THREE-DIMENSIONAL EVALUATION OF CONDYLAR VOLUME AND MANDIBULAR LENGTH FOLLOWING TREATMENT WITH SKELETALLY VERSUS DENTALLY ANCHORED HERBST APPLIANCE

Ahmed Abdel-Salam Mohamed *, Mohamed Helmy Saleh**, Al-Dany Atwa Mohammed***

ABSTRACT

Objective: The Objective of this study was to compare the condylar volume and mandibular length changes of skeletally versus dentally anchored Herbst appliance in the treatment of Class II division 1 patients due to mandibular deficiency. Subjects and Methods: The current study was conducted on 17 female patients with their age ranged between 14 and 20 years. All patients were treated by Type IV Herbst appliance. The active group (Group A) comprising 10 patients at whose the Herbst was anchored to the mandible directly by two reconstruction plates located bilaterally in the mandible between the canine and first premolar, while attached to the maxilla through dental splints utilizing orthodontic bands. The control group (Group B) comprising 7 patients, their CBCT data were taken from a previous study at which the Herbst appliance was anchored with custom made vitalium splints for both the maxillary and mandibular dental arches. The condylar volume and the 3D effective mandibular length was measured using Dolphin software. Results: Condylar volume showed no statically significant change with treatment in both groups, while the 3D effective mandibular length showed statistically significant increase with treatment in both groups. Conclusions: Skeletally anchored Herbst has same mandibular skeletal effect when compared with dentally anchored Herbst.

Keywords: Reconstruction plates; Fixed functional appliance; Herbst; Class II; Condyle.

INTRODUCTION

Skeletal Class II malocclusion is one of the most common orthodontic problems, the treatment of skeletal Class II malocclusion can be carried out through three different time intervals. The first is an early treatment before the pubertal growth spurt through changing the growth direction and stimulate a more mandibular growth through the use of functional appliances like activator and bi-onator. The second intervention would be during the maximum growth spurt through harnessing the spurt time to produce a more favorable skeletal and dentoalveolar effect through the use of functional appliances either removable or fixed(1). Once growth had ceased, the third and last possible intervention takes place. The treatment in such stage takes place through orthognathic surgery, camouflage treatment or promoting the remaining growth through the usage of Fixed Functional Appliances (FFA)(2-4).

Fixed functional appliances are aiming to stimulate mandibular growth by forward posturing of the mandible to correct the Skeletal Class II antero-posterior discrepancy(5), Herbst appliance a rigid type of FFA used for treating such malocclusion, commonly called a “bite-jumping” appliance.
Some studies indicate that orthodontic treatment (including the use of functional appliances) might be detrimental to the temporomandibular joint (TMJ), but more recent studies and reviews have shown that this is not the case. Nonetheless, there still seems to be some confusion about the long-term effects of the Herbst appliance on the TMJ. Because the Herbst appliance might affect the glenoid fossa, the condyle.

Mini screws have been used with the FFA, and although there was incremental enhancement in the skeletal effect by using them with the rigid type of FFA (e.g., Herbst appliance), however, the effect was still purely dentoalveolar when it came to semi-rigid FFA (e.g., Forsus FRD), never to say that the success rate of these mini screws in the mandible is very low when compared with the maxilla which means a more complication and inconsistency in the clinical results.

To overcome these limitations, mini plates anchored Forsus FRD were introduced, it showed high success rate in achieving a more skeletal effect, and although Herbst appliance is categorized as the best FFA with more stable skeletal and dentoalveolar effect, however, mini plates anchored Herbst had never been evaluated before.

The hypothesis tested was that the condylar volume and mandibular length changes following Herbst appliance with skeletal anchorage and dental anchorage significantly different in favor for the skeletally anchored Herbst group.

**SUBJECTS AND METHODS**

The current study was conducted on 17 female patients with their age ranged between 14 and 20 years. The active group (Group A) comprising 10 patients were selected from patients seeking orthodontic treatment at the Outpatient clinic, Department of Orthodontic, Faculty of Dental Medicine, Al-Azhar University, Cairo (Boys), while the control group (Group B) comprising 7 patients, their CBCT data were taken from a previous study that had been undertaken at the same department.

The criteria of selection includes (1) Skeletal and dental Class II malocclusion due to mandibular retrusion (SNA = 82±4, ANB ≥ 5°); (2) Overjet ≥ 5.0 mm; (2) Normal or low FMA angle; (3) All permanent dentition was erupted, excluding the third molars; (4) Growth had been ceased as confirmed by Hand-wrist radiograph (patients were at the maturity stage “MP3-I”).

Cone Beam Computed Tomographic scans (CBCT) (Planmeca ProMax® 3D Mid imaging unit, Ø200 x 170 mm, USA) were obtained before treatment and immediately after removal of Herbst appliance.

All patients in the current study were treated by Type IV Herbst appliance (Herbst IV set, Dentaurom GmbH &Co.KG, Germany), which can be compared to an artificial joint working between maxilla and mandible. The appliance consists of a bilateral telescope mechanism attached to upper and lower jaws keeping the mandible in an anterior jumped position.

**Treatment Steps in group A**

The Herbst appliance was anchored by two reconstruction plates located bilaterally in the mandible between the canine and first premolar, while attached to the maxilla through dental splints utilizing orthodontic bands, (Fig.1).

The reconstruction plates (Universal mandible fracture plates 2.3mm, 4 holes, Stryker, USA) were bended using a 3-jaw contouring and bending plier to be adapted to a 3-D printed model that printed with 3D printer machine (Anycubic Chiron 3D Printer, China) after extracted from the patient CBCT, on the predetermined location between mandibular canine and 1st premolar bilaterally, this step had allowed proper placement and adaption on bone surface during surgery and reduces surgical procedure overall time, (Fig.2).
Surgical placement of reconstruction plates was performed under local anesthesia, after performing an envelope flap extending apically to the chin level to allow unstrained placement of the reconstruction plate, (Fig.3).

Maxillary dental splint fabricated by selection of proper size readymade bands for the maxillary first premolars, first and second molars, while canine bands were custom made specifically for each patient because no readymade canine bands were available in the market, then palatal connecting wire and laser-welding the bands to the palatal wires was performed at the laboratory.

The mandible was advanced to an incisal edge-to-edge position in one step advancement, however, in two patients, because of the large overjet, the edge to edge position seemed to be traumatic, therefore two steps advancement about 5 mm each was undertaken using suitable spacers.

**Periodic recall**

Patients were recalled one day following appliance insertion then every two weeks, to check for the followings:

- Mucosal irritation.
- Oral hygiene monitoring.
- Reconstruction plate’s looseness.
- Easy sliding of the telescopic rods inside the tubes.
- Correct position of the C-clasp.
- Any signs of TMJ upset.

**Appliance removal**

The appliances were removed after nine months, the reconstruction plates were removed with a second surgery.

Completion of orthodontic treatment for each patient was performed with fixed appliance to reach firm and functioning stable occlusion.

**Treatment Steps in group B**

The anchorage option was to fabricate cobalt chromium (CrCo) metallic splints instead of using bands, the splints covered the premolars and 1st molars with palatal plate touching the palatal surface of the incisors. In the mandibular arch, the splints covered the canines, premolars and 1st
molars with lingula plate touching the lingual surface of the incisors.

The bite of the patient was registered in anterior jumped edge to edge position with special attention to the coincidence of the midlines.

The bases of the Herbst appliance were soldered at the 1st molar in the maxillary arch and at the canine in the lower arch to the corresponding splints, (Fig. 4).

**Study measurements:**

**3D measurement of the effective mandibular length**

Since the effective mandibular length is a determining measurement in the present study, this measurement was taken from Condylon point to point B (Co-B). Since the Co point can’t be easily determined on the constructed lateral cephalometric radiograph, 3D assessment for the effective mandibular length on the CBCT for both the right and left sides had been made.

**Condylar volume measurement**

The pre-treatment right condyle was separated first, the condyle was separated inferiorly by cutting along a line parallel to Frankfort horizontal plane at the level of the deepest point on sigmoid notch, using the clipping (making part of the skull volumes temporary disappear from the screen to expose the underlying structure) and cutting (marking and surrounding part of the skull volume to permanently remove it) feature of the software, leaving an isolated condyle.

Condylar volume was calculated using the software. The same steps are repeated for the left condyle. Condylar volume was calculated for all patients in both groups at T1 (before Herbst placement) and T2 (after Herbst removal).

**Glenoid fossa volume**

The glenoid fossa wasn’t captured in the CBCT data of group B, so this analysis is confined to pre and post Herbst treatment at group A only. Using the clipping and cutting feature again, the glenoid fossa was separated from the condyle and the rest of the skull. Glenoid fossa was then isolated together with minimal associated structures that can’t be removed due to anatomical limitations. The pre and post glenoid fossa volume was then calculated using the software.

**Statistical analysis**

To determine the intra-examiner error of measurements, second set of measurements were performed on the records of 4 patients from group A (40% of the sample), 3 patients from group B (42% of the sample) and compared to the first measurements taken from the total sample using interclass correlation test. The statistical results have demonstrated very high correlation between 1st and 2nd measurement.

The statistical data were checked for normality by using Shapiro-Wilk and d’Agostino-Pearson tests. All data were normally distributed; accordingly, parametric tests were used for statistical analyses.

**RESULTS**

Paired sample t-test has been performed between the pre and post treatment measurements to determine the statistical significance of the treatment effect of either skeletally or dentally anchored Herbst appliance, (Fig. 5 & 6). Condylar volume showed no statically significant change with treat-
ment in group A and group B (p = 0.176, 0.637 respectively), while 3-D effective mandibular length showed about 3mm increase with treatment which was a statistically highly significant in group A (p = 0.000) and a statistically significant 4 mm increase in group B (p=0.001). While the fossa volume (measured in group A only) showed a statistically significant increase with treatment (p = 0.013)

Independent sample t-test has been performed for the mean difference in the treatment changes between the two groups, Condylar volume and 3-D effective mandibular length showed no statistically significant difference between the two groups with (P= 0.0753 and 0.120 respectively).

DISCUSSION

Fixed functional appliances are aiming to stimulate mandibular growth by forward posturing of the mandible to correct the Skeletal Class II antero-posterior discrepancy (5,20). Although there is always a controversy regarding the effectiveness of these appliances in stimulating the mandibular growth after its cessation, many studies have demonstrated successful corrections of skeletal class II in adolescent patients through the use of FFA (21).

Although there was an incremental enhancement in the skeletal effect by using miniscrews with the rigid type of FFA (e.g. Herbst appliance), the effect was still more dentoalveolar when it came to semi rigid FFA (e.g. Forsus FRD) (11).

Later on, mini plates have been used with Forsus FRD (22,23), it showed high success rate in achieving a more skeletal effect when compared with miniscrews.

Although Herbst appliance was categorized as the best FFA with more stable skeletal and dentoalveolar effect (14), miniplates anchored Herbst had never been evaluated before.

Therefore, the aim of this study was to investigate the condylar volume changes with correlation to the changes at in the actual length of the mandible which had been measured utilizing the effective mandibular lengthen.

In this study, cone beam computed tomography (CBCT), which is a 3-dimensional (3D) tool, was utilized in an attempt to overcome the limitations of the traditional 2-dimesional projections as it can generate a 3D dentofacial reconstruction images of right and left side of the patient’s condyle which provide accuracy in assessing volumetric changes in each condyle separately with a relatively adequate resolutions and low dose of radiation.

In addition, an effective mandibular length was measured for right and left side separately from
the 3D CBCT as this measure was a critical and important in the assessment of the actual effect of treatment.

Unfortunately, the 3D volumetric analysis of the changes occurring in the mandibular condyle in response to Herbst treatment hasn’t been evaluated previously, therefore, no investigations are available for direct comparison, instead, the results of the present work were compared to MRI investigations\(^{(24-26)}\).

The results of the present study have indicated that condylar volume did increase with treatment in each group, however the amount of increase didn’t reach a statistically significant level \((p = 0.176095 \text{ in group A, } p = 0.637323 \text{ in group B})\). Consequently, no significant difference has been found on comparing the condylar volumetric changes between the two study groups \((p = 0.0753)\). On the other hand, the fossa volume showed a statistically significant increase with treatment in group A \((p = 0.013973)\). Unfortunately, the fossa volume couldn’t be assessed in group B due to limitation in the field of view in the retrospective CBCT data of this group.

Previous MRI studies\(^{\text{(16,25)}}\) have demonstrated that fixed functional orthodontic appliances in patients with Class 2 malocclusion cause remodeling of the mandibular condyle and glenoid fossa, repositioning the mandibular condyle within the fossa, associated with autorotation of the mandible. According to these studies, although these remodeling changes did occur, however, MRI lack the option to calculate the quantity or the quality of these changes.

MRI showed that real remodeling at the glenoid fossa contributed to the correction, while condyle fossa relationship remains insignificant. Anyway, their results did agree with the results of the current work regarding the fact that there had been a change, its amount had been clarified by volumetric analysis done in the present study.

The 3D effective mandibular length in this study showed a statistically significant increases in both groups \((2.9 \text{ mm in group A and } 4 \text{ mm in group B) } \) \((p=0.00000043,\ p=0.001 \text{ Respectively})\), which is concomitant with the results of previous studies that showed an increase in effective mandibular length ranged from 1 mm to 4 mm using dentally anchored Herbst appliances and conventional cephalometric evaluations\(^{(19,22,27-29)}\). Comparing the changes in effective mandibular length between the two study groups didn’t yield any significant difference \((p=0.120)\).

**CONCLUSION**

From the results of the present study, it could be concluded that Skeletally anchored Herbst has same skeletal effect regarding the condylar volume and lengthening the mandible when compared with dentally anchored Herbst which reject the initial hypothesis and as long as the lower incisors are in favorable angulation, the dentally anchored Herbst is considered a logical choice.

**REFERENCES**

1. Heinrichs D, Shammaa I, Martin C, Razmus T, Gunel E, Ngan P. Treatment effects of a fixed intermaxillary device to correct class II malocclusions in growing patients. Prog in Orthod 2014;15:45-57.
2. Panigrahi P, Vineeth V. Biomechanical effects of fixed functional appliance on craniofacial structures. Angle Orthod. 2009;79:668–75
3. Janson G, Sathler R, Fernandes TMF, Branco NCC, De Freitas MR. Correction of Class II malocclusion with Class II elastics: A systematic review. Am J Orthod Dentofacial Orthop. 2013;143:383–92.
4. Proffit WR, Philips C, Tulloch J, Medland P. Surgical versus orthodontic correction of skeletal Class II malocclusion in adolescents: Effects and indications. Int J Adult Orthod and Orthognathic Surg. 1992;7:209–20.
5. McNamara JA Jr BW. Orthodontics and dentofacial orthopedics. In: Orthodontics and dentofacial orthopedics. Needham Press, 2001
6. Popowich K, Nebbe B, Major P. Effect of Herbst treatment on temporomandibular joint morphology: A systematic literature review. Am J Orthod Dentofacial Orthop 2003;123:388-94.
7. Manni A, Mutinelli S, Pasini M, Mazzotta L, Cozzani. Herbst appliance anchored to miniscrews with 2 types of ligation: Effectiveness in skeletal Class II treatment. Am J Orthod Dentofacial Orthop 2016;149:871-80.

8. Upadhyay M, Yadav S, Nagaraj K, Uribe F, Nanda R. Mini-implants vs fixed functional appliances for treatment of young adult Class II female patients (A prospective clinical trial). Angle Orthod 2012;82:294–303.

9. Celikoglu M, Unal T, Bayram M, Candirli C. Treatment of a skeletal Class II malocclusion using fixed functional appliance with miniplaque anchorage. Eur J Dent 2014;8: 276–280.

10. Luzzi C, Luzi V, Melsen B. Mini-implants and the efficiency of Herbst treatment: a preliminary study. Prog in Orthod 2013;14:21-27.

11. Manni A, Pasini M, Mazzotta L, Mutinelli S, Nuzzo C, Grassi FR. Comparison between an Acrylic Splint Herbst and an Acrylic Splint Miniscrew-Herbst for Mandibular Incisors Proclination Control. Int J Dent 2014;18: 87-94.

12. Aslan B, Kucukkaraca E, Turkoz C, Dincer M. Treatment effects of the Forsus Fatigue Resistant Device used with miniscrew anchorage. Angle Orthod. 2014;84:76–87.

13. Unal T, Celikoglu M, Candirli C. Evaluation of the effects of skeletal anchored Forsus FRD using miniplaque inserted on mandibular symphysis: A new approach for the treatment of Class II malocclusion. Angle Orthod. 2015;85:413–19.

14. Bock N, Bremen J, Ruf S. Stability of Class II fixed functional appliance therapy—a systematic review and meta-analysis. Eur J Orthod 2016;38:129-139.

15. Cozza P, Baccetti T, Franchi L, Toffoli L, McNamara J. Mandibular changes produced by functional appliances in Class II malocclusion: A systematic review. Am J Orthod Dentofacial Orthop 2006;129:1-12.

16. Carlos F, Brian N, and Paul W. Use of Skeletal Maturation Based on Hand-Wrist Radiographic Analysis as a Predictor of Facial Growth: A Systematic Review. Angle Orthod.2004;74:118-124.

17. Cevidanes L, Ruellas A, Jomier J, Nguyen T, Pieper S, Budin F, et al. Incorporating 3-dimensional models in online articles. Am J Orthod Dentofacial Orthop. 2015;147:195-204.

18. Konik M, Pancerz H, Hansen K. The mechanism of Class II correction in late Herbst treatment. Am J Orthod Dentofacial Orthop 1997;112:87-91.

19. Elkordy S, Abouelezz A, Fayed M, Aboulfotouh M, Mostafa Y. Evaluation of the miniplaque-anchored Forsus Fatigue Resistant Device in skeletal Class II growing subjects: A randomized controlled trial. Angle Orthod. 2019;89:391–403.

20. Millett D, Cunningham S, O’brien K, Benson P, Oliveira C. Treatment and stability of Class II Division 2 malocclusion in children and adolescents: A systematic review. Am J Orthod Dentofacial Orthop 2012;142:159-169.

21. Espinosa D, Santos M, Mendes S, Normando D. Mandibular propulsion appliance for adults with Class II malocclusion: a systematic review and meta-analysis. Eur J Orthod, 2019;41:1–13.

22. Celikoglu M, Buyuk S, Ekizer A, Unal T. Treatment effects of skeletal anchored Forsus FRD EZ and Herbst appliances: A retrospective clinical study. Angle Orthod. 2016;86:306-314.

23. Turkkahraman H, Eliacik SK, Findik Y. Effects of miniplaque anchored and conventional Forsus Fatigue Resistant Devices in the treatment of Class II malocclusion. Angle Orthod 2016;86(6):1026–1032.

24. Cevindes L, Franco A, Gerig G, Profitt W, Slice D, Enlow D. Assessment of mandibular growth and response to orthopedic treatment with 3- dimensional magnetic resonance images. Am J Orthod Dentofacial Orthop 2005;128:16-26.

25. Phelan A, Tarraf N, Taylor P, Honsceid R, Drescher D, Baccetti T. Skeletal and dental outcomes of a new magnetic functional appliance, the Sydney Magnoglide, in Class II correction. Am J Orthod Dentofacial Orthop 2012;141:759-72.

26. Aidar LA de A, Dominguez GC, Abrahão M, Yamashita HK, Vigorito JW. Effects of Herbst appliance treatment on temporomandibular joint disc position and morphology: A prospective magnetic resonance imaging study. Am J Orthod Dentofacial Orthop 2009;136:412-24.

27. Ruf S, Pancerz H. Dento-skeletal effects and facial profile changes in young adults treated with the Herbst appliance. Angle Orthod1999;69:239-246.

28. Eissa O, El-shennawy M, Gaballah S, El-Meehy G, EL baly T. Treatment outcomes of Class II malocclusion cases treated with miniscrew- anchored Forsus Fatigue Resistant Device: A randomized controlled trial. Angle Orthod. 2017;87:824–833.

29. Amuk N, Baysal A, Coskun R, Kurt G. Effectiveness of incremental vs maximum bite advancement during Herbst appliance therapy in late adolescent and young adult patients. Am J Orthod Dentofacial Orthop 2019;155:48-56.