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# Change in morphology of condyle, glenoid fossa and articular eminence after myofunctional appliance therapy – A retrospective study

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## Abstract

The goal of dentofacial orthopaedics is to maximize the potential of growth and guide the growing face and developing dentition towards the pattern of optimal development.

In the treatment of patients with Class II malocclusion with mandibular retrognathia, different removable (Activator, Bionator, Twin-Block, etc) or fixed (Herbst, Jasper Jumper, Forsus, Twin-Force, etc) functional appliances have been used to encourage or redirect the growth of mandible to correct skeletal discrepancy.

In orthodontics, comparison of pre-treatment and post treatment data is important to assess treatment results. Cephalometric superimpositions have been used frequently for this purpose. To assess the morphological changes in the glenoid fossa, mandibular condyle and the articular eminence in response to myofunctional appliance. The purpose of the study is to correlate the changes in the glenoid fossa, articular eminence and the mandibular condyle.

**Keywords:** Mandibular condyle, articular eminence, Glenoid fossa, Myofunctional appliance, Radiographic study, Morphology, Twin block, Activator, Temporomandibular joint, Growth and development

## Introduction

Orthodontists are interested in Class II malocclusions since they account for 51% of all malocclusions (23 percent in children, 15 percent in youth and 13 percent in adults). Class II malocclusions can result from many contributing components, both dental and skeletal. Although both maxillary protrusion and mandibular retrusion have been identified as potential causes, it has been observed that mandibular retrusion is the most prevalent component in a Class II sample group.1 The optimal method of treatment for Class II patients with retrognathic mandibles is to target the mandible and try to change the quantity or direction of growth in the mandible. Functional appliance therapy is the most common treatment for this condition.[2]

Functional appliances, also known as myofunctional appliances, are utilised in growth modification treatments to intercept and cure jaw discrepancies that are mediated by the orofacial muscle. The idea that a new pattern of function dictated by the appliance leads to the formation of a matching new morphologic pattern is the theoretical foundation of functional therapy in general. The success of a functional appliance treatment is determined on case selection, diagnosis, and appliance selection.[3]

Functional appliances have been utilised to stimulate or redirect the growth of the mandible to rectify skeletal discrepancies in individuals with Class II malocclusion and mandibular retrognathism.[4]

The purpose of dentofacial orthopaedics is to optimise growth potential and steer the developing face and teeth toward an ideal development pattern.[5]

Functional appliances were not often used in orthodontics until the 1970s. This was partly due to ground-breaking animal experiments that showed that protruding the jaw forward might cause bone abnormalities. The hypothesis that soft tissue stretching might enhance bone formation appeared to be validated in the early investigations. As a result, there remained debate until the 1970s about the effectiveness of functional appliances in correcting Class II malocclusions.[6]

Because of the various variations in quantifying treatment outcome factors, it's currently impossible to get solid answers about appliance efficacy from the research. Some researchers use the Condylion (Co) as the posterior end point for determining total mandibular length, while others use the articulare (Ar). Furthermore, treatment durations and follow-up periods differ.[2]

In orthodontics, comparison of pre- treatment and post-treatment data is important to assess treatment results. Cephalometric super impositions have been used frequently for this purpose. Whereas we use examination of OPGs in our current study.

The three-dimensional position connection between the condyle, glenoid fossa, and articular eminence is represented by TMJ components. It is an articular triad with two points of contact provided by the TMJ and a third point of contact provided by the dentition. The TMJ is formed by the mandibular condyle fitting into the mandibular fossa of the temporal bone and is separated by the articular disc, which is a third non-ossified bone. It is well recognised that skeletal components have the capacity to remodel during life, which is an important consideration when establishing a direct link between a patient receiving myofunctional appliance therapy and his or her environment.[7]

The purpose of our study is to compare the changes in the glenoid fossa, articular eminence and the mandibular condyle before and after the functional appliance treatment using OPGs.

**Materials and method**

1. 0.35mm Lead pencil.

2. Matt acetate cephalometric tracing sheets. 3. X ray view box.

4. Pre-treatment and Post- functional panoramic radiographs of 30 patients.

5. Specially designed template with an inscribed millimetre scale at the angles of 30°,60°, 90°, 120°, 150° and 180° respectively. (fig.6).


Fig 1: Armentarium used for the study

Fig 2: X-ray View box

This is a retrospective study carried out in the department of Orthodontics and Dentofacial Orthopaedics.

The available records of the patients were used for the study. This study consisted of panoramic radiographs of 30 patients of 9 to 16 years old individuals and who had undergone myofunctional appliance therapy.

**Inclusion criteria**

1. Patients undergone myofunctional appliance therapy.

**Exclusion criteria**

1. Unacceptable quality radiographs.
2. History of orthodontic intervention.

Panoramic radiographs of 30 patients undergone myofunctional appliance treatment were selected from the archives of the Department of Orthodontics according to inclusion criteria. After the selection, all the panoramic radiographs were traced manually using a 0.35mm lead pencil on acetate tracing paper using the x-ray view box. Skeletal landmarks required for the evaluation of panoramic radiographs are located which are mentioned below;

**Landmarks**

1. Condylion (Co): Most superior point on head of mandibular condyle
2. Coronoid point (Cor): Most superior point on coronoid process
3. Sigmoid notch point (Snp): Deepest point on sigmoid/ mandibular notch
4. Gonion (Go): Most posteroinferior point at the angle of mandible
5. Ante onion (Ag): Highest point of the notch or concavity of the lower border of the ramus where it joins the body of the mandible
6. Orbitale (Or): Lowest point on bony orbit
7. Anterior nasal spine (ANS): Tip of bony anterior nasal spine

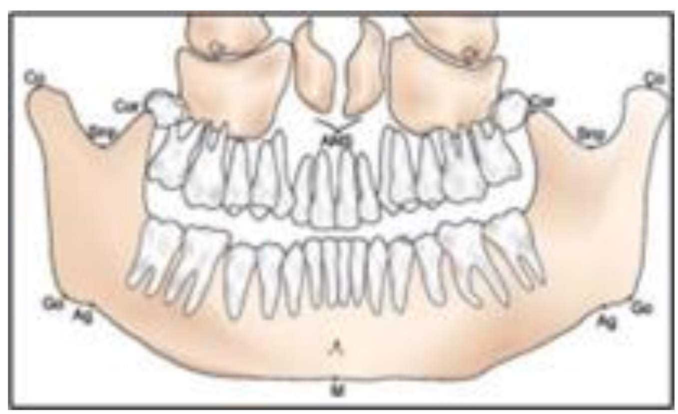


Fig 3: OPG Tracing and landmarks to be marked.

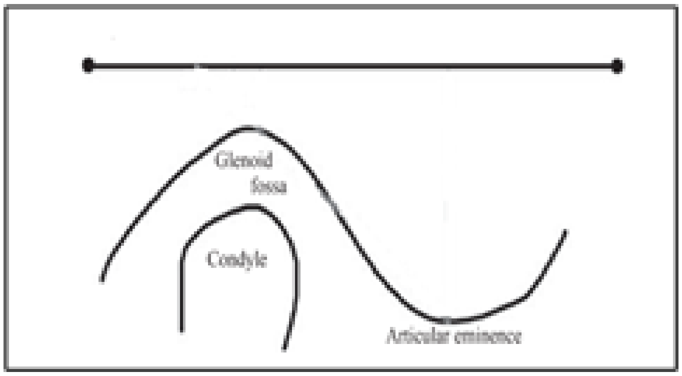



Fig 4: Condyle, Glenoid fossa & Articular eminence position on the OPG

The two orbitale (Or) points were joined on the panoramic radiographs by passing a line through it. The glenoid fossa, the condyle and the articular eminence were traced on the radiographs respectively (fig. 4).

Parameters which were studied are constructed and measured as follows

**Centre of the condyle**

- Two tangents were constructed to the condyle in the vertical plane parallel to each other (Line 1 and 2).
- An imaginary line (neck line) was constructed at the neck of the condyle perpendicular to the tangents (Line 3).
- A line was constructed (Head of the condyle line) parallel to this imaginary line and passing through the highest point on the condyle forming a rectangle (Line 4).
- Diagonals were constructed to this rectangle to construct the centre which will be considered as the centre of the condyle.

**Measuring procedure**

Using the centre of the condyle; the template was kept over the tracing such that the 0 coincides with the centre of the condyle. And the horizontal reference line on the scale was kept parallel to the imaginary line which was constructed at the neck of the condyle. The millimetre markings on the scale were than used to measure the condyle and the glenoid fossa at 30°,60°, 90°, 120°, 150° and 180° respectively. The millimetre markings on the scale were also used to measure the distance of articular eminence.

1. The measurements obtained, were than systematically filled in the table (Annexure). These measurements obtained were than calculated to their mean values of condyle, glenoid fossa and articular eminence respectively (Table no. 1,2,3).
2. All obtained data was statistically analysed.

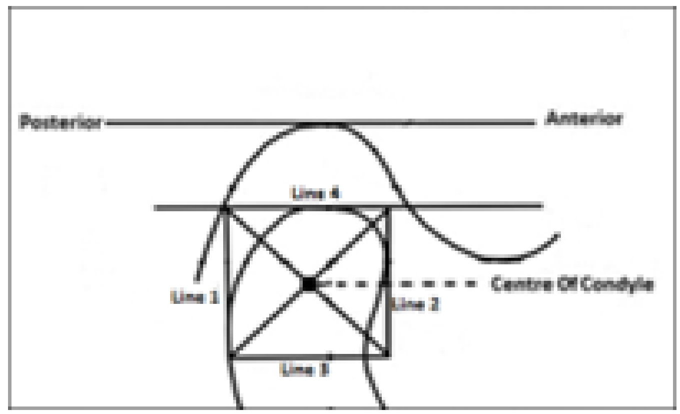



Fig 5: Schematic representation of location of centre of condyle

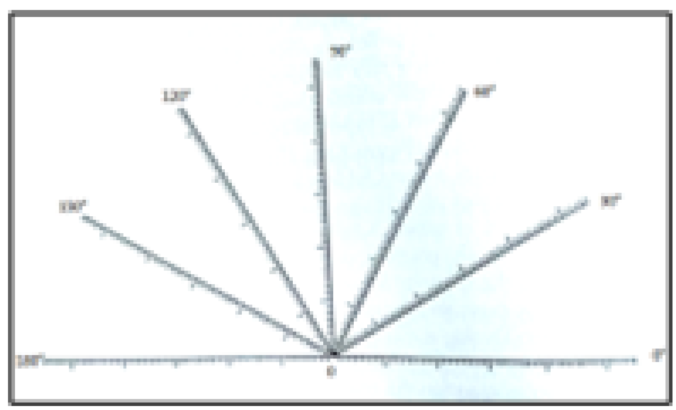


Fig 6: Specially designed scale used for measuring in mm.

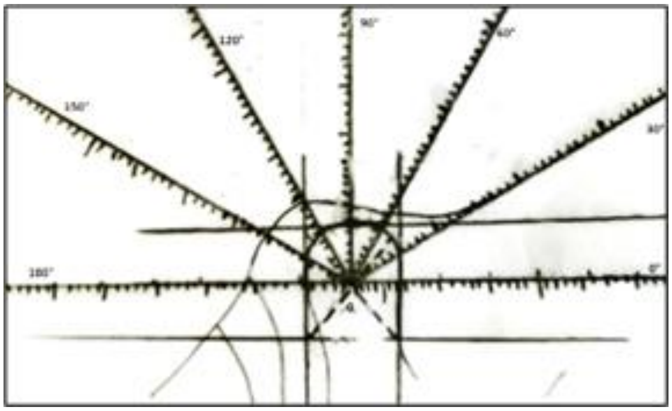



Fig 7: Representation of measuring the condyle, glenoid fossa and articular eminence using the centre of the condyle and the specially designed scale

**Results**

The present study was carried out to evaluate change in morphology of condyle, glenoid fossa and articular eminence after myofunctional appliance therapy. To perform this study panoramic radiograph of 30 patients undergone myofunctional appliance therapy were selected from the records. This study was performed by measuring the values obtained from the pre-treatment and post-functional analysis of condyle, glenoid fossa and the articular eminence respectively.

All the condylar, glenoid fossa and the articular eminence values were measured as follows

1. Pre-treatment and post-functional condyle and glenoid fossa were measured in millimetres using the template at 30°, 60°, 90°, 120°,150° and 180° respectively (Annexure).
2. Pre-treatment and post-functional articular eminence were measured in millimetres using the template (Annexure).
3. A mean value for all the condyle and the glenoid fossa were measured at 30°, 60°, 90°, 120°, and 180° respectively (Tables no. 1, 2).
4. A mean value for the articular eminence was measured (Table no. 3).
5. Standard deviation, mean difference and the standard deviation of difference were calculated. Paired t test was performed for the t value and the p value (Table no. 4).

**Statistical procedures**

All data were measured manually and then entered into a computer by giving coding system, proofed for entry errors

- Data obtained was compiled on a MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States).
- Data was subjected to statistical analysis using Statistical package for social sciences (SPSS v 26.0, IBM).
- Descriptive statistics like Mean & SD for numerical data has been depicted.

✓ Intra group comparison was done using paired t test (up to 2 observations)

For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power to the study as 80%.

* = statistically significant difference ($p<0.05$)

** = statistically highly significant difference ($p<0.01$)

# = non-significant difference ($p>0.05$) … for all tables

[a] since SD is 0, comparisons could not be made (Table no.4)

There was a statistically highly significant difference seen for the values between the time intervals ($p<0.01$) for: (Table no.4)

Post functional readings of CV 90 showed statistically higher significant difference. Post functional readings of CV 150 showed statistically higher significant difference. Post functional readings of CV 180 showed statistically higher significant difference. Post functional readings of GFV 90 showed statistically higher significant difference. Post functional readings of GFV 90 showed statistically higher significant difference.

Post functional readings of GFV 180 showed statistically higher significant difference.

There was a statistically non-significant difference seen for the values between the time intervals (p>0.05) for AEV, CV 30, GFV 60 & GFV 120 (Table no. 4)

Post functional readings of AEV showed statistically non-significant difference. Post functional readings of CV 30 showed statistically non-significant difference. Post functional readings of GFV 60 showed statistically non-significant difference. Post functional readings of GFV 120 showed statistically non-significant difference.

**Tables**

| Comparison of Pre and Post functional condylar mean values in millimetres | | |
|---|---|---|
| Value | Pre treatment | Post functional |
| CV 30 | 6 | 5.93 |
| CV 60 | 7 | 6 |
| CV 90 | 6.83 | 7.73 |
| CV 120 | 6.67 | 7.93 |
| CV 150 | 6.53 | 7.43 |
| CV 180 | 5.73 | 6.47 |

Table 1: Mean values of the Condyle.

| Comparison of Pre and Post functional Glenoid fossa mean values in millimetres | | |
|---|---|---|
| Value | Pre treatment | Post functional |
| GFV 30 | 8.5 | 8.77 |
| GFV 60 | 10.97 | 10.97 |
| GFV 90 | 11.27 | 12.2 |
| GFV 120 | 8.5 | 8.77 |
| GFV 150 | 14.77 | 12 |
| GFV 180 | 16 | 14.1 |

Table 2: Mean values of the Glenoid fossa.

| Comparison of Pre and Post functional Articular eminence mean values in millimetres | | |
|---|---|---|
| Value | Pre treatment | Post functional |
| AEV | 11.07 | 11.07 |

Table 3: Mean values of the articular eminence.

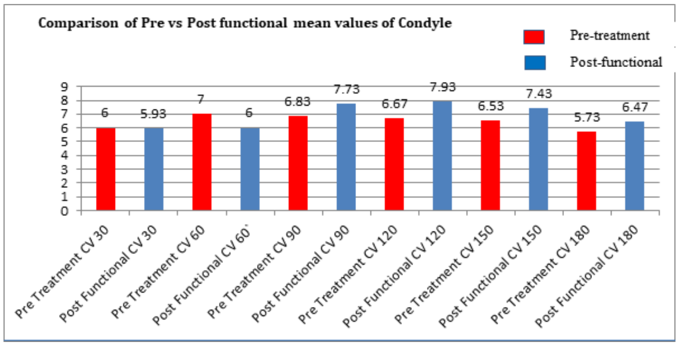
| | Mean | Std. Deviation | Std. Error Mean | Mean diff | SD of diff | T value | p value of paired t test |
|---|---|---|---|---|---|---|---|
| Pre-Treatment AEV | 11.07 | 1.081 | .197 | .000 | .371 | .000 | 1.000# |
| Post Treatment AEV | 11.07 | 1.015 | .185 | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Pre-Treatment CV 30 | 6.00 | .000 | .000 | .067 | .254 | 1.439 | .161# |
| Post Treatment CV 30 | 5.93 | .254 | .046 | | | | |
| Pre-Treatment CV 60 | 7.00[a] | .000 | .000 | --- | --- | --- | --- |
| Post Treatment CV 60 | 6.00[a] | .000 | .000 | | | | |
| Pre-Treatment CV 90 | 6.83 | .379 | .069 | -.900 | .607 | -8.115 | .000** |
| Post Treatment CV 90 | 7.73 | .583 | .106 | | | | |
| Pre-Treatment CV 120 | 6.67 | .479 | .088 | -1.267 | .583 | -11.894 | .000** |
| Post Treatment CV 120 | 7.93 | .450 | .082 | | | | |
| Pre-Treatment CV 150 | 6.53 | .507 | .093 | -.900 | .712 | -6.924 | .000** |
| Post Treatment CV 150 | 7.43 | .504 | .092 | | | | |
| Pre-Treatment CV 180 | 5.73 | .450 | .082 | -.733 | .740 | -5.430 | .000* |
| Post Treatment CV 180 | 6.47 | .571 | .104 | | | | |
| Pre-Treatment GFV 30 | 8.50 | .682 | .125 | .267 | .828 | 1.765 | .088# |
| Post Treatment GFV30 | 8.77 | .935 | . .171 | | | | |
| Pre-Treatment GFV 60 | 10.97 | .718 | .131 | .000 | .695 | .000 | 1.000# |
| Post Treatment GFV60 | 10.97 | .669 | .122 | | | | |
| Pre-Treatment GFV 90 | 11.27 | .907 | .166 | .933 | .868 | 5.887 | .000** |
| Post Treatment GFV90 | 12.20 | .887 | .162 | | | | |
| Pre-Treatment GFV120 | 8.50 | .682 | .125 | .267 | .828 | 1.765 | .088# |
| Post Treatment GFV 120 | 8.77 | .935 | .171 | | | | |
| Pre-Treatment GFV 150 | 14.77 | 1.073 | .196 | -2.767 | 1.165 | -13.006 | .000** |
| Post Treatment GFV 150 | 12.00 | .788 | .144 | | | | |
| Pre-Treatment GFV 180 | 16.00 | 1.050 | .192 | -1.900 | .803 | -12.960 | .000** |
| Post Treatment GFV 180 | 14.10 | .960 | .175 | | | | |

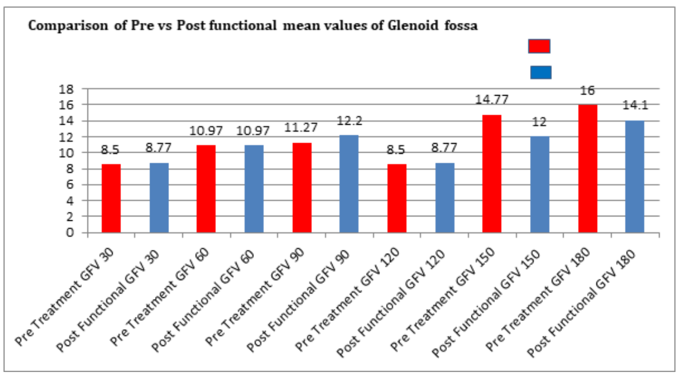
Table 4: Comparison of Pre vs Post values (T value and P value)

## Graphs

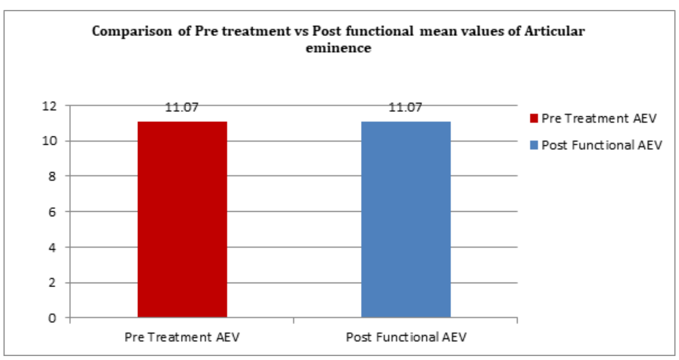
Graph 1: Mean values of the Condyle.




Graph 2: Mean values of the Glenoid fossa.




Graph 3: Mean values of the Articular Eminence.




## Discussion

The goal of dentofacial orthopaedics is to maximize the potential of growth and guide the growing face and developing dentition towards the pattern of optimal development[5]. The efficacy of functional appliances no longer needs to be proved. Researchers like Vahedi far M [36] claim the main effect of functional appliance therapy is increased condylar growth while other researchers such as Bhattacharya P [5] have contended that the main effect is remodelling of the glenoid fossa.

Comparison of pre- treatment and post- treatment data is important to assess treatment results. Cephalometric superimpositions have been used frequently for this purpose, whereas we have used examination of OPGs in our current study. This was a retrospective study in which pre and post functional therapy panoramic radiographs of 30 patients of 9 to 16 years old individuals, who had undergone myofunctional appliance therapy were studied and compared.

Here in our study the findings were as follows

### Condyle

According to the results growth in posterior and superior direction of the condyle was seen. The post functional readings of condyle showed growth/deposition of 0.9mm, 0.9mm and 0.7mm at 90°, 150° and 180° respectively. This resulted in forward and downward growth of the mandible.

According to Louis J. Baume's (1961) [37] study in macaca mulatta, Stephen William's (1982) [38] implant study to evaluate condylar development during activator treatment and Bus Chang et AL's (1998) [17] cephalometric study showed similar type of results as our study in which mandible is displaced in anterio-inferior direction because of cartilaginous deposition on posterior superior aspect of the condyle.

### Glenoid fossa

According to the results growth is seen in posterior and superior region of the glenoid fossa. Post functional readings showed deposition / growth of 0.9 mm, 2.7mm and 1.9mm at 90°, 150° and 180° respectively. Relative to the cranial base reference structures, the fossa was displaced anteriorly and inferiorly which lead to secondary displacement of mandible anteriorly and inferiorly.

D. G. Woodside et al (1987)[15] and Bhattacharya P et al. (2013) [5], on continuous and progressive mandibular protrusion which is similar to results as our study, showed. They studied the influence of functional appliance therapy on glenoid fossa remodelling and evaluated the glenoid fossa response to myofunctional treatment in skeletally retruded mandibular cases respectively. They also observed the displacement of the fossa anteriorly and inferiorly resulting from the forward and downward rotation of the mandible.

Bishara (1989) [1] also found the similar type of changes in the glenoid fossa after continuous anterior repositioning of the condyle in his animal experimental study. He observed all the experimental animals, including, most importantly, the mature adult, a large volume of new bone had formed in the glenoid fossa. With this bone formation and the resorption along the posterior border of the post glenoid spine, the glenoid fossa appeared to be remodeling anteriorly.[5]

Tuominen M, Kantomaa (1996) [39] found a contraindicating result of the study with increased upward displacement of the glenoid fossa on mandibular growth. It showed extensive anterior remodelling of the glenoid fossa and further it contributes toward Class II correction. The observation of the study was that the growth of the cartilage pushes the mandible downwards.

**Articular eminence**

Post functional readings in our study for articular eminence showed no significant difference.

Contradicting to our study, change in the morphology was seen in the studies performed by Elias G. Katsavrias (2003) [22] and Buschang et al (1998) [17] which showed the effect of activator appliance on the articular eminence. Articular eminence showed significantly more posterior and less superior growth than the condyle.

Robert Hinton (1981)[40] studied the changes in articular eminence morphology with dental function. The data from his study provided evidence that the temporomandibular joint (TMJ) undergoes continuous morphological alteration throughout adult life and that these alterations are probably mediated by dental function.

Lawther ('56) compared the x-ray contours of temporomandibular joints in two groups of male adults. The individuals who were edentulous for three years or more showed a decrease in slope of the articular tubercle and a decrease in height of the mandibular fossa when compared to similar aged individuals having good dentitions. Unpublished measurements by McCabe and Moffett on archaic Indian skulls show that in temporomandibular joints with clear-cut arthritic changes, the posterior slope of the tubercle forms a smaller angle with the Frankfurt plane than that seen on the opposite normal joint in the same specimen or in comparable skulls with both joints normal. The same kind of regressive remodeling can be demonstrated roentgenologic ally on the articular tubercle if one follows the continuing arthritic changes in a patient. Various types of evidence are available which indicate that joint contours do undergo regressive changes.[41] This shows that change in dentition can result in regressive changes in the temporomandibular joints.

As our study is conducted on growing patients the eruption of teeth in the mixed dentition period can result in change in the morphology of the temporomandibular joints.

The studies above showed changes in the morphology of the articular eminence. Whereas, it is contradicting to the results obtained in our study. Probably due to poor resolution of older x-rays used in the study could not have shown the changes in the articular eminence. Some better investigation methods like MRI and CT scans would have shown changes in the articular eminence.

**Mode of action of functional appliance**

The temporomandibular joints (TMJ) is a complex articular system which is located between the mandible and the temporal bone. The articular eminence forms the anterior limit of the glenoid fossa and is a part of the temporal bone on which the condylar process slides during mandibular movements. The temporomandibular joint consists of articulations between three surfaces; the glenoid fossa and articular tubercle (from the squamous part of the temporal bone), and the head of mandible that is the condyle (fig: 8).

Articular disc - The articular disc is a fibrous extension of the capsule that runs between the two articular surfaces of the temporomandibular joint. The disc articulates with the mandibular fossa of the temporal bone above and the condyle of the mandible below. The disc divides the joint into two sections, each with its own synovial membrane. The disc is also attached to the condyle medially and laterally by the collateral ligaments. The anterior disc attaches to the joint capsule and the superior head of the lateral pterygoid. The posterior portion attaches to the mandibular fossa and is referred to as the retro discal tissue.[42]

The capsule is a fibrous membrane that surrounds the joint and attaches to the articular eminence, the articular disc and the neck of the mandibular condyle (fig. 9).

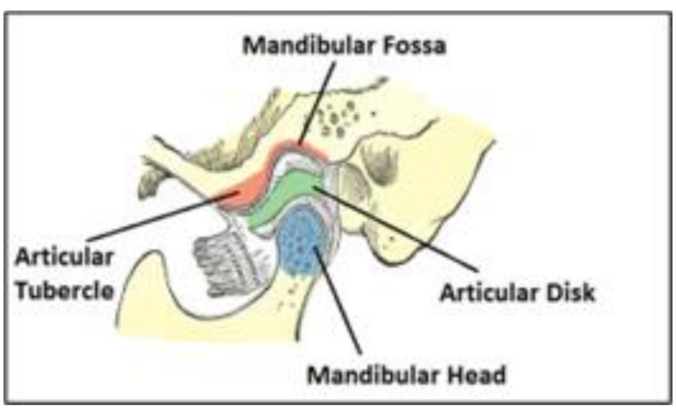



Fig 8: Anatomy of the TMJ [42]

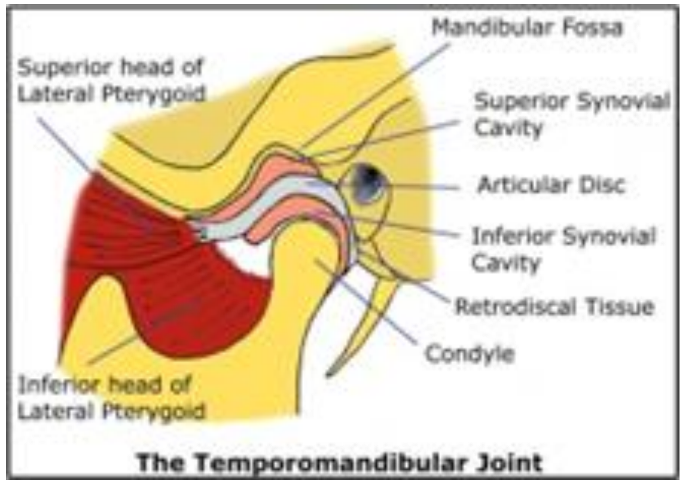



Fig 9: The Temporomandibular Joint [42]

Our study showed growth in the posterior and superior direction of the condyle and posterior aspect and the roof of the glenoid fossa. Similarly, according to John Voudouris [20] the glenoid fossa promotes condylar growth with the use of orthopedic mandibular advancement therapy. Initially, that displacement affects the fibro cartilaginous lining in the glenoid fossa to induce bone formation locally. The glenoid fossa and the displaced condyle are both influenced by the articular disk, fibrous capsule, and synovium, which are contiguous, anatomically and functionally, with the viscoelastic tissues (fig.10). Therefore, condylar growth is affected by viscoelastic tissue forces via attachment of the fibrocartilage that blankets the head of the condyle.[20]

Three-dimensional perspective illustrates the growth relativity hypothesis in the orthopedically advanced condyle. The posterior, anterior, and lateral attachments of the retrodiskal-articular disk complex are shown (fig.11). The condyle may be guided upward and backward by these and other attachments. The retrodiskal-articular disk complex is pulled in the opposite direction of the arrows for glenoid fossa modification. The altered dynamics of the clear, viscous synovial fluid that perfuses posteriorly in the small lower TMJ chamber may facilitate growth beneath the hydrophilic condylar fibrocartilage. This is followed by the stretch of non-muscular viscoelastic tissues. Third and the most interesting aspect is the new bone formation some distance from the actual retrodiskal tissue attachments in the fossa (fig.12). In the upper chamber, the opposing anterior flow of synovial fluids may similarly influence GF growth.[20] In our study, we observe the downward and forward repositioning of the mandible which resulted in viscoelastic tissue forces on the head of the condyle and the glenoid fossa. This further resulted in condylar and glenoid fossa growth. The effective TMJ changes can be attributed to remodeling and repositioning of the glenoid fossa and/or to condylar position changes within the fossa. [15]

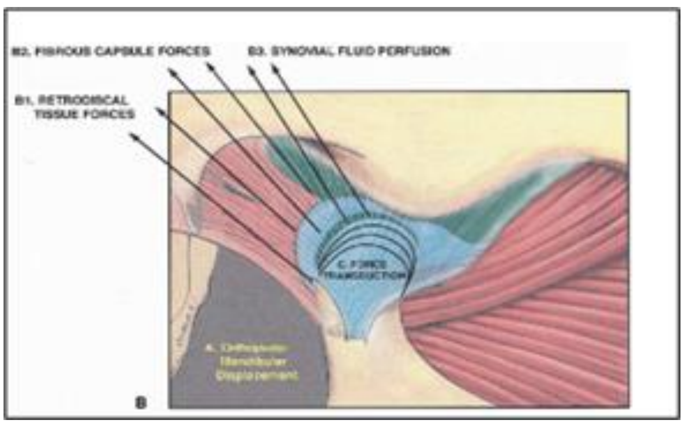



Fig 10: Growth relativity hypothesis for condylar and glenoid fossa growth with continuous orthopaedic displacement.[20]

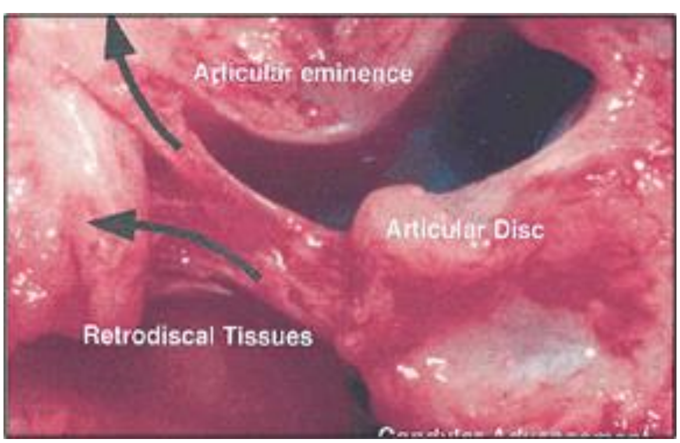



Fig 11: The growth relativity hypothesis in the orthopedically advanced condyle.[20]

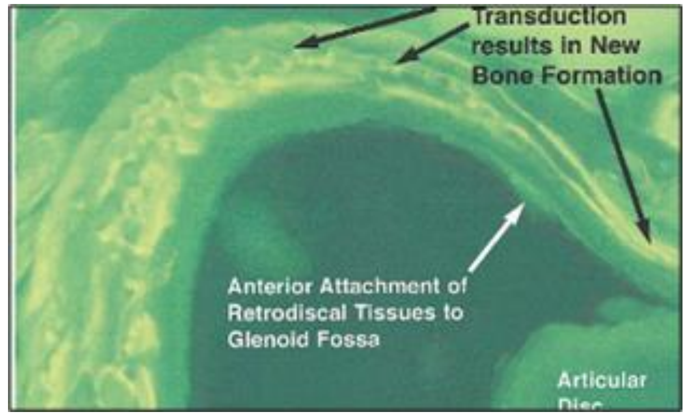



Fig 12: Transduction: photomicrograph of under calcified parasagittal section of the glenoid fossa where the condyle was orthopedically advanced for 12-weeks.[2]

**Limitation of the study**

1. Further research with a large sample size is warranted for establishing more significant values of all the parameters measured under this study.
2. The Millimeter scale used is a large unit of measurement.
3. Study using other methods like MRI and CT scan can give more precise readings and less human errors.

**Clinical significance**

The present study has uncovered the contribution in the relocation of glenoid fossa, condyle and articular eminence in functional correction of Class II malocclusion.

There was strong correlation between anterior displacement of the glenoid fossa and sagittal repositioning of mandible.

This study will also help in differentiating the skeletal and the dento - alveolar changes.

**Conclusion**

The present study concludes that

1. Favourable effective changes in the TMJ were observed post myofunctional appliance therapy.
2. There were significant changes seen in the morphology of the condyle and the glenoid fossa.

3. The anterior mandibular positioning contributes to the glenoid fossa remodelling.

4. There were no to minimum changes seen in the morphology of the articular eminence.

**List of Abbreviations**

| Abbreviation | Full forms |
|---|---|
| Mm | Millimetre |
| SD | Standard Deviation |
| Fig | Figure |
| No | Number |
| N,n | Sample |
| GF | Glenoid Fossa |
| Co | Condyle |
| AE | Articular eminence |
| Cov | Condylar value |
| Gfv | Glenoid fossa value |
| AEV | Articular eminence value |
| TMJ | Temporomandibular joint |
| OPG | Orthopantomagram |

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