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CBCT evaluation of changes in condylar position following fixed functional appliance therapy: A comparative *in vivo* study

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Abstract
Objective: to evaluate and compare the condylar positional changes after the treatment of class ii malocclusion patients using powerscope appliance and forsus fatigue resistant device using pre-treatment and post-treatment CBCT images.
Materials and Method: twenty subjects of adult age group having class ii division 1 malocclusion, horizontal to average growth pattern, orthognathic maxilla, retrognathic mandible, increased overjet were included in this study.
The subjects were divided into two groups, forsus group and power scope group. A pre-treatment cbct scan was taken before the start of the treatment using Kodak 9000 3d extraoral imaging system. In group i, forsus fatigue resistant appliance was used to achieve class i occlusion. After completion of the forsus therapy another CBCT scan was taken. In group ii, powerscope appliance was used to achieve class i occlusion. Sequential activation of the powerscope appliance was done using crimpable shims depending on the amount of skeletal discrepancy in each patient's mouth, until edgeto-edge bite was obtained. After completion of the powerscope appliance therapy, another CBCT scan was taken.
After the pre and post treatment CBCT scans were analyzed, position of the condyle were assessed on the dicom images, using the cs 3d imaging software. The field of view was confined to the right and left TMJ. This was done so that condylar head, glenoid fossa and external auditory meatus were visualized and the data obtained were subjected to statistical analysis. Comparison of all the pre & post treatment parameters were done by paired-t test. Comparison of forsus and power scope group was done using independent t-test.
Results: an average forward shift of mandibular condyle by. 85 mm was seen after 7- 9 months of treatment in forsus appliances therapy and. 79 mm after powerscope therapy indicating that the forward mandibular condylar shift is greater in forsus group than the powerscope group, the forward condylar shift of two groups was statistically insignificant with a mean difference of. 060 mm.
Although both the forsus and powerscope groups showed a downward shift of mandibular condyle, there was a greater downward shift in forsus group (2.69 mm) compared to the powerscope group (2.29 mm), the downward condylar shift of two groups was statistically insignificant with a mean difference of 0.42mm.
Conclusion: forsus appliance brought about a more anterior and downward shift in the mandibular condylar position, compared to power scope group but the difference were not statistically significant between the two appliances i.e. Forsus and powerscope.

Keywords: Forsus appliances, power scop appliances, CBCT

Introduction
Skeletal malocclusions are caused due to abnormalities in the maxilla and mandible and the defects can be in size, shape, position or relationship between the jaws. The skeletal malocclusion can occur in three planes of space. In the sagittal plane, skeletal class ii malocclusion can occur, as a result of prognathic maxilla or retrognathic mandible or a combination of both. Skeletal class ii malocclusion due to retrognathic mandible has a profound unaesthetic effect on facial appearance and facial profile.

Apart from skeletal features, they have dental features like increased overjet, increased overbite, crowding, narrow upper arch, a small lower arch and hyperactive mentalis. So the correction of skeletal class ii malocclusion has been considered as a common goal for the patient and the orthodontist.

Functional orthopaedic approach has been commonly used in the field of dentofacial orthopaedics for the correction of mandibular retrognathia during active skeletal growth, by the forward repositioning of the mandible to optimize the development of facial skeleton. The mode of action of these appliances is a matter of debate among researchers. It is believed that growth modulation of the condylar cartilage and adaptive changes in the glenoid fossa may be important mechanisms for the action of mandibular advancement functional appliance.

Orthopaedic appliances can be categorized into removable and fixed appliances.

The twin block appliance is the most popular functional appliance. It was first introduced by clark in 1984 and consists of two separate upper and lower removable plates with acrylic blocks trimmed to an angle of 70 degrees. These separate plates make the twin block appliance different in comparison with other removable functional Monoblock appliances as it is less bulky, increased patient acceptance for the appliance and patients have more freedom in their mandibular movements. It is designed for full time wear to take advantage of all functional forces applied to the dentition including masticatory forces. All these considerations could conceptually produce different treatment results compared with the removable functional monoblock

Fixed functional appliances can be grouped into rigid or flexible devices. The most commonly used rigid fixed functional appliances are the herbst and mandibular anterior repositioning appliance (mara). However, there were certain disadvantages associated with rigid type of devices, the foremost being the patient's inability to perform lateral side-to-side mandibular movements with ease and hence, more chances of breakage. To overcome these disadvantages, flexible devices were developed.

The forsus fatigue resistant device (3m unitek corp., monrovia, calif) is one of innovative three-piece telescoping spring for class ii correction. It consists of a universal spring module, an 'l' pin and a push rod that is available in five different sizes. It is assembled so that the appropriately sized push rod attaches directly to the lower archwire distal to the canine teeth, and the spring to the headgear tube via the 'l' pin. It is available in various sizes, hence a large inventory must be maintained, and chairside application time is increased as size selection is needed. However, frequent breakage of canine brackets and soft tissue lacerations have been reported with forsus.

The powerscope (American orthodontics, Sheboygan, wis) is a hybrid, rigid telescoping system which has been recently introduced to the orthodontic fraternity. It is delivered as a onesize-fits-all appliance, pre-assembled with attachment nuts for quick and easy chairside application. The appliance is a wire-to-wire installation with attachments placed mesial to the first molar in the maxillary arch and distal to the canine of the mandibular arch. Powerscope also has the advantage of permitting lateral movements due to exclusive ball and socket joints and typical telescopic mechanism is also advanced feature, unlike other class ii correctors, there is no need for assembly measuring or appliance manipulation. This wire-to-wire device delivers unmatched patient comfort and eliminates the need for headgear tubes or special band assembles.

Previously few studies have been done which showing the treatment effects and clinical application of powerscopand forsus fatigue resistant device, but most of Theas studies are using conventional 2d radiography technique. Thus the purpose of this study is to measure the changes in condylar position produced by the power scope Appliance and to compare these effects with those produced by the forsus fatigue resistant device by using CBCT, a more accurate 3d radiography imaging technique than conventional 2 dradiography technique used in the past.

Materials and Methods

The present study was a prospective, nonpharmacological, randomized clinical study conducted in the department of orthodontics and dentofacial Orthopedics, at Ruhs College of dental sciences, Jaipur (Rajasthan).

Ethical clearance was obtained from the ethical committee of ruhs college of dental sciences, Jaipur (Rajasthan) explaining the aim & importance of the study, before starting the study.

The study sample consisted of 20 patients of north Indian origin reporting to the department of orthodontics and dentofacial orthopedics, at Ruhs College of dental sciences, jaipur (rajasthan), for fixed orthodontic treatment.

The subjects were divided into two groups

Group I: Consisted of 10 subjects (forsus fatigue resistant device group).

Group II: Consisted of 10 subjects (powerscope group).

The individuals were selected based on the following criteria-

Inclusion criteria

- Subjects presenting with class ii division 1 malocclusion with Orthognathic maxilla and mandibular retrognathia (ANB angle greater than 4 degrees).
- Bilateral class ii molar and canine relation.
- Age group: adult age group both male and female.
- Average to horizontal growth pattern.
- Overjet greater than 5 mm.
- Positive pre-treatment visual treatment objective.
- Minimum crowding in the dental arches requiring no extraction of any permanent teeth (excluding third molars).

Exclusion criteria

- Presence of periodontal disease.
- Subjects with previous orthodontic treatment.
- Subjects with a history or symptoms of temporomandibular joint disease.
- Systemic diseases affecting bone metabolism.
- Severe proclination and crowding of anterior teeth.

Radiographic examination

The CBCT analysis presented was obtained from a full head cone beam CT images of patients in maximum dental intercuspation. During scanning, the patient position was standardized as follow; the frankfort horizontal plane was parallel to the floor and midsagittal plane was perpendicular to the frankfort horizontal plane.

Fig 1: CBCT machine with patient positioning.

A cbct were taken before starting the treatment to check for the position of the condyle using kodak 9000 3d extraoral imaging system (carestream health, rochester, new york) with exposure time of 24 sec and dose of 218 mgymm2and the data was exported as dicom images to cs 3d imaging software (carestream health, rochester, new york).

After cbct scans were analyzed, position of the condyle were assessed on the dicom images, using the cs 3d imaging software. The field of view was confined to the right and left tmj. This was done so that condylar head, glenoid fossa and external auditory meatus were visualized. This also enabled us to have a voxel size of 98 µm for greater accuracy of measurements and to have as less radiation dose as possible. Before the cbct was taken personal protective equipments were worn by the subjects

3d assessment

Slicing in the sagittal view should be standardized for more accuracy and reproducibility, for this reason the sagittal cuts should be parallel to the long axes of the condyles, which was achieved by reorientation of each condyle separately in the axial view till the long axis (mediolateral dimension) makes 90° with the midsagittal plane (msp) [40].

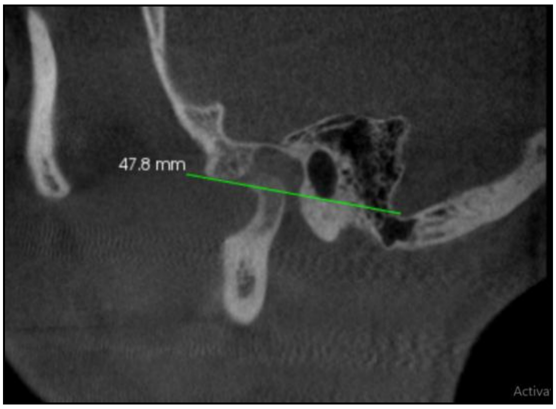


Fig 2: Method of Standard Orientation and Reference Line in

Saggital View of CBCT Scan

Reference Lines

Tuberculo-meatal line (tm): the line between the most inferior point of the articular tubercle to the most inferior point of the auditory meatus (vitral *et al*., 2004; vitral *et al*., 2011).

The axial section was reoriented so that the midsagittal plane should pass through the most accurately represented points in the midline of the skull base to check the actual orientation and position of the condyles. Those points are; posterior nasal spine, the most inferior point of anterior margin of foramen magnum [basion (ba)], the most inferior point of posterior margin of the same landmark [opisthion (op)] and external occipital crest (eoc) which is a ridge structure along the midline at the bottom of the skull (barkovich *et al*., 1986) [40].

The mid-sagittal plane: the line bisecting the skull base into two equal halves.

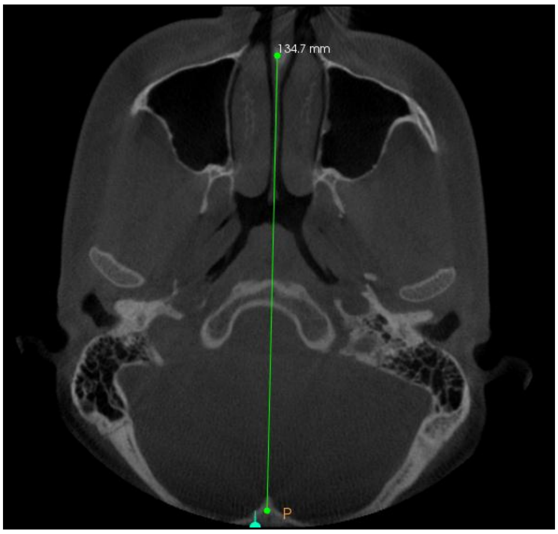


Fig 3: Method of Standard Orientation and Reference Line in Axial View of CBCT Scan

Technique to measure forward shift of condyle

After orientation standardization of axial section was done of condyle with maximum thickness. This was opened in sagittal section and atuberculo-meatal line was drawn, a perpendicular to tubo-mental line passing tangentially to posterior surface of glenoid fossa was made and then a perpendicular distance from this tangent was measured horizontally to the most superior point of condyle.

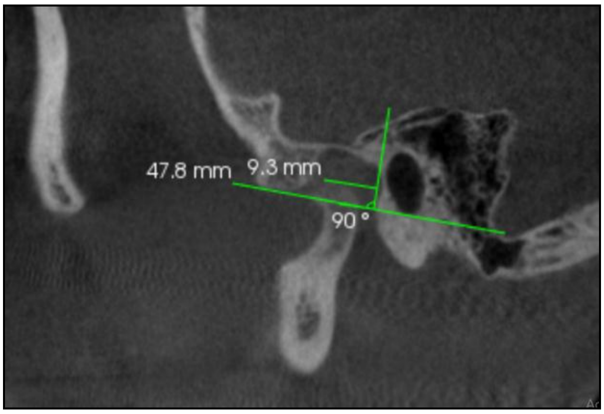


Fig 4: Technique to measure forward shift of condyle

Technique to measure downward shift of condyle

After orientation standardization of axial section was done of condyle with maximum thickness. This was opened in segittal section and atuberculo-meatal line was drawn, a perpendicular to tubo-mental line passing tangentially to posterior surface of glenoid fossa was made and then a perpendicular distance from this tangent was measured horizontally to the most superior point of condyle. The distance was measured vertically from most superior point of condyle to most superior point of glenoid fossa.

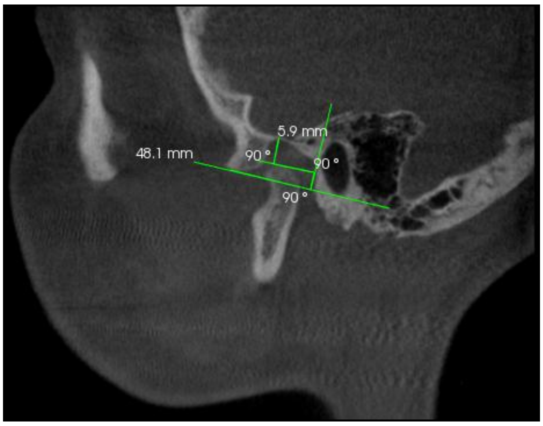


Fig 5: Technique to measure downward shift of condyle

Statistical analysis

After completion of the forsus and powerscope phase of treatment cbct scans were taken to quantify the skeletal changes produced in position of condylar head. The data obtained was subjected to statistical analysis. Means, standard errors, and standard deviations were tabulated, with the paired t test and unpaired t test (calculated with the help of spss (statistical package for social sciences software). The level of significance was set at $p \leq 0.05$.

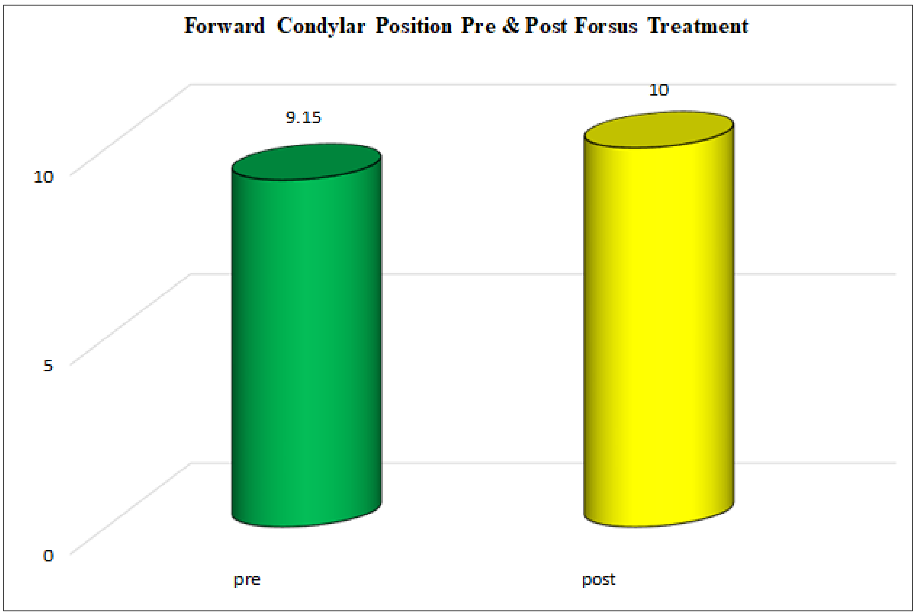
Results

1. Comparison of forward condylar position between pre & post forsus treatment on cbct scans

Forward condylar position in pre forsus treatment showed mean forward position of 9.15+/- 1.483 and in post forsus meanforward position was 10+/-1.413 with a mean difference of 0.85 mm. Difference between the forward condylar position in pre & post forsus treatment was statistically significant ($p \leq 0.05$). Table 1 show the comparison of forward condylar position between pre & post forsus treatment.

Table 1: Comparison of forward condylar position between pre & post forsus treatment on CBCT scans

Forsus	Mean	SD	Mean Difference	T Value	P Value
Pre	9.15 mm	1.483	0.85	18.74	0.0001
Post	10.00 mm	1.413			



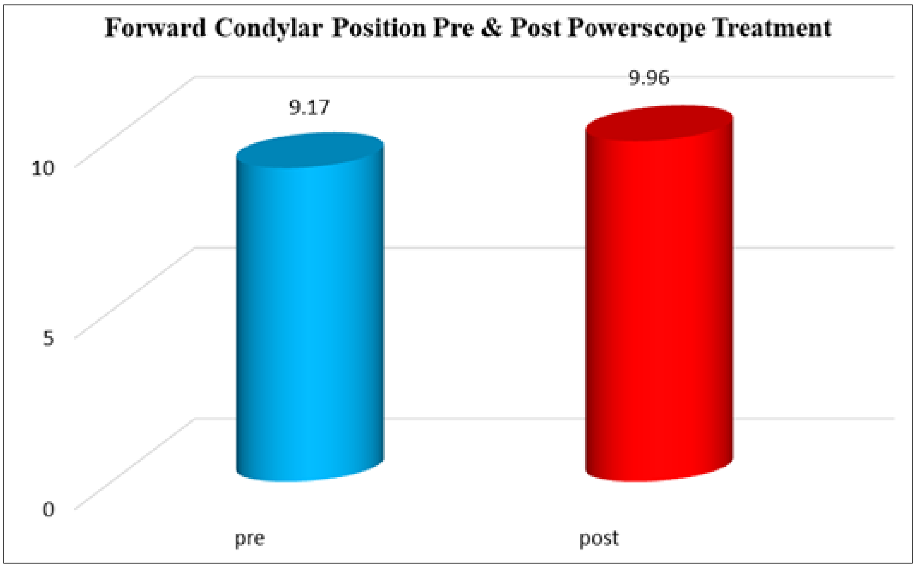
Graph 1: Comparison of forward condylar position between pre & post forsus treatment on CBCT scans

2. Comparison of forward condylar position between pre and post powerscope treatment on CBCT scans

Forward condylar position in pre powerscope treatment showed mean forward position of 9.17+/- 1.46 and in post powerscope mean forward position was 9.96+/ 1.45 with a mean difference of.079 mm. Difference between the forward condylar position between pre and post powerscope treatment was statistically significant ($p \leq 0.05$). Table 2 show the comparison of forward condylar position between pre and post powerscope treatment.

Table 2: Comparison of Forward Condylar Position Between Pre and Post Powerscope Treatment on CBCT Scans

Power scope	Mean	SD	Mean Difference	T Value	P Value
Pre	9.17 mm	1.46	0.79	33.85	0.0001
post	9.96 mm	1.45			



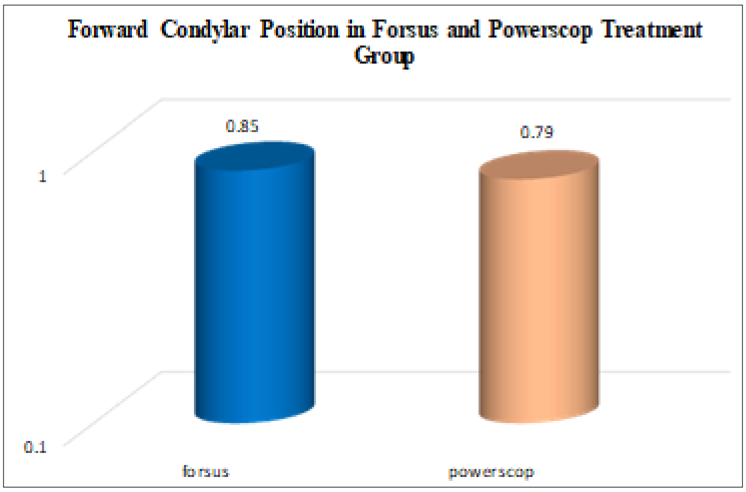
Graph 2: Comparison of Forward Condylar Position Between Pre and Post Powerscope Treatment on CBCT Scans

3. Comparison of mean difference in forward condylar position between pre-treatment and post treatment cbct scans among forsus and powerscope appliance

Forward condylar position in forsus treatment group showed mean forward positioning of 0.85+/-. 143 and in powerscope treatment group mean forward positioning was 0.79+/. 074 with a mean difference of. 060 mm. Difference between the forward condylar position of two groups was statistically insignificant (p>_0.05). Table 3 show the comparison of mean difference in forward condylar position between pre-treatment and post treatment CBCT scans among forsus and powerscope appliance subjects

Table 3: Comparison of the mean difference in forward condylar position between pre-treatment and post treatment CBCT scans among forsus and power scope appliance

	Mean	SD	Mean Difference	T Value	P Value
Forsus	0.85	0.143	0.060	1.176	0.2546
Powerscope	0.79	0.074			



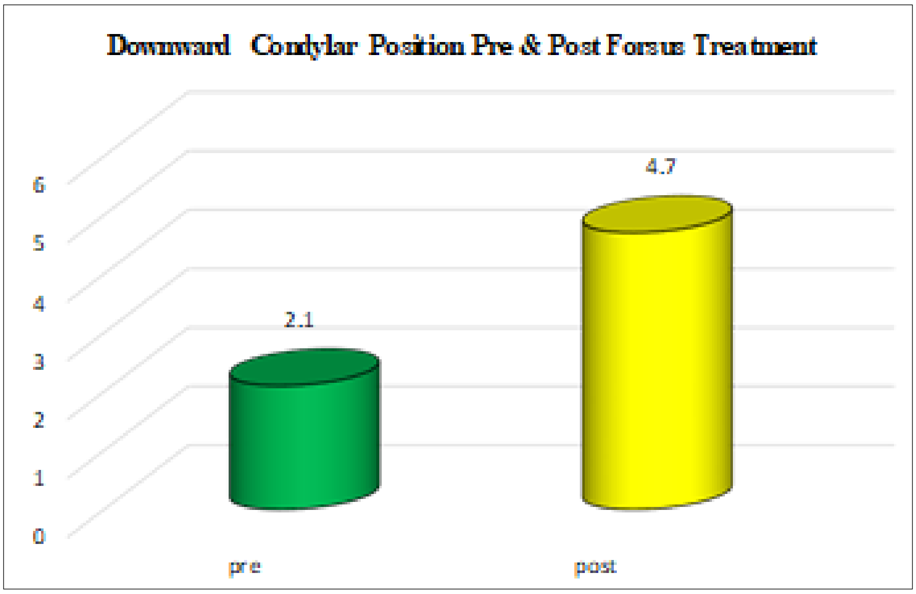
Graph 3: Comparison of Mean Difference in Forward Condylar Position Between Pre-treatment and Post Treatment CBCT Scans Among Forsus and Powerscope Appliance

4. Comparison of downward condylar position between pre & post forsus treatment on CBCT scans

Downward condylar position in pre-treatment showed mean downward position of 2.1+/-. 337 and in post forsus mean downward position was 4.79+/-.540 with a mean difference of 2.66 mm. Difference between the downward condylar position in pre & post forsus treatment was statistically significant (p≤0.05). Table 4 and graph 4 show the comparison of downward condylar position between pre & post forsus treatment.

Table 4: Comparison of Downward Condylar Position Between Pre and Post Forsus Treatment on CBCT Scans

Forsus	Mean	SD	Mean Difference	T Value	P Value
Pre	2.1mm	.337	2.69	22	0.0001
Post	4.79mm	.540			



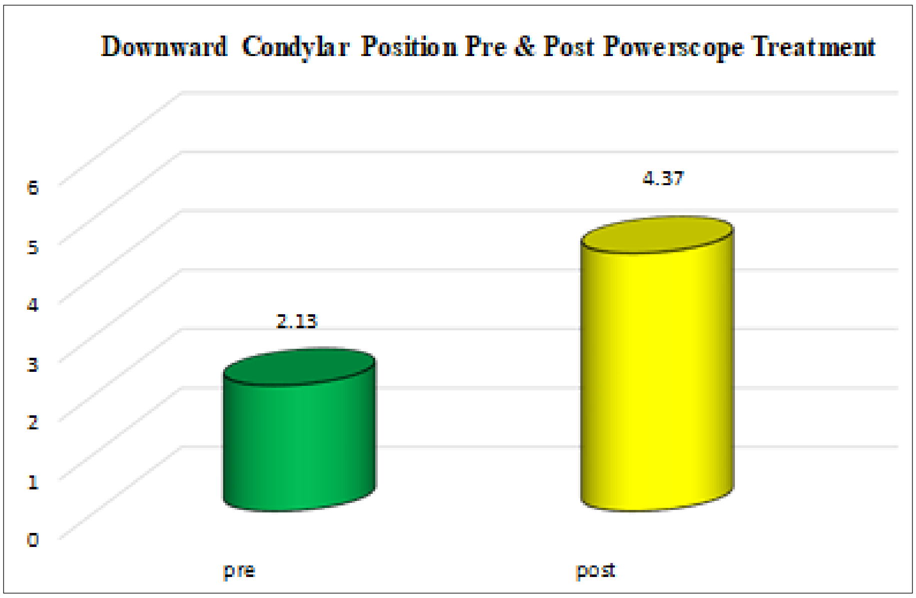
Graph 4: Comparison of downward condylar position between pre and post forsus treatment on CBCT scans

5. Comparison of of downward condylar position between pre and post powerscope treatment on CBCT scans

Downward condylar position in pre-treatment showed mean downward position of 2.13+/-. 271 and in post powerscope mean downward position was 4.37+/-.487 with a mean difference of 2.24 mm. Difference between the downward condylar position in pre & post powerscope treatment was statistically significant (p≤0.05). Table 5and graph 5 show the comparison of downward condylar position between pre & post powerscope treatment.

Table 5: Comparison of downward condylar position between pre and post powerscope treatment on CBCT scans

Powerscope	Mean	SD	Mean Difference	T Value	P Value
Pre	2.13mm	.271	2.24	12	0.0001
Post	4.37mm	.487			



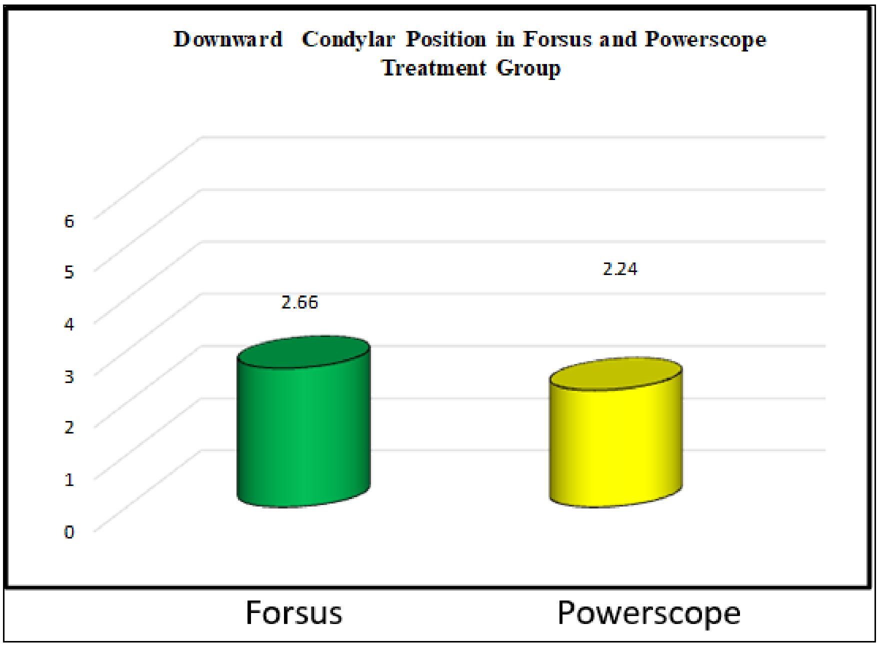
Graph 5: Comparison of Downward Condylar Position Between Pre and Post Powerscope Treatment on CBCT Scans

6. Comparison of mean difference in downward condylar position between pre-treatment and post treatment cbct scans among forsus and powerscope appliance

Downward condylar position in forsus treatment group showed mean downward position of 2.66+/-. 389 and in powerscope treatment group mean downward position was 2.24+/. 365 with a mean difference of. 42 mm. Difference between the downward condylar position of two groups was statistically significant (p>_0.05). Table 6 and graph 6 show the comparison of mean difference in downward condylar position between pre-treatment and post treatment cbct scans among forsus and powerscope appliance groups.

Table 6: Comparison of mean difference in downward condylar position between pre-treatment and post treatment CBCT scans among forsus and powerscope appliance

	Mean	SD	Mean Difference	T Value	P Value
Forsus	2.66	0.389	0.420	2.486	0.0229
Powerscope	2.24	0.365			



Graph 6: Comparison of mean difference in downward condylar position between pre-treatment and post treatment CBCT scans among forsus and powerscope appliance

Discussion

Class ii malocclusion is one of the most common orthodontic problems, and it occurs in about one third of the population. The most consistent diagnostic finding in class ii malocclusion is mandibular skeletal retrusion. A therapy able to enhance mandibular growth is indicated in these patients. The objective is to stimulate mandibular growth and correct the sagittal misalignment by bringing the condyles forward and downward within the glenoid fossa, as well as remodeling the condyle and glenoid fossa, causing anterior rotation of the mandible and consequently projecting it forwards. The treatment period lasts approximately 6 to 9 months [1].

Functional appliances can be categorized into either removable or fixed ones (ffas). An important discriminating factor between them is the need for patient compliance, which is considered to be a possible influence on the treatment outcomes.

The lack of success of removable functional appliance has in some circumstance been attributed to lack of patients' compliance in appliance wear due to removable in nature which leads to failure to achieve optimum results.

This led to the evolution of fixed functional appliances which are fixed to the upper or lower jaws for nonmotivated, noncompliant patients. They are well known as "noncompliant class ii correctors." They are rigid, flexible, and hybrid fixed functional (hff) appliances [38].

A new fixed functional appliance can save both time and trouble. The appliance is effective 24 hours a day without being dependent on patient compliance. This is of particular interest in the case of non-motivated, non-compliant adolescents or of handicapped patients. This treatment effectively shortens the duration of therapy, and ideal use can be made of the remaining growth of a patient beyond the pubertal growth spurt. The fixed appliance is of minimal disturbance to the wearer since almost all oral functions are still possible. The only disadvantage is the limited mouth opening.

When the functional appliance is inserted, the condyles are moved to a higher position in the articular eminence, which is capable of adaptation, so it could be hypothesized that some morphological changes may take place. Although many orthodontists have no doubts about the effectiveness of functional appliances, their impact on the tmj is still considered a subject of debate.

Previously only few studies have been done which showing the treatment effects and clinical application of powerscope and forsus fatigue resistant device, but most of the sestudies are using conventional 2d radiography technique.

Thus the purpose of this study is to measure the changes in condylar position produced by the powerscope appliance and to compare these effects with those produced by the forsus fatigue resistant device by using cbct, a more accurate 3d radiography imaging technique than conventional radiography technique used in the past.

In our study table 1 and graph 1 showed that condylar position in pre forsus treatment showed mean condylar position of 9.15+/- 1.483 and in post forsus treatment mean anterior position was 10+/-1.413 with a mean difference in anterior positioning of 0.85 mm at p value. 0001. Which show statistically significant difference between the condylar position in pre & post forsus treatment.

Table 2 and graph 2 showed that condylar position in pre powerscope treatment showed mean condylar position of 9.17+/- 1.46 and in post powerscope mean anterior position was 9.96+/ 1.45 with a mean difference in condylar position of.079 mm at p value. 0001. Which show statistically significant difference between the condylar position between pre and post powerscope treatment.

Table 3 and graph 3 shows that mean anterior condylar position in forsus treatment group is 0.85+/-. 143 and in powerscope treatment group mean anterior positioning was 0.79+/-. 074 with a mean difference in anterior positioning of. 060 mm at p value of 0.2546. So our study shows that the forsus appliance shows more downward shift of condyle compare to powerscope appliance but the difference is statistically insignificant.

Table 4 and graph 4 shows that mean downward position of condyle in pre forsus treatment is 2.1+/-. 337 and in post forsus treatment mean downward position was 4.79+/ -.540 with a mean difference in downward condylar position of 2.69 mm at p value of 0.0001. Which show statistically significant difference in the downward condylar position between pre and post forsus appliance treatment.

Table 5 and graph 5 shows that mean downward position of condyle in pre powerscope treatment is 2.13+/-. 271 and in post-powerscope treatment mean downward position was 4.37+/. 487 with a mean difference in downward condylar position of 2.24 mm at p value of 0.0001. Which show statistically significant difference in the downward condylar position between pre and post powerscope appliance treatment.

Table 6 and graph 6 shows that mean downward position of condyle in forsus treatment group is 2.66+/-. 389 and in powerscope treatment group mean downward position was 2.24+/ -.365 with a mean difference in downward condylar position of. 420 mm at p value of 0.0229. So our study shows that the forsus appliance shows more downward shift of mandibular condylecompared to powerscope appliance but the difference isstatistically insignificant.

Hence overall our study shows that the forsus appliance shows more downward and forward shift of mandibular condylecompared to powerscope appliance with a mean difference of0.060 mm and 0.420 mm respectively.

Previously, many studies have analysed tmj changes using conventional cephalograms, mri or computed tomography.

A study conducted on the tmj by pancherz, using radiographs taken before and after herbst treatment revealed unchanged condylar relationships [42].

Chavan *et al*., conducted a magnetic resonance imaging (mri) study on changes in the tmj following twin block and bionator appliance therapy, and mri demonstrated that a translation of the mandibular condyle occupied a more anterior position in the fossa, to its pre-treatment position.

Wadhawan *et al*., documented a study to evaluate the changes in the condyle-glenoid fossa (cgf) complex and the positional variations of the glenoid fossa after the use of removable functional appliance and at the end of completion of fixed appliance therapy; forward condylar position as well as articular disc retrusion with respect to the condylar head was reported by them and they also emphasised that, even though there is forward relocation of the condyle-glenoid fossa, their internal rearrangement returns to a pre-treatment position [3].

Yuan-yuanjiangaliansuna, bhuawanga, at al conducted a three-dimensional (3d) study for evaluating temporomandibular joint (tmj) changes during twin-block treatment. They found found the condyle to be in a more forward position after 8 months of twin-block treatment[44].

Arici *et al*., conducted a computed tomography study to test the hypothesis that fixed functional appliances brings changes in the condylar position in glenoid fossa and results of this study concluded that the forsusnitinol flat-spring appliance significantly repositioned the condyle posteriorly in the glenoid fossa in the pubertal growth period [41].

Aras *et al*., reported drastic change in an articular disc position and showed a tendency to position disc progressively in relation to the condyle. The mri revealed that the condyle-fossa relationship remains unaffected by the forsus fatigue resistant device treatment. This might be because of appositional growth at condyle and glenoid fossa. However, there was no clear evidence of remodelling at the condyle and the glenoid fossa [43].

Nishanth b, gopinath a, ahmed s at al conducted a cephalometric and computed tomography study to evaluation of dentoalveolar/soft-tissue change and alteration in condyle-glenoid fossa relationship using the powerscopethay concluded that there is no significant change in con and gf changes with powerscope appliance [37].

Conclusion

This clinical prospective study was done to compare changes in condylar position between forsusappliance and powerscope appliance in treatment of class ii malocclusion using cone beam computed tomography.

From the results of the present study, it can be concluded that.

1. An average forward shift of mandibular condyle by. 85 mm was seen after 7- 9 months treatment in forsus appliances therapy and. 79 mm after powerscope therapy indicating that the forward mandibular condylar shift is greater in forsusgroup than the powerscope group.
2. Although both the forsus and powerscope groups showed a downward shift of mandibular condyle, there was a greater downward shift in forsusgroup (2.69 mm) compared to the powerscope group (2.29 mm), indicating a greater downward shift of mandibular condyle in forsus therapy.
3. Overall the forsus appliance shows more downward and forward shift of mandibular condyle compared to powerscope appliance with a mean difference of 0.060 mm and 0.420 mm respectively.

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