

Effect of Orthodontic Treatment on Temporomandibular Joint. A Review

Mohamed Zahoor Ul Huqh¹, Rozita Hassan¹, Mohammed Irfan Azhar¹, Roselinda Abdul Rahman², Jawaad Ahmed Asif², Asilah Yusof³, Syed Altafuddin Quadri⁴

¹ Dr. Mohamed Zahoor Ul Huqh, PhD (Orthodontics), Orthodontic unit, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian-Malaysia

¹ Dr. Rozita Hassan, Professor, Orthodontic unit, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian-Malaysia

¹ Dr. Mohammed Irfan Azhar, MSc-D (Orthodontics), School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian-Malaysia

² Dr. Roselinda Abdul Rahman, Senior Lecturer, Department of Oral and Maxillofacial surgery, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian-Malaysia

² Dr. Jawaad Ahmed Asif, Senior Lecturer, Department of Oral and Maxillofacial Surgery, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian-Malaysia

³ Dr. Asilah Yusof, Senior Lecturer, Department of Oral biology, School of Dental Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian-Malaysia

⁴ Dr. Syed Altafuddin Quadri, Assistant Professor, Department of Dental Technology, CAOMS, King Khalid University, Abha-Kingdom of Saudi Arabia

Abstract

Introduction:

The morphology of temporomandibular joint varies among individuals and the most important factor that could affect its shape is functional load impacted on it. This depends on the closed association between the morphology and function which demonstrates that presumed differences in condyle-fossa position and morphology among subjects vary with different types of malocclusion. The objective of this literature review is to determine the temporomandibular joint characteristics in response to orthodontic treatment.

Materials and Methods:

A web-based search was carried out using electronic databases such as PubMed, Science Direct and Google scholar between the year 2007 to 2017 with a focus on longitudinal studies, Prospective, Case-control, Retrospective and Randomized Controlled Trials.

Results:

60 studies were searched in which 21 articles have been selected based on inclusion criteria. Among these studies, 2 were randomized controlled trials, 15 were prospective longitudinal studies without randomization and 4 were retrospective studies.

Conclusions:

After a detailed review of the studies found in the latest literature, it has been concluded that association between different types of orthodontic treatment and the development of TMD signs and symptoms could

not be established. There is no evidence for a direct cause-effect relationship between the orthodontic treatment and TMD.

Keywords: Orthodontic treatment, Temporomandibular joint, Magnetic Resonance Imaging, Computed Tomography, Cone Beam Computed Tomography

Introduction

The impact of orthodontic treatment on temporomandibular joint (TMJ) is still a debatable subject. The use of assessments has always been consistent in determining its correlation. This can be illustrated by routine radiographic examinations that were broadly used to examine the effect of orthodontic treatment on the TMJ [1]. However, this method of imaging examination has some limitations since TMJ is one of the complex structures of the human body. It is more crucial to be very well-anticipated radiographically because of the overlapping in a few adjoining hard bony structures [2].

The morphology of temporomandibular joint differs among individuals and the most important factor that could impact its shape is functional load inflicted on it [3]. This depends on closed relationship between morphology and function which substantiates that presumed differences in condyle and mandibular fossa position and morphology among subjects varies with different types of malocclusion. The cause of Temporomandibular disorder (TMD) is multi factorial. Trauma, untreated malocclusions, structural imbalance, stress and other psychological factors have been considered as possible causative factors [4].

It has been reported that variation in facial morphology such as a hyperdivergent profile of the face may alter the TMJ morphology lead to the development of TMD [5, 6].

It has been suggested in few studies that orthodontic treatment raises the risk of development of TMDs [7-9]. Thus, the aim of this review was to analyze the impact of orthodontic treatment on temporomandibular joint characteristics based on scientific evidence.

Materials and Methods

A web-based search was carried out. A total of 60 articles were searched using electronic databases such as PubMed, Science direct and Google scholar. Only published articles from 2007 to 2017 were included. The description used such as orthodontic treatment, Temporomandibular joint (TMJ), Magnetic Resonance Imaging [1], Computed tomography (CT) and Cone Beam Computed Tomography (CBCT) which evaluates the effects of orthodontic treatment on TMJ. The Diagnostics methods used were shown in Fig. 1. The inclusion criteria were; Journal articles which shows longitudinal studies, Prospective, Case-control, Retrospective and Randomized Controlled trials. The study designs used were shown in Fig. 2. The articles which shows studies using electromyography, conventional radiographs and those studies which involves orthognathic surgery, case reports, case series and incomplete orthodontic treatment have been excluded.

Results

A total of 60 studies were searched in which 21 articles have been selected based on inclusion criteria. Among these studies, 2 were randomized controlled trials, 15 were prospective longitudinal studies without randomization and 4 were retrospective studies. The sample articles which were selected depending on methodology is available in Table 1. Among all articles selected

2 were based on Magnetic Resonance Imaging [1], 9 were based on CBCT images, 3 were on CT scan and 4 were based on lateral cephalometric radiographs as shown in (Table 1).

Discussion

The potential relationship between orthodontic treatment and TMD commands great importance in the latest literature. However, despite many studies, the assumption whereby orthodontic treatment might influence the cause of TMDs is still unknown. Here, we have evaluated the role that orthodontic treatment might play in the development of TMDs [30, 31].

It is very much necessary to assess the recent literature in a critical and proper way to determine what level of scientific evidence that the information generates. The application of methodological considerations for research such as sample size determination, randomization, blinding and control of involved elements are essential to qualify the level of evidence generated. And this information must be available for evaluation and discussion for the researcher [2].

MRI and CT are methods with greater diagnostic accuracy compared with conventional radiography, because of higher anatomic resolution. CT is the ideal method for evaluation of bony structures, while MRI allows the study of soft tissues, including articular disc. Both methods often augment the study of abnormalities of the temporomandibular joint (TMJ), thus becoming vital tools in the differential diagnosis of various diseases in TMJ area [32].

A study revealed that the growth due to bone-anchored maxillary protraction and response to orthodontic treatment resulted in bone apposition at the anterior wall of the articular eminence which corresponds to posterior displacement of the anterior condylar region, and bone resorption at the posterior wall of the articular eminence corresponds well with the posterior displacement of the posterior condylar region. This high degree of association between modeling at the posterior and anterior glenoid fossa eminences and the resultant displacement of the opposing surfaces of the condyle suggested that the anteroposterior chin displacement was not due to a positional mandibular shift between pre and post treatment. However, this bone remodeling is due to the combined effect of orthopedic traction and normal growth [19].

Whether mandibular growth is reduced or deflected by using chin-cup has been a matter of debate in previous literature, and the method by which a chin-cup therapy results in development of skeletal Class III malocclusion is still not clear. It is widely accepted that mandibular growth is altered mainly due to condylar growth. However, it has been emphasized that growth of the condyle is not a distinctive feature in craniofacial growth and development. Hence, it would be considered as one of the factor which attribute growth of the mandible only to condylar growth [33, 34]. In chin-cup treatment, an orthopedic force is directed backwards and upwards on the TMJ, with pressure exerted from the chin to the condylar region. Forces that are applied in posterosuperior direction have been pretended to be the contributing factor for development of TMD [34].

However, there are limited studies that have evaluated the impact of facemask on the TMJ, although it has an effect similar to the chin cup. It is well known that facemask exerts force to the maxilla which gets its support from the chin. Almost 75 % of this force is imparted to the TMJ [35, 36].

Modified Jasper Jumper and Delaire type Facemask appliances were used as an alternative to extraoral devices to reduce problems of cooperation in the early treatment of Class III malocclusions with maxillary retrognathism. In this study, no adverse effect on TMJ was reported for either of the appliances [36].

Therefore, from previous retrospective studies it has been suggested that the patients who have been treated earlier does not show any TMD symptoms when compared with untreated individuals [37-40].

Prospective and longitudinal studies also support this opinion that the patients who have taken orthodontic treatment do not have a higher risk of developing TMD later in life [40-44].

In this review various studies have shown different methods used to treat the malocclusions such as class I, Class II and Class III malocclusion which utilized multiple treatment approaches like fixed functional, multiloop edgewise arch wires, facemask, mandibular cervical head gear, herbst, Inter-arch elastics, mini implants and modified reverse twin block appliance wherein the authors did not find any significant differences in the TMJ characteristics. Based on the scientific evidences, it has been revealed that no association exists between the orthodontic treatment and TMD.

Conclusion

After a detailed review of the studies found in the latest literature, we can conclude that

a) Correlation between different types of malocclusions and development of TMD signs and symptoms without any interventions could not be verified.

b) According to the various studies included in this review suggest that, there is no evidence for a direct cause-effect relationship between the orthodontic treatment and TMD.

c) Various therapeutic methods have been implied in treating non ortho-related TMD using different treatment approaches which does not show any significant changes in TMJ morphology.

References

1. Baskaradoss, J.K., et al., Relationship between Caregivers' Oral Health Literacy and their Child's Caries Experience. *Community Dent Health*, 2019. **36**: p. 111-117.
2. Machado, E., R.A. Grehs, and P.A. Cunali, Imaging from temporomandibular joint during orthodontic treatment: a systematic review. *Dental Press J Orthod*, 2011. **16**(3): p. 54-56.
3. Merigue, L.F., et al., Tomographic evaluation of the temporomandibular joint in malocclusion subjects: condylar morphology and position. *Braz Oral Res*, 2016. **30**(1).
4. Mohlin, B., et al., TMD in Relation to Malocclusion and Orthodontic Treatment. A Systematic Review. *The Angle Orthod*, 2007. **77**(3): p. 542-548.
5. Nebbe, B., P.W. Major, and N.G. Prasad, Adolescent female craniofacial morphology associated with advanced bilateral TMJ disc displacement. *Eur J Orthod*, 1998. **20**(6): p. 701-12.
6. Hwang, C.J., S.J. Sung, and S.J. Kim, Lateral cephalometric characteristics of malocclusion patients with temporomandibular joint disorder symptoms. *Am J Orthod Dentofacial Orthop*, 2006. **129**(4): p. 497-503.
7. Hirsch, C., No Increased risk of temporomandibular disorders and bruxism in children and adolescents during orthodontic therapy. *J Orofac Orthop*, 2009. **70**(1): p. 39-50.

8. Mohlin, B.O., et al., Malocclusion and temporomandibular disorder: a comparison of adolescents with moderate to severe dysfunction with those without signs and symptoms of temporomandibular disorder and their further development to 30 years of age. *Angle Orthod*, 2004. **74**(3): p. 319-27.
9. Henrikson, T., M. Nilner, and J. Kurol, Signs of temporomandibular disorders in girls receiving orthodontic treatment. A prospective and longitudinal comparison with untreated Class II malocclusions and normal occlusion subjects. *Eur J Orthod*, 2000. **22**(3): p. 271-81.
10. Paeng, J., et al., Temporomandibular joint fossa difference according to the skeletal malocclusion. *Int J Oral Maxillofac.*, 2017. **46**: p. 362.
11. Lee, H., et al., Three-dimensional changes in the temporomandibular joint after maxillary protraction in children with skeletal class III malocclusion. *J Oral Sci*, 2016. **58**(4): p. 501-508.
12. Alhammadi, M.S., M.S. Fayed, and A. Labib, Three-dimensional assessment of temporomandibular joints in skeletal Class I, Class II, and Class III malocclusions: cone beam computed tomography analysis. *J World Fed Orthod*, 2016. **5**(3): p. 80-86.
13. Al-koshab, M., P. Nambiar, and J. John, Assessment of condyle and glenoid fossa morphology using CBCT in South-East Asians. *PloS one*, 2015. **10**(3): p. e0121682.
14. Coskuner, H.G. and S. Ciger, Three-dimensional assessment of the temporomandibular joint and mandibular dimensions after early correction of the maxillary arch form in patients with Class II division 1 or division 2 malocclusion. *Korean J Orthod*, 2015. **45**(3): p. 121-129.
15. He, S., et al., Camouflage treatment of skeletal Class III malocclusion with multiloop edgewise arch wire and modified Class III elastics by maxillary mini-implant anchorage. *The Angle Orthod*, 2013. **83**(4): p. 630-640.
16. Kim, H.O., et al., Comparison of the condyle-fossa relationship between skeletal class III malocclusion patients with and without asymmetry: a retrospective three-dimensional cone-beam computed tomography study. *Korean J Orthod*, 2013. **43**(5): p. 209-217.
17. Liu, H. and J.-X. Li, Non-surgical treatment of an Angle Class III malocclusion in adults. *Int J Clin Exp Med*, 2013. **6**(9): p. 738-746.
18. Saccucci, M., et al., Condylar volume and condylar area in class I, class II and class III young adult subjects. *Head face Med*, 2012. **8**(1): p. 34.
19. De Clerck, H., et al., Three-dimensional assessment of mandibular and glenoid fossa changes after bone-anchored Class III intermaxillary traction. *Am J Orthod Dentofacial Orthop*, 2012. **142**(1): p. 25-31.
20. Kurt, H., et al., The effects of two methods of Class III malocclusion treatment on temporomandibular disorders. *Eur J Orthod*, 2011. **33**(6): p. 636-641.
21. Aidar, L.A.A., et al., Changes in temporomandibular joint disc position and form following Herbst and fixed orthodontic treatment. *Angle Orthod*, 2010. **80**(5): p. 843-852.
22. El, H. and S. Ciger, Effects of 2 types of facemasks on condylar position. *Am J Orthod Dentofacial Orthop*, 2010. **137**(6): p. 801-808.
23. Rodrigues, A.F., M.R. Fraga, and R.W.F. Vitral, Computed tomography evaluation of the temporomandibular joint in Class II Division 1 and Class III malocclusion patients: condylar symmetry and condyle-fossa relationship. *Am J Orthod Dentofacial Orthop*, 2009. **136**(2): p. 199-206.

24. Krisjane, Z., et al., Three-dimensional evaluation of TMJ parameters in Class II and Class III patients. *Stomatologija*, 2009. **11**(1): p. 32-6.
25. Arici, S., et al., Effects of fixed functional appliance treatment on the temporomandibular joint. *Am J Orthod Dentofacial Orthop*, 2008. **133**(6): p. 809-814.
26. Rey, D., G. Oberti, and T. Baccetti, Evaluation of temporomandibular disorders in Class III patients treated with mandibular cervical headgear and fixed appliances. *Am J Orthod Dentofacial Orthop*, 2008. **133**(3): p. 379-381.
27. Serbesis-Tsarudis, C. and H. Panchez, "Effective" TMJ and chin position changes in Class II treatment: orthodontics versus orthopedics. *Angle Orthod*, 2008. **78**(5): p. 813-818.
28. Sezgin, O.S., P. Celenk, and S. Arici, Mandibular asymmetry in different occlusion patterns: a radiological evaluation. *Angle Orthod*, 2007. **77**(5): p. 803-807.
29. Kinzinger, G., C. Kober, and P. Diedrich, Topography and morphology of the mandibular condyle during fixed functional orthopedic treatment—a magnetic resonance imaging study. *J Orofac Orthop*, 2007. **68**(2): p. 124-147.
30. Egermark, I., G.E. Carlsson, and T. Magnusson, A prospective long-term study of signs and symptoms of temporomandibular disorders in patients who received orthodontic treatment in childhood. *Angle Orthod*, 2005. **75**(4): p. 645-650.
31. Fernández-González, F.J., et al., Influence of orthodontic treatment on temporomandibular disorders. A systematic review. *J Clin Exp Dent*, 2015. **7**(2): p. e320.
32. Garcia, M.d.M., K.F.S. Machado, and M.H. Mascarenhas, Magnetic resonance imaging and computed tomography of the temporomandibular joint: beyond dysfunction. *Radiologia Brasileira*, 2008. **41**(5): p. 337-342.
33. Koski, K., *Cranial growth centers: Facts or fallacies?* *Am J Orthod Dentofacial Orthop*, 1968. **54**(8): p. 566-583.
34. Zurfluh, M.A., et al., Effect of chin-cup treatment on the temporomandibular joint: a systematic review. *Eur J Orthod*, 2015. **37**(3): p. 314-324.
35. Deguchi, T., et al., Clinical evaluation of temporomandibular joint disorders (TMD) in patients treated with chin cup. *Angle Orthod*, 1998. **68**(1): p. 91-4.
36. Kurt, H., et al., The effects of two methods of Class III malocclusion treatment on temporomandibular disorders. *Eur J Orthod*, 2011. **33**(6): p. 636-41.
37. Larsson, E. and A. Rönnerman, Mandibular dysfunction symptoms in orthodontically treated patients ten years after the completion of treatment. *Eur J Orthod*, 1981. **3**(2): p. 89-94.
38. Dahl, B.L., et al., Signs and symptoms of craniomandibular disorders in two groups of 19-year-old individuals, one treated orthodontically and the other not. *Acta Odontol Scand*, 1988. **46**(2): p. 89-93.
39. Kess, K., K. Bakopulos, and E. Witt, TMJ function with and without orthodontic treatment. *Eur J Orthod*, 1991. **13**(3): p. 192-6.
40. Magnusson, T. and A.S. Guimarães, Is orthodontic treatment a risk factor for temporomandibular disorders? *Dental Press J Orthod*, 2012. **17**: p. 97-103.
41. Olsson, M. and B. Lindqvist, Mandibular function before and after orthodontic treatment. *Eur J Orthod*, 1995. **17**(3): p. 205-14.
42. Egermark, I. and B. Thilander, Craniomandibular disorders with special reference to orthodontic treatment: an evaluation from childhood to adulthood. *Am J Orthod Dentofacial Orthop*, 1992. **101**(1): p. 28-34.

43. Egermark, I., T. Magnusson, and G.E. Carlsson, A 20-year follow-up of signs and symptoms of temporomandibular disorders and malocclusions in subjects with and without orthodontic treatment in childhood. *Angle Orthod*, 2003. **73**(2): p. 109-15.
44. Egermark, I., G.E. Carlsson, and T. Magnusson, *A prospective long-term study of signs and symptoms of temporomandibular disorders in patients who received orthodontic treatment in childhood*. *Angle Orthod*, 2005. **75**(4): p. 645-50.

Figure Legends

Fig 1. Diagnostic Methods Used

Fig 2. Study Design

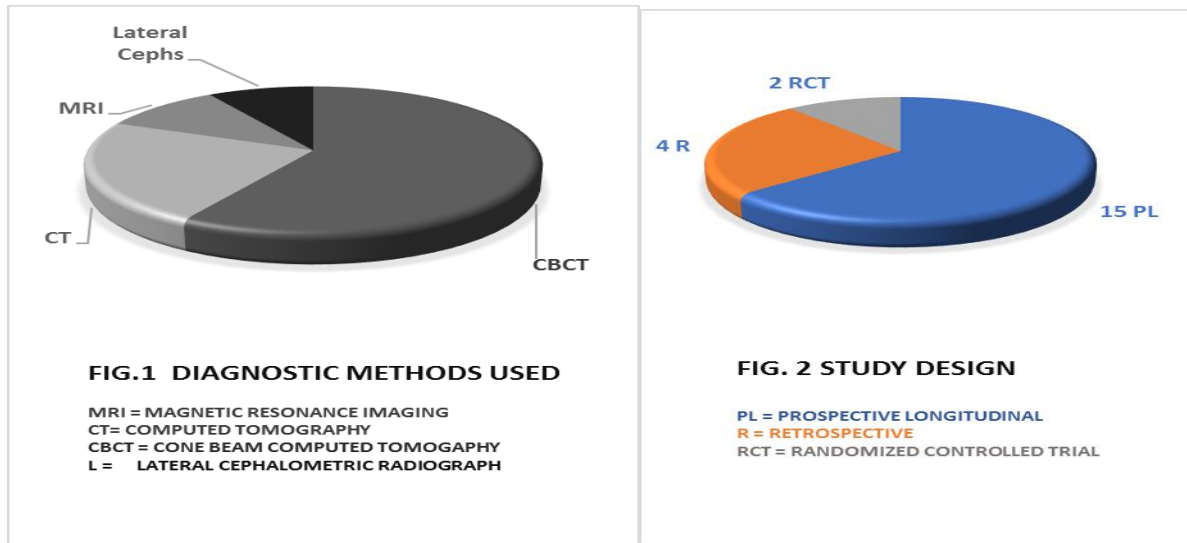


Table 1. Studies based on radiographic methods used for assessment.

No.	Study Title and Authors	Appliance used / class of malocclusion	Study Design	Sample Size and study Population	Clinical / Radiological assessment	TMJ Changes
1.	Temporomandibular joint fossa difference according to the skeletal malocclusion [10]	Class I, Class II and Class III malocclusion.	P	20 Korean subjects in each group.	CBCT	Statistically significant (P < 0.05 Ant. fossa point to post. fossa point distance. External auditory canal wall thickness Height and inclination of articular eminence.
2.	TMJ changes after maxillary protraction in children with class III malocclusion [11]	Facemask	PL	18 Korean subjects	CBCT	Superior and posterior rotation of the condyle.
3.	TMJ evaluation in Class I and Class II malocclusion subjects [3]	Class I and Class II malocclusion	PL	49 Brazilian subjects	CBCT	Prominent convex condylar shape.

4.	Three-dimensional assessment of TMJ is skeletal Class I, Class II and Class III malocclusion [12]	Class I, Class II and Class III malocclusion	PL	60 Egyptian young adult subjects of 18 – 25 years old among which 20- skeletal class I 20- skeletal class II 20- skeletal class III.	CBCT	Class II patients revealed lowest condylar width, highest condylar height and anterior joint space. The condylar position was most inferior. Class III patients revealed lowest superior, anterior and medial joint spaces and the width mandibular fossa and anteroposterior dimension of the condyle was highest. The position of the condyle was most superior.
5.	Assessment of Condyle and glenoid fossa morphology in South East Asians [13]	All types of Malocclusion	PL	100 Malay subjects	CBCT	Higher condylar height, width and volume.
6.	Three-dimensional assessment of the temporomandibular joint and mandibular dimension in patients with Class II division 1 or division 2 malocclusion [14]	Class II division 1 and division 2 malocclusion	PL	28 Turkish Patients Group I- 14 patients Group II- 14 patients	CBCT	No effect on TMJ
7.	Camouflage treatment with multiloop edgewise arch wire appliance and modified class III elastics by maxillary mini implant anchorage [15]	Multiloop Edgewise Arch wire (MAEW Mini-Implants Class III elastics	PL	44 Chinese subjects	Lateral Cephalograms	Increased Mandibular angle
8.	Comparison of the condyle-fossa relationship between skeletal class III malocclusion patients with and without asymmetry [16]	Skeletal Class III malocclusion	R	Group 1 consists of 40 Korean subjects with normal occlusion. Groups 2 and 3 consists of patients with skeletal class III.	CBCT	No significant changes were observed in all the groups except in group 3 which showed steeper axial condylar angle.
9.	Non-surgical treatment of class III malocclusion in adults [17]	Modified fixed reverse twin block appliance	PL	32 Chinese subjects	Lateral Cephalograms	Condylar displacement anteriorly and posteriorly. Retruded position of the mandible.

10.	Condylar volume and condylar area in Class I, Class II and Class III young adult subjects [18]	Class I, class II and Class III malocclusion	R	200 Caucasian patients	CBCT	Condylar Volume and area were higher in Class III group.
11.	Three-dimensional assessment of mandibular and glenoid fossa changes after bone-anchored Class III intermaxillary traction [19]	Class III intermaxillary elastics and bilateral miniplates Class III malocclusion of both skeletal and dental origin.	PL	25 Caucasian patients (13 girls, 12 boys age between 9 and 13 years.	CBCT	Mandible was posteriorly displaced in all subjects (mean of posterior ramus, 2.74 ± 1.36 mm; condylar mean, 2.07 ± 1.16 mm; mean of the chin, -0.13 ± 2.89 mm). Glenoid fossa remodeling takes place at the anterior eminence (mean, was 1.38 ± 1.03 mm) and bone resorption takes place at the posterior wall (mean was, -1.34 ± 0.6 mm) in most of the patients.
12.	The effects of two methods of Class III malocclusion treatment on temporomandibular disorders [20]	Class III malocclusion	RCT	46 Turkish patients	Lateral Cephalograms	No statistically significant differences
13.	Changes in temporomandibular joint disc position and form following Herbst and fixed orthodontic treatment [21]	Herbst and Fixed Class II division I and Mandibular retrognathism	PL	32 Brazilian adolescent subjects- 16 boys and 16 girls with Mean age: 12.8 ± 1.2 years	MRI	42 Joints showed superior disc position and in T2 the disc tend towards retruded position with regard to the condyle while closing the mouth. In open mouth position the disc was, in between the articular eminence.
14.	Effects of two types of Facemasks on Condylar Position [22]	Delaire and Grummons Protraction Facemasks	PL	34 Turkish Patients treated with protraction facemask. Divided into two groups: Group I- 18 patients treated with Delaire facemask. Group II- 16 treated with Grummons facemask.	Lateral Cephalograms	Downward and forward movement from centric relation to maximum intercuspal position for both condyles at the start of treatment for most patients. After the treatment, difference between centric relation and maximum intercuspation was decreased in the group I than in the group II.

15.	CT evaluation of TMJ in Class II div I patients and Class III malocclusion [23]	Class I malocclusion	P	30 Italian patients	CT scan	Higher Post. articular space in both right and left sides.
16.	Three-dimensional evaluation of TMJ parameters in Class II and Class III patients [24]	Class II and Class III Malocclusion	PL	15 European subjects with skeletal Class II their mean age was 18.0 years. 14 patients with skeletal Class III with the mean age of 19.2 years.	CT Scan	length of the processus condylaris was increased in Class III cases.
17.	Effects of fixed functional appliance treatment on TMJ [25]	Fixed Functional appliance- Forsus nitinol flat spring class II div I with Mandibular retrusion.	RCT	60 Turkish patients in which 30 patients randomly selected treated with appliance. 30 patients in control group. Mean age- 12 years 7 months.	CT Scan	Significant differences ($P < 0.05$) ^c were observed in anterior and Posterior joint spaces. Condyles were more backwardly placed in the study group.
18.	Evaluation of TMD in Class III patients treated with Mandibular Cervical Headgear and Fixed appliances [26]	Mandibular Cervical Headgear and Fixed appliances	PL	75 Italian subjects	Lateral Cephalograms	No Statistically significant.
19.	“Effective” TMJ and Chin Position Changes in Class II Treatment [27]	Tip edge Multibracket with Class II elastics. Herbst appliance	R	64 German patients Group 1 - 24 patients Group 2 – 40 patients	Lateral cephalograms	Favorable TMJ and chin position changes with Herbst
20.	Mandibular Asymmetry in Different Occlusion Patterns [28]	Class I, Class II Div1, Class II Div2, Class III malocclusion and Normal occlusion.	R	189 Turkish patients Group 1 (Class I- 39 Group 2 (class II/1)-43 Group 3 (class II/2)-39 Group 4 (Class III)- 42 Group 5 (Control)- 26	Lateral Cephalograms	Higher condylar asymmetry in class II/1 group.
21.	Topography and Morphology of the Mandibular Condyle during Fixed	Fixed Functional appliance	PL	20 German Patients	MRI	No adverse effect

	Functional Orthopedic Treatment [29]					
--	--------------------------------------	--	--	--	--	--

P=Prospective, PL= prospective longitudinal, RCT= Randomized Controlled Trial, R=Retrospective, MRI=Magnetic Resonance Imaging, CBCT= Cone Beam Computed Tomography, CT= Computed Tomography, L= Lateral