1.	Mesio-distal condylar diameter (mm)	17.2±1.8	18.2±2.2	16.7±2.5	0.536	0.55	0.004**
2.	Antero-posterior condylar diameter (mm)	6.8±1.0	7.2±1.4	7.5±0.8	0.639	0.289	0.809
3.	Condylar inclination (°)	71.4±4.9	65.3±4.3	71.3±7.2	0.041*	0.997	0.048*
4.	Condylar distance (mm)	48.3±3.0	49.7±3.2	47.1±4.1	0.628	0.727	0.223
Left side							
1.	Mesio-distal condylar diameter (mm)	17.2±2.0	18.4±1.9	14.4±2.6	0.442	0.016	0.001**
2.	Antero-posterior condylar diameter (mm)	6.9±0.9	7.5±1.4	7.0±1.2	0.535	0.970	0.680
3.	Condylar inclination (°)	70.2±5.2	69.5±5.8	66.1±6.5	0.961	0.253	0.382
4.	Condylar distance (mm)	47.5±3.1	48.2±2.5	47.0±3.5	0.829	0.944	0.638
Condylar difference							
1.	Antero-posterior difference of condylar process (mm)	1.0±0.6	1.7±0.9	1.4±0.7	0.157	0.542	0.692

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. CG: Control group, UPCB: Unilateral posterior crossbite, BPCB: Bilateral posterior crossbite. N= Total number of subjects in each arch form group; SD - indicates standard deviation; P value of inter-group comparison using post hoc scheffe test; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 12 shows multiple inter-group comparison of condylar morphology variables between different transverse posterior bite groups using post hoc scheffe test.

Results revealed that the mesio-distal condylar diameter on right and left side was found to be significantly (P< 0.01) higher in Group II (unilateral posterior crossbite) as compared to Group III (Bilateral posterior crossbite). However, no statistically significant difference (P> 0.05) was found between Group I (Control) and Group II (Unilateral posterior crossbite) and between Group I (Control) and Group III (Bilateral cross bite).

The condylar inclination on right side was found to be significantly (P< 0.05) lower in Group II (Unilateral posterior crossbite) as compared to Group I (Control) and Group III (Bilateral posterior crossbite). However, no statistically significant difference (P> 0.05) was found between Group I (Control) and Group III (Bilateral posterior crossbite).

Other condylar morphology variables which include the antero-posterior condylar measurement on both right and left side, condylar inclination on left side, condylar distance on both right and left side and condylar difference showed no significant differences (P> 0.05) among the various transverse posterior bite groups.

Table 13. Multiple comparison of glenoid fossa variables between different transverse posterior bite groups using post hoc scheffe test.

S.No	Glenoid fossa variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value		
		Mean ±S. D			CG vs UPCP	CG vs BPCB	UPCB vs BPCB
Right side							
1.	Width of the glenoid fossa (mm)	21.3±1.7	23.7±1.7	23.5±1.5	0.005**	0.013*	0.938
2.	Depth of the glenoid fossa (mm)	8.3±0.9	8.9±1.0	8.2±1.0	0.369	0.980	0.277
Left side							
1.	Width of the glenoid fossa (mm)	21.4±1.7	23.9±2.0	23.4±1.3	0.006**	0.036*	0.750
2.	Depth of the glenoid fossa (mm)	8.1±0.8	8.7±0.9	8.1±1.0	0.352	0.995	0.303

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. CG: Control group, UPCB: Unilateral posterior crossbite, BPXB: Bilateral posterior crossbite. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using post hoc scheffe test; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 13 shows multiple inter-group comparison of glenoid fossa variables between different transverse posterior bite groups using post hoc scheffe test.

Results revealed that the width of the glenoid fossa on right and left side was found to be significantly (P< 0.01) higher in Group II (Unilateral posterior crossbite) and Group III (Bilateral posterior crossbite) as compared to Group I (Control). However, no statistically significant difference (P> 0.05) was found between Group I (Normal posterior bite and Group III (Bilateral cross bite) and between Group II (Unilateral posterior crossbite) and Group III (Bilateral posterior crossbite).

Other glenoid fossa variables which include depth of the glenoid fossa on both right and left side showed no significant differences (P> 0.05) among the various transverse posterior bite groups.

Table 14. Multiple comparison of temporomandibular joint space variables between different transverse posterior bite groups using post hoc scheffe test.

S.No	Temporomandibular joint space variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value		
		Mean ±S. D			CG vs UPCP	CG vs BPCB	UPCB vs BPCB
Right side							
1.	Anterior joint space (mm)	2.1±0.7	2.0±1.0	1.6±0.4	>0.99	0.370	0.383
2.	Superior joint space (mm)	2.5±0.6	2.8±0.8	2.4±0.7	0.306	0.242	0.306
3.	Posterior joint space (mm)	2.6±0.5	2.4±0.9	2.2±0.7	0.847	0.397	0.729
Left side							
1.	Anterior joint space (mm)	2.0±0.5	1.5±0.7	1.8±0.5	0.223	0.775	0.577
2.	Superior joint space (mm)	3.5±0.8	2.6±1.0	2.4±0.8	0.091	0.035*	0.901
3.	Posterior joint space (mm)	2.4±0.4	2.8±1.0	2.1±0.5	0.398	0.604	0.072

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. CG: Control group, UPCB: Unilateral posterior crossbite, BPCB: Bilateral posterior crossbite. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using post hoc scheffe test; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 14 shows multiple inter-group comparison of temporomandibular joint space variables between different transverse posterior bite groups using post hoc scheffe test.

Results revealed that the superior joint space left side was found to be significantly (P< 0.05) lower in Group III (Bilateral posterior crossbite) as compared to Group I (Control). However, no statistically significant difference (P> 0.05) was found between Group I (Control) and Group III (Bilateral cross bite) and between Group II (Unilateral posterior crossbite) and Group III (Bilateral posterior crossbite).

Other temporomandibular joint space variables which include the anterior joint space on both right and left side, superior joint space on right side, posterior joint space on both right and left side showed no significant differences (P> 0.05) among the various transverse posterior bite groups.

Table 15. Multiple comparison of transverse discrepancy variables between different transverse posterior bite groups using post hoc scheffe test.

S.No	Transverse discrepancy variables	Group I (Control) N=12	Group II (Unilateral posterior crossbite) N=12	Group III (Bilateral posterior crossbite) N=12	P – Value		
		Mean ±S. D			CG vs UPCP	CG vs BPCB	UPCBvs BPCB
Right side							
1.	Maxillary molar inclination (°)	98.3±3.9	97.2±3.4	94.1±4.9	0.830	0.065	0.205
2.	Mandibular molar inclination (°)	79.1±3.7	83.0±4.3	84.7±4.2	0.087	0.009**	0.614
3.	Maxillary buccal bone thickness (mm)	1.2±0.7	0.8±0.6	0.9±0.7	0.544	0.669	0.978
4.	Maxillary buccal bone height (mm)	2.8±0.6	3.1±0.4	2.9±0.6	0.562	0.894	0.832
Left side							
1.	Maxillary molar inclination (°)	97.8±2.8	102.7±7.9	95±4.1	0.105	0.461	0.006**
2.	Mandibular molar inclination (°)	77.2±2.6	78.9±8.2	83.6±4.5	0.758	0.031*	0.142
3.	Maxillary buccal bone thickness (mm)	1.0±0.4	0.8±0.5	0.8±0.7	0.720	0.908	0.933
4.	Maxillary buccal bone height (mm)	2.7±0.7	3.1±0.5	2.7±0.5	0.324	0.999	0.340

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side. CG: Control group, UPCB: Unilateral posterior crossbite, BPCB: Bilateral posterior crossbite. N= Total number of subjects in each arch form group; SD indicates standard deviation; P value of inter-group comparison using post hoc scheffe test; NS= Non-Significant, *=Significant (P <0.05), **= Highly Significant (P<0.01), ***= Very Highly Significant (P<0.001)

Table 15 shows multiple inter-group comparison of transverse discrepancy variables between different transverse posterior bite groups using post hoc scheffe test.

Results revealed that the maxillary molar inclination on left side was found to be significantly ($P < 0.01$) higher in Group II (Unilateral posterior crossbite) as compared to Group III (Bilateral posterior crossbite). However, no statistically significant difference ($P > 0.05$) was found between Group I (Control) and Group II (Unilateral posterior crossbite) and between Group I (Control) and Group III (Bilateral cross bite). The mandibular molar inclination on right and left side was found to be significantly ($P < 0.01$, $p<0.05$ respectively) higher in Group III (Bilateral posterior crossbite) as compared to Group I (Control). However, no statistically significant difference ($P > 0.05$) was found between Group I (Control) and Group II (Unilateral posterior crossbite) and between Group II (Unilateral posterior crossbite) and Group III (Bilateral posterior crossbite).

Other transverse discrepancy variables which include the maxillary molar inclination on right side, maxillary buccal bone thickness on right and left side and maxillary buccal bone height on right and left side showed no significant differences ($P > 0.05$) among the various transverse posterior bite groups.

DISCUSSION

Temporomandibular joint is one of the complex joints in the body and it is the area where craniomandibular articulation occurs. This articulation is closely associated with transverse relationship of maxillary and mandibular teeth. Any deviation from normal transverse relationship of maxillary and mandibular teeth directly affects the temporomandibular joint. (14,15) A bilateral crossbite due to skeletal imbalance between maxillary and mandibular transverse dimension differs from a unilateral crossbite only in degree of severity. The discrepancy between widths of maxilla to mandible is less in unilateral crossbite. The maxillary arch is usually symmetrical with coincident dental and skeletal midlines. Mandibular shifts in patients with a bilaterally constricted maxilla occur to facilitate better occlusal relationships and results in unilateral crossbites and a deviation of the mandibular midline toward the crossbite side (44).

Posterior unilateral crossbite and an associated functional shift imply a change in the pattern and intensity of functional forces applied to the mandible and temporomandibular joint. Electromyographic studies (25,26,58,59) have reported asymmetry in masticatory muscle activity during dynamic occlusion and asymmetric muscular potential in the postural position of the mandible in patients with posterior unilateral crossbite. It has been hypothesized that functional imbalances associated with posterior unilateral crossbite may modify the developmental pattern of related skeletal units, producing positional asymmetry in the TMJs and asymmetry in the three-dimensional posture and path of the condyles in the glenoid fossae. This is followed by adaptive anteroposterior repositioning of the glenoid fossae, which can lead to permanent structural asymmetry of the mandible.

However, controversies still exist concerning the development of a posterior unilateral crossbite into a mandibular structural asymmetry in adults if left untreated. At the same time there is no sufficient evidence about temporomandibular joint changes in patients with posterior bilateral crossbite comparison with unilateral crossbite and normal posterior occlusion patients.

Therefore, the present study was conducted to compare the condylar dimensions, glenoid fossa, temporomandibular joint space and transverse discrepancy in posterior unilateral crossbite, bilateral crossbite and normal posterior occlusion groups.

The anatomical position of TMJ within the fossa is difficult to evaluate with traditional radiography. Tsiklakis et al. (60) showed that CT images are of high diagnostic quality for morphologic assessment of the bony structures of the TMJ and are recommended to be the technique of choice. It is a valuable method for assessing the mandibular condyle and articular fossa as it provides accurate measurements of inclination, position and parameters of each component in the three orthogonal planes (61,62). Studies have been conducted in the past using three-dimensional radiography to evaluate TMJ in various malocclusion where they assessed only the anterior, posterior and superior joint spaces and condylar heights. A detailed, standardized three-dimensional evaluation of the TMJ was undertaken in the present study using Dolphin Imaging software.

At the baseline, the mean age of the patients was found to be similar in all three group. There was no significant difference on basis of gender of the patients between the three groups.

Assessment of condylar morphology variables in different transverse posterior bite groups:

In the intra-group comparison, there was no significant difference in mesiodistal diameter of condyle on left and right side in all the three groups. However, the anteroposterior diameter of condyle showed significant difference between the left and right side only in the bilateral crossbite group. There was significant difference between the condylar inclination on the left and right side in both the crossbite groups. The distance of the condyle to mid-sagittal plane showed significant difference between the left and right side in unilateral posterior crossbite group. This shows the difference in mesiodistal positioning of condyle on either side can be variable in people with unilateral posterior crossbite due to mandibular shift towards crossbite side.

In the inter-group comparisons, unilateral crossbite showed the largest mesiodistal diameter of condyle on both the sides when compared to the other two groups. This finding is similar to the study conducted by Veli et al. (41) this can be a consequence of an untreated unilateral crossbite which caused the displacement of the ipsilateral condyle toward crossbite side and an increased growth of the contralateral condyle.

Also, there can be continuous condylar displacement resulting from occlusal problems in the glenoid fossa during the growth period (63).

There was no significant difference in anteroposterior diameter of condyle between all the three groups. Various studies (29,54,64) also found similar results in anteroposterior condylar diameter between normal posterior occlusion and unilateral crossbite group. This was in contrast to the study conducted by Almaqrami et al. (57) who found significant differences between normal posterior occlusion group and both the crossbite groups for the right and left sides. However, it may be an incidental finding as the difference in anteroposterior diameter was found to be clinically insignificant (0.8mm).

In the present study, unilateral crossbite group showed more condylar inclination on crossbite side when compared to the other two groups. This may occur due to the error in precise localization of the condylar landmarks which can significantly affect the measurement of inclination.

There was no significant difference in condylar distance from mid-sagittal plane on left and right side between the groups. It is in agreement with the previous study, which were conducted in various malocclusion in sagittal dimension (65-68). To the best of our knowledge, there has been only one study which measured condylar distance from mid-sagittal plane. The previous study (57) found a significant difference in the same parameter between normal posterior occlusion group when compared with unilateral crossbite and bilateral crossbite groups. This difference is due to the variation in the selected landmarks for measurement of condylar distance, which was measured from the most anterior condylar point in axial section. In the present study geometric center of condyle was chosen for measuring the same.

In the present study, the anteroposterior difference between the geometric center of the right and left condylar processes as reflected on the mid-sagittal plane was found to be similar in all three groups.

Assessment of glenoid fossa variables in different transverse posterior bite groups:

In the intra-group comparison, there was no significant difference in width and depth of glenoid fossa between left and right side in either of the groups.

In the inter-group comparison, there was an increased in the width of glenoid fossa in unilateral and bilateral crossbite patients when compared with patients having normal posterior occlusion. In contrast to the present study a previous study (57) showed no statistically significant difference in glenoid fossa width between the three groups. The landmark used in the previous study for measurement of width of glenoid fossa, was posterior wall which may have been remodelled during growth as an adaptive response to existing malocclusion. A recent CBCT study (55), also explained the changes in the walls of glenoid fossa due to the growth remodelling. The reference point taken in the present study was the most inferior point of the auditory meatus which may be not be greatly influenced by growth remodelling.There was no significant difference in depth of the glenoid fossa between either of the groups. This was similar to the study by Almaqrami et al. (57) who used similar reference point for glenoid fossa depth measurement.

Assessment of temporomandibular joint space variables in different transverse posterior bite groups:

In the present study, there was no statistically significant difference in temporomandibular joint spaces between left and right sides in all three groups.

In the inter-group comparison, there was no statistically significant difference in anterior and posterior joint spaces in either group. However, the superior joint space was significantly decreased in bilateral crossbite group when compared with patients having normal posterior occlusion group which is in agreement with previous studies (42,57). In contrast with the present study, Hesse et al. (28) found asymmetric pretreatment condylar position with condyle placed more anteriorly and inferiorly in the glenoid fossa of the non-crossbite side leading to reducing anterior joint space and increased posterior joint space. However, the subjects selected in the former study were in growing phase (4.1 years to 12 years) where remodelling of glenoid fossa may not have been completed. Previous studies (30,55) did not find any significant difference in temporomandibular joint space and therefore, position of the condyle in crossbite and non-crossbite side. The possible explanation for the lack of difference in anterior and posterior joint space can be due to adaptive remodelling of condyle according to the existing transverse discrepancy during growth phase. O'Byrn et al. (24) and Lam et al. (69) found that the mandible in adults with unilateral posterior crossbite was rotated relatively posteriorly on the crossbite side as related to the cranial floor. However, lack of demonstrable difference in condylar position and temporomandibular joint spaces within the fossa was assumed to be due to remodelling. Similar results were reported by Muraglie et al. (55) who showed that remodelling was mainly located at the articular eminence and lateral-posterior wall of the glenoid fossa.

A strong theory behind the symmetry found in joint spaces on crossbite and non-crossbite sides in unilateral posterior crossbite subjects recorded before treatment could be explained by compensatory condyle fossa remodeling and or variation in thickness of the articular TMJ disc as described by various authors (28,70,71,72). Wang (71) suggested that the TMJ disc has the ability to adapt to any alteration caused by occlusal changes occurring in the space between the condyle and fossa.

Assessment of transverse discrepancies variables in different transverse posterior bite groups:

In the intra-group comparison, the maxillary molar inclinations were found to be increased on non-crossbite side although, the difference was not statistically significant. There was no difference in maxillary molar inclination between the left and right side in patients with bilateral posterior crossbite and normal posterior bite. The mandibular molar inclination was found to be increased in crossbite side when compared to non-crossbite side in unilateral posterior crossbite cases. However, it was found to be similar between the left and right side in bilateral posterior crossbite and normal posterior bite groups. Maxillary buccal alveolar bone height was found to be significantly different in left and right sides in bilateral crossbite group which may be an incidental finding. Further studies with larger sample size may be required to confirm the present finding.

In the inter-group comparison, maxillary molar inclination was found to be significantly higher in non-crossbite side of unilateral posterior crossbite when compared with bilateral posterior cross-bite group which may be due to dental compensations for the transverse skeletal discrepancy in the unilateral crossbite group, causing the crossbite to be expressed only on one side. Bishara et al. (73) also reported similar finding in unilateral crossbite patients however, they failed to specify the side where the inclination was increased. The lack of presentation of dental compensation in the bilateral crossbite group might be due to the severity of maxillomandibular transverse width discrepancy which was found to be more when compared to unilateral crossbite group. There was no significant difference in maxillary molar inclination between normal posterior bite and bilateral crossbite groups. This fact is in agreement with the study of Miner et al. (44) who explained that in the unilateral crossbite, maxillary width was not a significantly different, from that of the normal posterior occlusion group, so that the dental tipping obtained normal transverse dental relationships.

In the present study, mandibular molar inclination showed statistically significant differences between bilateral posterior crossbite and normal posterior bite groups. This may be due to true skeletal discrepancy, leading to some amount mandibular molar decompensation further leading to establishment of the cusp fossa relation between maxillary and mandibular molars. Dental decompensation, in the form of buccal tipping of the mandibular molars, is often observed in patients with a bilateral posterior crossbite. However, in contrast to the present study, Miner et al. (44) found no significant inclination difference in regard to mandibular molar dental decompensation in bilateral crossbite patients. The mandibular molar inclination was significantly higher on crossbite side of unilateral posterior crossbite group leading to a more upright position in relation to mandibular plane. Miner et al. (44) also found similar results in regard to the dental decompensations in patients with unilateral crossbites, where the mandibular molar was more upright on the crossbite side.

In the present study, results showed maxillary molar buccal bone thickness and maxillary molar buccal alveolar bone heights were similar between unilateral, bilateral and no posterior crossbite group. There have been previous studies (52,74,75,76) that compared maxillary molar buccal alveolar bone thickness and height between pre-expansion and post-expansion treatment in different malocclusion however, there has been no study for comparing the same between unilateral, bilateral and normal posterior occlusion groups.

Strengths and Limitations of the study:

The present study has extensively measured various skeletal and dental parameters of patients having malocclusion in transverse dimension, which have not been evaluated in previous studies. The present study has attempted to select landmarks which have minimum impact of growth. The reference planes selected in the present study are more reliable as they are independent of occlusal plane. The previous studies have evaluated the transverse parameters using functional occlusion as reference plane which is difficult to assess in patients with transverse malocclusion. Additionally it is susceptible to change due to minor movement in jaw position during the time of a scan. A small sample size is a major limitation of the study. The present study can be extended to compare condylar position after the correction of transverse malocclusion. Future studies may include of the assessment of masticatory muscles and bite force along with various other skeletal parameters.

CONCLUSIONS

This study was conducted to assess condylar morphology, glenoid fossa, temporomandibular joint space and transverse discrepancies variables in different transverse posterior bite groups.

The following conclusion can be drawn from the study:

1. Condylar distance was found to be significantly higher in the crossbite side as compared to the non-crossbite side in unilateral posterior crosssbite group.
2. Mesio-distal condylar diameter was found to be significantly higher in unilateral posterior crossbite group as compared to the bilateral posterior crossbite group.
3. Width of the glenoid fossa was found to be significantly higher in the unilateral and bilateral posterior crossbite groups as compared to normal posterior bite group.
4. Anterior, superior and posterior joint spaces did not show significant difference between the groups.
5. Mandibular molar inclination was increased (decompensation) in bilateral posterior crossbite group when compared to normal posterior bite group.
6. Non-crossbite side maxillary molar inclination (compensation) and crossbite side mandibular molar inclination (decompensation) was increased in unilateral posterior crossbite group.

SUMMARY

Objectives:

1. To compare condylar morphology and glenoid fossa dimensions in patients with normal posterior bite (control) and posterior crossbite.
2. To compare in molar inclination, buccal alveolar bone thickness and buccal alveolar bone height in patients with normal posterior bite (control) and posterior crossbite.

Materials and Methods: Thirty-six CT scans was selected according to inclusion and exclusion criteria. After selection, the sample was divided into three groups based on transverse posterior occlusion into normal posterior bite (Group I, N=12), unilateral posterior crossbite (Group II, N=12) and bilateral posterior crossbite (Group III, N=12). CT images were exported as Digital Imaging and Communication in Medicine (DICOM) files and imported into Dolphin Imaging Software (version 11.95; Dolphin Imaging and Management Solutions, Chatsworth, Calif). The CT images were reoriented with different reference planes to standardize the measurements and minimize errors. After CT orientation, various measurements of condylar morphology, glenoid fossa, temporomandibular joint space and transverse discrepancy variables were made upto $1/10^{th}$ of mm using measurement tool of dolphin imaging software. One-way Analysis of Variance (ANOVA) followed by Post-hoc Scheffe test was used to find differences between the groups. Intragroup analysis of right and left for assessing differences in different transverse posterior bite group was done using Student's t- test.

Results: In condylar morphology variables, unilateral posterior crossbite showed significantly ($P<0.05$) increased mesio-distal condylar width and decreased condylar inclination on crossbite side while antero-posterior condylar diameter, condylar distance, condylar difference did not show statistically significant differences among the different transverse posterior bite groups. In glenoid fossa variables, width of the glenoid fossa was found significantly ($P<0.05$) higher in unilateral and bilateral posterior crossbite groups while depth of the glenoid fossa did not show statistically significant differences among the different transverse posterior bite groups. In temporomandibular joint space variables, superior joint space was found significantly ($P<0.05$) lower in bilateral posterior crossbite group while anterior and posterior joint space did not show

statistically significant differences among the different transverse posterior bite groups. In transverse discrepancy variables, maxillary molar inclination in unilateral posterior crossbite group on non-crossbite side and mandibular molar inclination in bilateral posterior crossbite group were significantly ($P<0.05$) increased while maxillary buccal bone thickness, maxillary buccal bone height did not show statistically significant differences among the different transverse posterior bite groups. In the intra-group comparison, unilateral posterior crossbite group showed significant ($P<0.05$) difference in condylar distance and mandibular molar inclination in between crossbite and non-crossbite side.

Conclusion: The unilateral posterior crossbite group had a greater difference in condylar distance between the crossbite and non-crossbite sides, as well as increased mesiodistal condylar width and glenoid fossa width. When compared to other groups, there was no significant difference in anterior, superior, or posterior joint space. In the unilateral posterior crossbite group, non-crossbite side maxillary molar inclination (compensation) and crossbite side mandibular molar inclination (decompensation) were both increased.

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ANNEXURES

Annexure I: Institutional Ethical Clearance Certificate

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर

All India Institute of Medical Sciences, Jodhpur

संस्थागत नैतिकता समिति

Institutional Ethics Committee

No. AIIMS/IEC/2020/3347 **Date: 03/11/2020**

ETHICAL CLEARANCE CERTIFICATE

Certificate Reference Number: **AIIMS/IEC/2019-20/976**

Project title: **"Comparative Evaluation of Morphological Differences in Temporomandibular Joint (TMJ) in Patients with Posterior Cross bite"**

Nature of Project:	**Research Project**
Submitted as:	**M.D.S. Dissertation**
Student Name:	**Dr. R.Baskar**
Guide:	**Dr.Vinay Kumar Chugh**
Co-Guide:	**Dr.Pravin Kumar**

Institutional Ethics Committee after thorough consideration accorded its approval on above project.

The investigator may therefore commence the research from the date of this certificate, using the reference number indicated above.

Please note that the AIIMS IEC must be informed immediately of:

- Any material change in the conditions or undertakings mentioned in the document.
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research.

The Principal Investigator must report to the AIIMS IEC in the prescribed format, where applicable, bi-annually, and at the end of the project, in respect of ethical compliance.

AIIMS IEC retains the right to withdraw or amend this if:

- Any unethical principle or practices are revealed or suspected
- Relevant information has been withheld or misrepresented

AIIMS IEC shall have an access to any information or data at any time during the course or after completion of the project.

Please Note that this approval will be rectified whenever it is possible to hold a meeting in person of the Institutional Ethics Committee. It is possible that the PI may be asked to give more clarifications or the Institutional Ethics Committee may withhold the project. The Institutional Ethics Committee is adopting this procedure due to COVID-19 (Corona Virus) situation.

If the Institutional Ethics Committee does not get back to you, this means your project has been cleared by the IEC.

On behalf of Ethics Committee, I wish you success in your research.

Dr. Praveen Sharma

Member secretary
Institutional Ethics Committee
AIIMS, Jodhpur

Basni Phase-2, Jodhpur, Rajasthan-342005; **Website:** www.aiimsjodhpur.edu.in; **Phone:** 0291-2740741 Extn. 3109
E-mail : ethicscommittee@aiimsjodhpur.edu.in; ethicscommitteeaiimsjdh@gmail.com

Annexure II: Patient Information Leaflet (English)

All India Institute of Medical Sciences, Jodhpur

Department of Dentistry

<u>Patient Information Leaflet</u>

You are being invited to willing fully participate in the study entitled

"COMPARATIVE EVALUTION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"

You have been requested to volunteer for a research study since you have undergone fixed orthodontic treatment. Posterior crossbite is one of the reason patient seeking orthodontic treatment. Posterior crossbite may have effect on temporomandibular joint. Since there is less literature describing or comparing, the condylar morphology and glenoid fossa dimensions in patients with normal posterior bite and posterior crossbite. So this study is aimed to analyze condylar morphology and glenoid fossa dimensions in patients with posterior cross bite using cone beam computerized tomography.

Confidentiality

Your medical records and identity will be treated as confidential documents. They will only be revealed to other doctors/scientists/monitors/auditors of the study if required. The results of the study may be published in a scientific journal but you will not be identified by name.

Ethics committee approval has been obtained for the study.

Your participation and rights

Your participation in the study is fully voluntary and you may withdraw from the study anytime without having to give reasons for the same. In any case, you will receive the appropriate treatment for your condition. You will not be paid any amount for the participation in the study. You will have to pay for the routine investigations that will be done.

Contact Person: for further queries-

Dr. R.BASKAR

Post Graduate student,

Orthodontics and Dentofacial Orthopaedics,

Department of Dentistry,

AIIMS, Jodhpur.

Mobile No: - 8124039513

Email ID: baskarbds95@gmail.com

Annexure III: Patient Information Leaflet (Hindi)

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर
दंत चिकित्सा विभाग
<u>रोगी सूचना पत्र</u>

आपको अध्ययन में पूरी तरह भाग लेने के लिए आमंत्रित किया जा रहा है

शीर्षक: **"COMPARATIVE EVALUTION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"**

आपसे शोध अध्ययन के लिए स्वयंसेवक बनने का अनुरोध कर रहा है क्योंकि आप फिक्स्ड ऑर्थोडॉन्टिक ट्रीटमेंट करवा रहे है । पोस्टीरियर क्रॉस बाईट एक महत्वपूर्ण कारण है जिसके लिए मरीज़ ऑर्थोडॉन्टिक ट्रीटमेंट करवाते है। पोस्टीरियर क्रॉस बाईट से टेम्पोरोमैंडिब्यूलर जॉइंट पे असर होता है और बहुत कम लिटरेचर या स्टडी है जो कोनडीलर मॉर्फोलॉजी और ग्लेनोइड फ़ॉसा डाइमेंशन्स, नोर्मल पोस्टीरियर बाईट और पोस्टीरियर क्रॉस बाईट के बारे में दर्शाता है या उनकी तुलना करता है, इसीलिए यह स्टडी का लक्ष्य है की कोनडीलर मॉर्फोलॉजी और ग्लेनोइड फ़ॉसा डाइमेंशन्स की तुलना करना उन् मरीज़ो में जिनमे पोस्टीरियर क्रॉस बाईट है। यह स्टडी कोन बीम कंप्यूटराइज्ड टोमोग्राफी की मदद से की जाएँगी।

गोपनीयता

आपके मेडिकल रिकॉर्ड और पहचान को गोपनीय दस्तावेज माना जाएगा। यदि आवश्यक हो तो वे केवल अध्ययन के अन्य डॉक्टरों / वैज्ञानिकों / मॉनीटर / लेखा परीक्षकों को ही प्रकट किए जाएंगे। अध्ययन के परिणाम वैज्ञानिक पत्रिका में प्रकाशित किए जा सकते हैं लेकिन आपको नाम से पहचाना नहीं जाएगा। अध्ययन के लिए नैतिकता समिति की मंजूरी प्राप्त की गई है।

आपकी भागीदारी और अधिकारअध्ययन में आपकी भागीदारी पूरी तरह से स्वैच्छिक है और आप इसके कारणों के बिना किसी भी समय अध्ययन से वापस ले सकते हैं। किसी भी मामले में, आपको अपनी स्थिति के लिए उचित उपचार प्राप्त होगा। अध्ययन में भागीदारी के लिए आपको कोई राशि नहीं दी जाएगी। आपको नियमित जांच के लिए भुगतान करना होगा जो किया जाएगा।

संपर्क व्यक्ति: आगे के प्रश्नों के लिए-

डॉ.र.भास्कर.

पोस्ट ग्रजुएट छात्र
ऑर्थोडोंटिक्स और डेंटोफेशियल ऑर्थोपेडिक्स
दंत चिकित्सा विभाग
एम्स, जोधपुर
मोबाइल नंबर: -8124039513
ईमेल आईडी:- baskarbds95@gmail.com

Annexure IV: Informed Consent Form (English)

All India Institute of Medical Sciences, Jodhpur

Department of Dentistry

Informed Consent Form

Subject**: "COMPARATIVE EVALUATION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"**

Patient OPD No: ____

I, ______________________________S/o or D/o___________________________

R/o ________________________give my full, free, voluntary consent to be a part of the study "COMPARATIVE EVALUTION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"

The procedure and nature of which has been explained to me in my own language to my full satisfaction. I confirm that I have had the opportunity to ask questions. I give my permission for the use of orthodontic records, including photographs, made in the process of examinations and treatment for the purposes of research, education, or publication in professional journals.

I understand that my participation is voluntary and I am aware of my right to opt out of the study at any time without giving any reason.

I understand that the information collected about me and any of my medical records may be looked at by responsible individual from AIIMS Jodhpur or from regulatory authorities. I give permission for these individuals to have access to my records.

Date:_____________ _________________________

Place: ____________ Signature/Left thumb impression (Patient) (Caregiver)

This to certify that the above consent has been obtained in my presence.

Date:________________ ___________________________

Place: ________________ Signature of Principal Investigator

1. Witness 1 2. Witness 2

Name: ______________________ Name: ______________________

Annexure V: Informed Consent Form (Hindi)

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर

दंत चिकित्सा विभाग

सूचित सहमति प्रपत्र

शीर्षक: **"COMPARATIVE EVALUTION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"**

रोगी / स्वयं सेवी पहचान संख्या: ___________________

मैं,______________________ पुत्र/पुत्री___________________________

निवासी____स्वयं को अध्ययन का हिस्सा होने के लिए अपनी पूर्ण स्वैच्छिक सहमति देता हूँ। इस अध्ययन का शीर्षक है

"COMPARATIVE EVALUTION OF MORPHOLOGICAL DIFFERENCES IN TEMPOROMANDIBULAR JOINT (TMJ) IN PATIENTS WITH POSTERIOR CROSSBITE"

मेरी पूर्ण संतुष्टि के लिए मेरी खुद की भाषा में मुझे समझाया गया है।मैं इस बात की पुष्टि करता/करतीहूं कि मुझे सवाल पूछने का पूर्ण अवसर मिला है।

मैं पेशेवर पत्रिकाओं में अनुसंधान, शिक्षा, या प्रकाशन के प्रयोजनों के लिए परीक्षाओं और उपचार की प्रक्रिया में किए गए फोटोग्राफ सहित ऑर्थोडोंटिक रिकॉर्ड्स के उपयोग के लिए मेरी अनुमति देता/देती हूं।

मैं यह समझता/समझतीहूँ कि मेरी भागीदारी स्वैच्छिक है और बिना कोई कारण बताए किसी भी समय इस अध्ययन से स्वयं को वापस लेने के लिए मेरे अधिकार के बारे में मुझे पता है।

मैं यह समझता/समझती हूँ कि मेरे मेडिकल रिकॉर्ड की एकत्रित की गई जानकारी "अखिल भारतीय आयुर्विज्ञान संस्थान जोधपुर" यानि यामक अधिकारियों द्वारा देखी जा सकती है।मैं इन व्यक्तियों को मेरे रिकॉर्ड के उपयोग के लिए अनुमति देता/देती हूँ।

दिनांक: हस्ताक्षर / वाम अंगूठे का निशान

स्थान:

यह प्रमाणित किया जाता कि इस संस्करण की सहमति मेरी उपस्थिति में प्राप्त की गयी है।

दिनांक: प्रमुख अन्वेषक के हस्ताक्षर

स्थान:

1. साक्षी1	2. साक्षी2
हस्ताक्षर: _____________	हस्ताक्षर: ____________
नाम:_______________	नाम: _____________
पता: _____________	पता: _____________

Annexure VI: CBCT record form

CBCT RECORD FORM

Sr. No.: Clinic No:

Name: Age/Sex:

AIIMS ID: Date:

Group: **A) Patients with normal posterior bite** ☐

B) Patients with posterior bilateral crossbite ☐

C) Patients with posterior bilateral crossbite ☐

S.No	**Mandibular condyle measurements**	**Right**	**Left**
1.	Antero-posterior condylar diameter		
2.	Mesio-distal condylar diameter		
3.	Condylar inclination		
4..	Condylar distance		
5.	Condylar difference		

S.No	**Glenoid fossa measurements**	**Right**	**Left**
1.	Depth of the glenoid fossa		
2.	Width of the glenoid fossa		

S.No	**TMJ space measurements**	**Right**	**Left**
1.	Anterior joint space		
2.	Superior joint space		
3.	Posterior joint space		

S.No	**Measurements**	**Right**	**Left**
1.	Maxillary molar inclination		
2.	Mandibular molar inclination		
3.	Maxillary buccal alveolar bone thickness		
4.	Maxillary buccal alveolar bone height loss		

For a unilateral crossbite, the right side was the crossbite side and the left side was the non-crossbite side.

Annexure VII: Plagiarism Certificate

Plagiarism Certificate

Comparative evaluation of morphological differe...
By: Baskar Ravi
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Pittman, Lance. "Cbct evaluation of condylar changes in children with unilateral posterior crossbites with a functional shift.", Proquest, 2014.

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bmccancer.biomedcentral.com

40 words / < 1% match - Crossref
Lance Pittman, Thomas Shipley, Chris Martin, Jun Xiang, Peter Ngan. "CBCT Evaluation of Condylar Changes in Children with Unilateral Posterior Crossbites and a Functional Shift", Seminars in Orthodontics, 2019

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repositorio.unicamp.br

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N. R. Krishnaswamy. "Expansion in the absence of crossbite – rationale and protocol", APOS Trends in Orthodontics, 2019

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aeronline.org

30 words / < 1% match - Crossref
Simone Muraglie, Rosalia Leonardi, Khaled Aboulazm, Chiara Stumpo, Carla Loreto, Cristina Grippaudo. "Evaluation of structural skeletal asymmetry of the glenoid fossa in adult patients with unilateral posterior crossbite using surface-to-surface matching on CBCT images", The Angle Orthodontist, 2020

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