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# Effects of Fixed Functional Appliance Therapy on Temporomanibular Joint Assessed by MRI: A Literature Review

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## 1. Introduction

Class II malocclusion is one of the most common skeletal or dental deformities, affecting approximately one-third of the patients seeking orthodontic treatment[1-3]. The etiology of Class II malocclusion could be credited to numerous factors; maxillary protrusion, mandibular retrusion, or both, together with abnormal dental relationships and soft tissue profile discrepancy, hence, a precise diagnosis is important for the selection of the appropriate treatment plan. Mandibular retrognathism is considered most prevalent among all these factors[4]. Functional appliances have been used for more than a hundred years for the correction of mandibular retrognathism preferably during active skeletal growth[5]. There is a wide range of removable and fixed functional appliances which are intended to modify the arrangement of the muscle groups that affect the function and position of the mandible in order to transmit forces to the dentition and the basal bone. These muscular forces are generated by varying the mandibular position which results in orthodontic and orthopedic changes[6].

Emil Herbst in 1909, designed a removable splint with inclined plane aimed at moving the mandible forward[7]. Patients often did not comply with the use of removable appliances making the success of the treatment depends on their compliance. Thus, Herbst developed a fixed appliance to permanently move the mandible forward, regardless of the patient's compliance. After 1930, the Herbst appliance was rarely used and was rediscovered by Pancherz in 1979[8]. Since then many different fixed functional appliances (FFA) have been developed for the correction of Class II malocclusion. The effects of FFA on dentofacial structures have been adequately validated by cephalometric studies[9,10]. However, there is limited knowledge about the consequences of fixed functional therapy on the temporomandibular joints (TMJ). It is believed that FFA leads to adaptive changes in the glenoid fossa and causes growth modulation of the condylar cartilage. Following are the adaptive processes by which the TMJs of adolescents and young adults may respond to the treatment[11,12]

1. Condylar remodeling
2. Glenoid fossa remodeling
3. Alterations in the position of condyle within the fossa
4. Change in articular disc position

Some studies have found the functional therapy to be detrimental to the TMJ[13-15] whereas more recent studies and reviews have a different opinion[16-18]. But the observations of these studies have been limited to the bony changes in the sagittal view.

Many methods have been used in the literature to evaluate the TMJ tissues. Although magnetic resonance imaging (MRI) is a sensitive and valid tool to analyze the morphology of TMJ articular disc, joint effusions, and synovitis. The multiplanar imaging of both the soft and hard tissues of the TMJ has been made possible by the introduction of MRI. This technique is non-invasive, radiation-free and gives a more superior contrast resolution than any other imaging modality[19,20]. It is considered as the imaging modality of choice for the diagnosis of internal derangement of TMJ[21].

With this review article, an attempt has been made to thoroughly investigate the effects of the fixed functional appliance therapy on the TMJ using MRI as the diagnostic tool.

**Temporomandibular Disc Position**

Pancherz [22] analyzed possible changes in the relative position of the mandibular articular disc to the condyle during different phases of Herbst appliance treatment. For the assessment of the disc position, he calculated a disc position index:

(a:b) X 100

Cm: Midpoint of the mandibular condylar head (assessed by visual inspection)

Tm: Midpoint of the tuberculum articulare (assessed by visual inspection)

Da: Anterior point of the articular disc

Dp: Posterior point of the articular disc

Dm: Midpoint of the articular disc (the midpoint of the line Da-Dp)

a: Position of the articular disc defined by the distance Dm (on the line Da-Dp) to the line Cm -Tm

b: Half the length of the articular disc, defined by the distance (Da-Dp):2

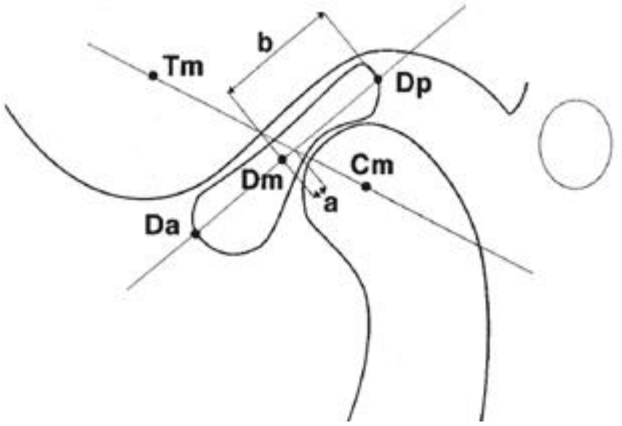


**Figure 1:** Reference points and linear variables used for the assessment of the mandubular articular disk position in the closed mouth MRI

The index describes the position of the articular disc in relation to the mandibular condyle and the temporal articular eminence. In a centreddisc position, the midpoint of the disc (Dm) is on the line Cm-Tm; the distance 'a' is zero (0). In a protrusive disc position, Dm is in front of the line Cm-Tm; the distance 'a' is positive (+). In a retrusive disc position, Dm is behind the line Cm-Tm; the distance 'a' is negative (-).

At the start of Herbst treatment, the mandible was advanced to an incisal edge to edge position and kept there by the telescoping mechanism. The condyles were displaced out of the glenoid fossa and positioned on the top of the articular eminence. After treatment, the condyles of the subjects had, on average, returned to their original fossa position. This was a result of adaptive dental and skeletal changes: posterior movement of the upper dentition and anterior movement of the lower dentition, stimulation of sagittal condylar growth, and remodeling of the glenoid fossa.
Because of the physiologic relative movement of disc and condyle on mandibular protrusion, the disc attained a pronounced retrusive position. At the end of treatment, the disc had almost returned to its original pre-treatment position. In conclusion, the author stated that Herbst treatment did not result in any adverse changes in the articular disc position. On the contrary, the Herbst appliance could possibly be useful in the therapy of patients with anterior disc displacement.
Most previous MRI studies analyzing sagittal disc position were based on visual descriptive methods. According to several authors, the posterior band of the disc should normally be in a "12 o'clock" position. The disadvantage with the "12 o'clock" method is, however, that the inclination of the articular slope is not considered, which can lead to a misinterpretation of the disc position. Several metric methods for the analysis of sagittal disc position exist. The present method used by Panherz[22] is based on that of Bumann et al[23] and Vargas Pereira[24].

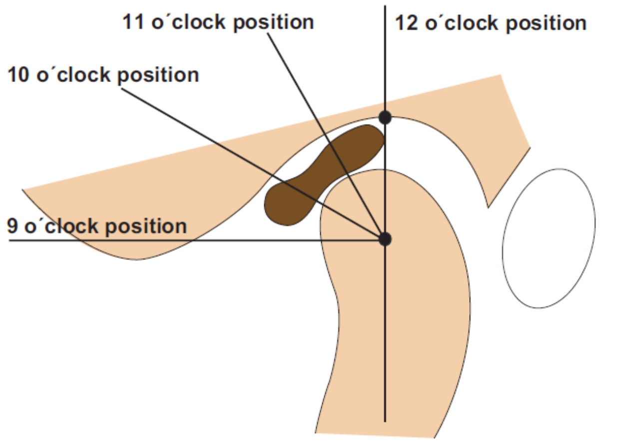


**Figure 2:** The physiological position of the articular disc (black) in relation to the mandibular condyle; mouth closed, posterior band sagittally- located between the 11 o'clock and 12 o'clock positions

Pancherz et al.[25] conducted a study to determine whether bite-jumping causes temporomandibular disorders (TMD). The function of the TMJ was assessed anamnestically, clinically, and using MRI taken before, after, and 1 year after Herbst treatment. To determine the articular disc position they used the 12'0 clock criteria.

**12 o'clock criterion:** The MRIs were evaluated visually using the "12 o'clock criterion." The disc position was considered normal if the thickest part of the posterior band was situated between the 11 and 1 o'clock positions. Discs with the thickest part of the posterior band located anterior or posterior to this position were considered displaced.

**Posterior band criterion:** The position of the posterior band (PB) was measured using the method described by Drace and Enzmann[26]. The normal range for the ''Drace and Enzmann angle'' as described by Silverstein et al,[27] is 18.78 to 225.78 (Ideal value 5 23.58). A positive value indicates an anterior disc position, whereas a negative value indicates a posterior disc position.

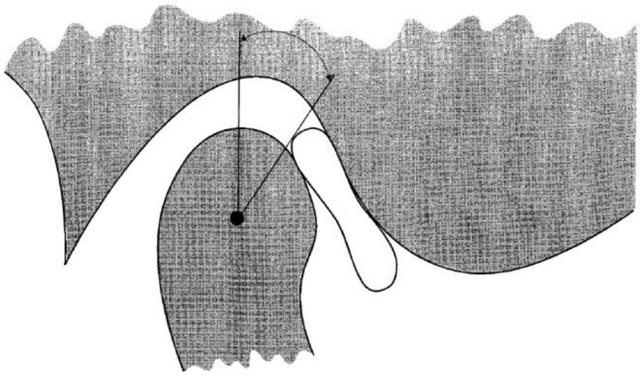

**Figure 3:** Posterior band (PB) criterion. Measurement of the angle (degrees) between the 12 o'clock position and the posterior band of the articular disc.

**Intermediate zone criterion:** The location of the intermediate zone (IZ) was measured using the method described by Bumann et al.[23] The normal range for the IZ location as described by Vargas-Pereira[24] is 1.7 to 21.1 mm (Ideal value 5 0.3 mm). A positive value indicates an anterior disc position, whereas a negative value indicates a posterior disc position.

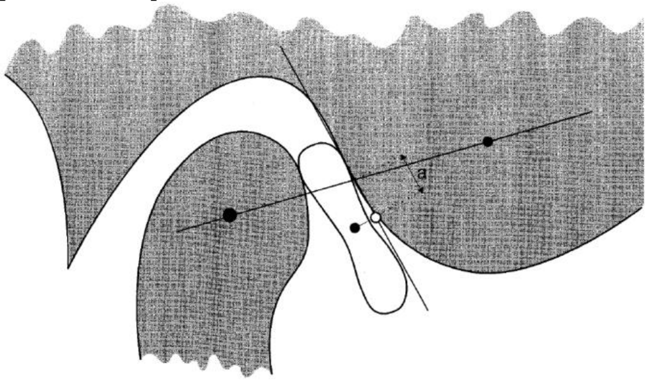


**Figure 4:** Intermediate zone (IZ) criterion. Measurement of the distance (mm) between the midpoint of the articular disc and a line connecting the midpoint of the condyle and the tuberculum articulare. The distance ‘‘a’’ was measured after perpendicular projection of the midpoint of the disc to a tangent on the articular eminence.

The largest changes in disc position were seen during the period from before to immediately after treatment. The disc position changes seemed to be the result of the anterior condylar position immediately after treatment, which is known to be associated with a more posterior position of the disc relative to the condyle. However, the disc position changes tended to revert during the post-treatment period from immediately after treatment to 1 year after treatment. Over the entire observation period, the disc position was, on anaverage, unchanged for the complete sample.

They concluded that Herbst appliance treatment placed the articular disc in a normal functional position even when it was initially anteriorly displaced. The treatment results in a stable repositioning of the disc in the subjects with partial disc displacement. Total disc displacement does not seem to be a contraindication for Herbst treatment, as signs and symptoms of TMD in these patients partially subsided during treatment.

But it was not clear whether the disc position index was a reliable tool to quantify disc displacement, especially with the significant variation in disc morphology between subjects.

Ruf and Pancherz [22,25]evaluated the disc position through three assessment tools that were not proven to be valid or reliable. The sagittal position of the articular disc in the closed mouth position was assessed by 3 different approaches, 2 of them describing the posterior band location by using 12’O clock & posterior band criteria, and the third evaluating the intermediate zone location of the disc in relation to the condyle. The disc was categorized to have ‘displacement tendency’ if indicated by one tool only and ‘completely displaced’ if indicated by two assessment tools. There was a lack of agreement between the tools resulting in variations in categorizing disc position. The disc position was found to ‘vary largely in different image slices and at different times of examination’. The disc position was found to vary significantly between the patients at all examination times.The largest changes in disc position, both for the whole sample and within the disc position groups, were seen during the period from before to immediately after treatment.The disc position changes seemed to be the result of the anterior condylar position immediately after treatment, which is known to be associated with a more posterior position of the disc relative to the condyle.

Kinzinger et al.[28] conducted a study to assess the changes in the disc- condyle relation following fixed mandibular advancer (FMA) & Herbst therapy. He categorized the disc-condyle relation into 5 categories based on the visual examination of the MR images:

1) Physiological disc-condyle relationship (PDCR): Physiological position of the articular disc in closed-mouth and maximum-open positions (three slices from each position).
2) Partial anterior disc displacement with reduction (PADDwR): Articular disc displacement in one or two slices in closed-mouth position and physiological position in all three slices in maximum-open mouth position.
3) Partial anterior disc displacement without reduction (PADDnoR): Articular disc displacement in one or two slices in closed-mouth position with no disc reduction in maximum-open position.
4) Total anterior disc displacement with reduction (TADDwR): Articular disc displacement in all three slices in closed-mouth position and physiological position in all three slices in maximum-open position.
5) Total anterior disc displacement without reduction (TADDnoR): Articular disc displacement in all three slices in closed-mouth position with no disc reduction in maximum-open position.

In this study, the visual examination of the MR images and Manual structural analysis revealed no deterioration in the disc-condyle relationship in any of the joints as a consequence of FMA treatment. Rather, a total of five joints improved: two joints with total anterior disc displacement with reduction initially exhibited only partial disc displacement after FMA removal, and the disc-condyle relationship improved to the physiological condition in three joints initially presenting partial anterior disc displacement with reduction. Metric analysis of the MR images confirmed these results. There is a direct cause-and-effect relationship between the disc position changes observed during treatment and the treatment-induced position changes in the condyle. Appliance insertion resulted in the advancement of the condyles positioned on the articular eminence and concurrent relative disc retrusion. The condyles returned to their original position later during treatment, as did the discs. Disc retrusion decreased, although it tended to persist in all the joints, even after FMA removal.

On the other hand, in joints exhibiting partial or total anterior disc displacement pre-treatment, the extent of disc retrusion was found to have improved considerably from the initial findings: both the position of the intermediate zone and the sagittal position of the posterior band of the articular disc in relation to the mandibular condyle showed improved repositioning of the discs toward dorsal, as compared with the initial findings[29,30].

Aidar et al.[31] evaluated the disc position in 20 adolescents patients who were treated with Herbst appliance, using coronal and parasagittal MRIs at three times. Articular disc position was assessed with a method modified from Orsini et al[32]. A reference line was traced from the center of the condyle to the center of the tuberculum articulare. Another line was traced from the center of the condyle to the DP point (defined below), located in the posterior band of the articular disc. The articular disc position was determined by the angular measurement that resulted from both lines in closed mouth (CM) and Open mouth (OM) positions. A semicircular protractor for use with lenses (SAM [München, Germany]), which magnified the tracings 7 times, was used. The following reference points, lines, and angle were used in CM and OM positions:

1) CC: midpoint found by the placement of the most fitted circle chosen from a circle template (Trident [São Paulo, Brazil]) to the condyle outline. The geometrical center of the condyle was found by the intersection of 2 lines traced in the farthest distance in both horizontal and vertical directions in the circle mentioned above.
2) CT: midpoint found by the placement of the most fitted circle chosen from a circle template (Trident) to the tuberculum articulare outline, the superior limit of which was the floor of the middle cranial fossa. The geometrical center of the tuberculum articulare was found by the intersection of 2 lines traced in the farthest distance in both horizontal and vertical directions in the circle mentioned above.
3) DP: midpoint of the posterior band limit of the articular disc (assessed visually).
4) CC-CT line: line traced from the condyle geometric center (CC) to the tuberculum articulare geometric center (CT).
5) CC-DP line: line traced from the condyle geometric center (CC) to the DP point.
6) Angular measurement to assess the articular disc position: the angle formed by CC-CT and CC-DP lines.


**Figure 5:** Semicircular protractor for use with lenses (SAM), which magnified tracings 7 times, used to measure articular disc position

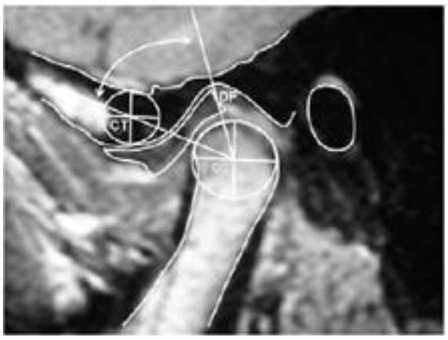


**Figure 6:** Anatomic drawing and tracing used to measure articular disc position in CM position.


**Figure 7:** Anatomic drawing and tracing used to measure articular disc position in OM position.

In agreement with the previous studies, they also concluded that no disc position change occurred in patients treated with a Herbst appliance. However, too many unnecessary variables were considered with a limited sample size to support adequate statistical analyses. In 2009 the authors[33] further complicated the study by introducing more variables for disc position categories and two new categories of disc morphology. In 2010[34], further MR imaging was carried out to evaluate the disc position after full orthodontic treatment was completed. Similar descriptive data was presented, that was not statistically analyzed and resulted in inconclusive results.

### Osseous changes in TMJ

Ruf and Pancherz [35]conducted a study on class II division 1 malocclusion patients treated by Herbst appliance. The authors evaluated high signal intensity changes on MR images due to hydrated subcortical layer as an indicator to the bone remodeling. They founded the increase in MRI signal intensity on the posterosuperior aspect of the condyle at 6 to 12 weeks of treatment that could possibly resemble the histologically proven hyperplasia of the prechondroblastic-chondroblastic area. Signs of ramus remodeling were seen in 7% of the treated individuals during 6-12 weeks of treatment. Fossa remodeling as visualized in 22 of the 28 TMJs of the young adult subjects with the Herbst appliance and in 36 of the 50 investigated TMJs of adolescents occurred at a later treatment stage than condylar remodeling. Fossa remodeling in both skeletal maturity groups was most intensive at the inferior part of the anterior border of the postglenoid spine leading to an anteclination of the spine. It was revealed that effective TMJ changes in both skeletal maturity groups could be significantly increased during the Herbst treatment period of approximately 8 months when compared with a group of untreated individuals with ideal occlusion. Furthermore, the effective TMJ changes were more horizontally (posterior) than vertically (superior) directed.

Pancherz et al.[22,25] assessed the condylar position metrically on the parasagittal MRIs in the closed mouth position employing a method described by Mavreas and Athanasiou[36]. The anterior (ant) and posterior (post) joint spaces were evaluated and a Joint Space Index (JSI) was calculated:

$$\mathrm{JSI} = \frac{\mathrm{post} - \mathrm{ant}}{\mathrm{post} + \mathrm{ant}} \times 100.$$

The physiologic range for the condylar position as described by Vargas-Pereira[37] is an index value of 21.1 to 32.5. A positive value indicates an anterior condylar displacement and a negative value a posterior condylar displacement. They concluded that during active treatment period condylar position was changed anteriorly possibly due to the sagittal occlusal overcompensation during Herbst treatment. During the post-treatment period, condylar position reverted as a result of the settling of the occlusion. Thus in the total observational period, the condylar position was on average unchanged for the whole sample.

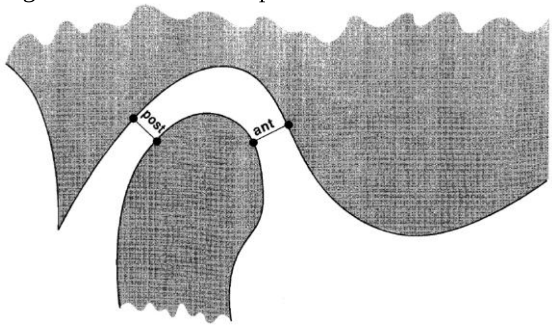


**Figure 8:** Joint Space Index. Assessment of the anterior and posterior joint spaces (mm) as the shortest distances between the condylar head and the articular eminence (ant) and the condylar head and the postglenoid spine (post).

Kizinger et al[28-30] showed that after the insertion of fixed functional orthopedic appliances, the condyles were displaced toward ventral and toward caudal from their position within the fossa. At the end of treatment, the condyles return to their initial, centric fossa relationship. Significant changes in the condyle-fossa relationship from pre-treatment to post-treatment could not be detected. They stated that after completion of the treatment, the condyle-fossa relationship returns to a physiological state in the region of the TMJs. The improved occlusion is not achieved at the price of unphysiological repositioning in the TMJ.

**Condyle Repositioning toward Ventral and Caudal, Total Repositioning**

The displacement in the condyle's sagittal plane within the glenoid fossa was measured individually for ventral and caudal repositioning during treatment. The lines used for reference were the horizontal tangent that is parallel to the upper edge of the image running through the uppermost point of the fossa (the fossa tangent), and a vertical line, at right angles to the latter, running through the most cranial point of the fossa (fossa perpendicular). The first step was determining the absolute distance from the reference lines. The effective repositioning of the condyle as a consequence of treatment could then be computed in a second step. The condyle displacement toward ventral (v) at T1, T2, and T3 during treatment in comparison to baseline findings (time T0) is the result calculated as v = v2 – v1. Analogously, the condyle displacement toward caudal (c) at T1, T2, and T3 during treatment in comparison to baseline findings (time T0) are computed as c = c2 – c1. The total linear displacement (x) at the same points in time during treatment can then be calculated as the result of $x = \sqrt{(v2 + c2)}$.

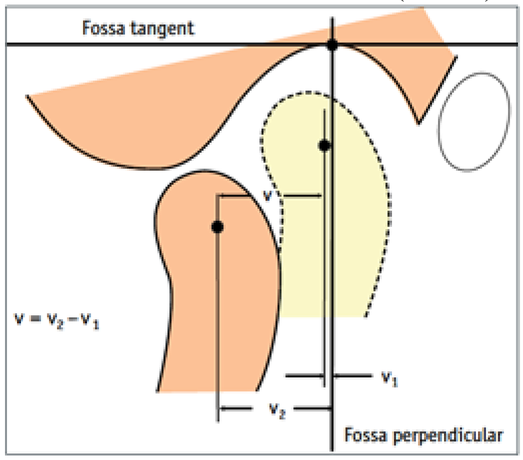


**Figure 9:** Sagittal displacement of the condyle toward ventral (v) in relation to the findings at baseline method according to Kinzinger et al.

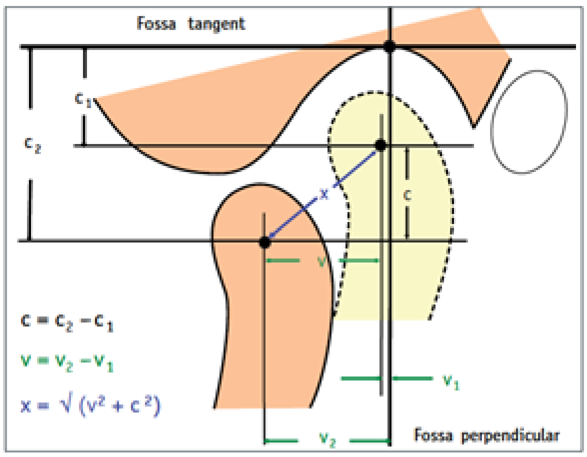


**Figure 10:** Total sagittal displacement of the condyle (x) method according to Kinzinger et al.

## 2. Conclusion

Following this review, it may be concluded that observations after treatment with fixed functional appliances for mandibular advancement have found:

- The condyle in a more advanced position
- Condylar remodeling and adaptation of the morphology of the glenoid fossa.
- No significant adverse events concerning the TMJ have been found in healthy patients
- This treatment can improve joints that initially present forward disc dislocation.

## 3. Limitations of this Review

The scientific evidence collected on changes in the TMJ following the use of fixed functional appliances was not abundant despite a detailed systematic search for articles. Most of the studies included are prospective clinical studies without having a control group for comparison. Additionally, the sample size was small in most of these studies. Further, a lack of randomized control trials and long term follow up have made the results of these studies less reliable.

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