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A Three-Dimensional Clinical Evaluation of The Effect of Tandem Appliance in The Treatment of Class III Malocclusion

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ABSTRACT

Purpose: This study was conducted to evaluate the skeletal and dental effects of the Tandem appliance in three dimensions for the correction of skeletal Class III malocclusion. **Materials and methods:** Twenty-two female girls with skeletal Class III malocclusion due to maxillary retrognathia were selected for this study with age of 7 to 10 years. All patients received The Tandem appliance for treatment of class III malocclusion. CBCT images and digital study models were made at two stages; before and after treatment with The Tandem appliance. CBCT images and digital study models were analyzed and data were statistically analyzed. **Results:** The use of Tandem appliance significantly enhanced the forward growth of the maxilla without any noticeable effects on the mandible. The anterior and posterior facial height were significantly increased. There was a significant increase in the proclination of the upper incisors and retroclination of the lower incisors. In addition, there was a significant increase in the upper and lower inter-molar widths and also, in the upper inter-canine width. **Conclusion:** The Tandem appliance showed effective results in the treatment of skeletal Class III malocclusions with maxillary retrognathia. It had a combination of skeletal and dental effects.

KEYWORDS

Skeletal class III, Three Dimensional, CBCT, Digital cast analysis, Tandem.

INTRODUCTION

Skeletal Class III malocclusion is highly challenging for the clinician to manage.(1) It could be due to maxillary retrusion, mandibular protrusion or both. Maxillary retrognathia prevails in most cases with class III malocclusion(2). Different treatment modalities have been enumerated for treatment of Class III malocclusion. They include early orthopedic treatment using protraction therapy, chin cup therapy, orthodontic camouflage or combined surgical/orthodontic approach for patients with

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severe skeletal discrepancies(3). Protraction therapy has been recommended in the treatment of the class III growing patients with maxillary retrognathia aiming to achieve maximum skeletal and minimum dental changes. Early treatment of Class III malocclusion has been recommended in literature to avoid complications like compromised dental and facial esthetics to eliminate an anterior functional shift of the mandible and to decrease the possibility of later orthognathic surgery, but still the treatment of Class III malocclusion has been a dilemma, as it may depend on the growth tendency of an individual which makes its treatment highly challenging in growing patients(4). Intraoral appliances is much more preferable than extra oral ones for correcting Class III malocclusion because of patient's compliance, pressure sores on the chin and forehead and poor esthetics due to the physical appearance of the extra oral appliance(5)**.** Thus the idea of this study was aroused to evaluate three-dimensionally the Tandem Appliance as an intraoral appliance in treatment of class III malocclusion.

MATERIALS AND METHODS

Twenty-two subjects for this prospective study selected from the department of Orthodontics outpatient clinic, Faculty of Dentistry, Ain Shams University. All records were obtained before and after one year of application of The Tandem appliance. Photographs (extraoral&intraoral photos), Digital Orthodontic study models as well as Radiographic records (CBCT) were taken before and after treatment. Subjects were imaged using iCAT® CBCT scanner (iCAT ® scanner (Model 17/19 series; Imaging Sciences International, Hatfield, PA) at the Department of the Radiology, Faculty of Dentistry (Ain Shams University). Patient selection was according to the following inclusion criteria; Growing female girls with age range from 7-10 years, dental Class III malocclusion with an anterior cross bite or edge to edge relationship, skeletal Class III due to maxillary retrusion or a combination of maxillary retrusion and mandibular protrusion, and finally fully erupted permanent first molars. The study protocol was reviewed and approved by the Ethics Committee of the Faculty of Dentistry, Ain Shams University. Before treatment was carried out, all subject`s parents signed a detailed written Arabic consent after full explanation of the procedure and the aim of the study**.** We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. All of the sources of funding for the work described in this publication are self-funding.

Appliance design

The Tandem appliance used in this study had three components, two fixed and one removable. The upper fixed appliance consists of maxillary Hyrax expander. Fig. (1). The lower component consists of modified fixed lingual arch with occlusal coverage added as bite raiser and removable face bow, bows were bent out to allow insertion of extra oral elastics. Fig (2)

Alternative Rapid Maxillary Expansion and Constriction(6) as a protocol for expansion was used for all subjects. Extra oral elastics were attached from hooks at the canine region of the maxillary part to mandibular face bow with a force of 150 gm/side at the beginning for two weeks, then 300 gm/side for 1 month and increased up to 450-500 gm/side to the end of the treatment. Force of traction was measured using Mechanical (Analog) The traction direction made an angle of 30° to the patient occlusal plane exerting force in a downward and forward vector. The angle was adjusted by bending the modified face bow and then inserted in extra oral tube of lingual arch as angle was adjusted outside patient mouth on study models and then the appliance was cemented with glass ionomer cement and fully seated using a band pusher and a band seater. Excess cement was removed and the patient was instructed to bite on a cotton roll for isolation for 10 minutes.

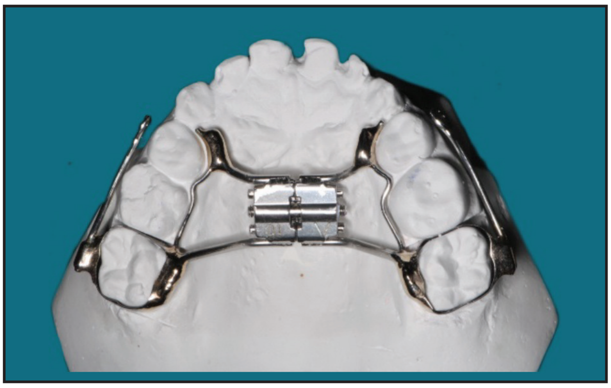

Figure (1) showing hyrax expander with soldered buccal arms

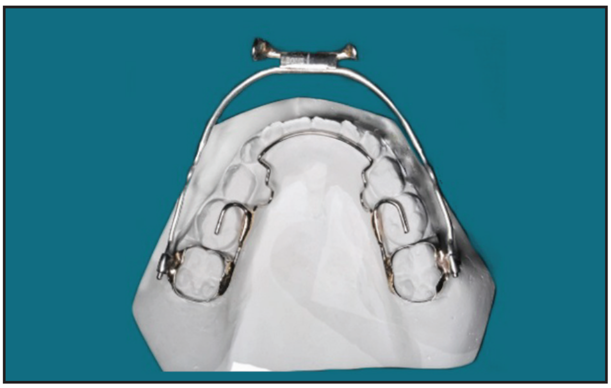

Figure (2): Modified lingual arch with extra oral face bow.

Three dimensional analysis

Orientation of CBCT was done for standardization and reproducibility of the measurements, co-ordinate system was used with origin at Nasion. The horizontal plane was set up as the Frankfurt horizontal plane, identified by using three points: c was defined using 2 points; Nasion and Basion the frontal plane will be parallel to the patient's infra-orbital plane. Then Defining the desired landmarks, the desired landmarks were created and described into skeletal, dental and soft tissue landmarks. Creating the reference lines and reference planes using the "3D analysis setup" tool, the reference lines and planes needed for the analysis were created and described, the type of needed measurements was selected and component landmarks were defined, then the defined measurements were made automatically table (1)

All landmarks where identified on Invivosoftware (iCAT Vision software™ (version 1.7.0.7, Imaging Sciences International).

Table (1) *skeletal, dental and soft tissue measurements*

Measurement	Abbreviation	Definition
SNA	SNA	The angle between three landmarks: S, N, A.
SNB	SNB	The angle between three landmarks: S, N, B
ANB	ANB	The angle between three landmarks: A, N, B
Foramen Spinosum Point A	(ELSA-A)	Linear distance between foramen spinosum plane and point A
Foramen Spinosum Point B	(ELSA-B)	Linear distance between foramen spinosum plane and point B
Foramen Spinosum—ANS	(ELSA-ANS)	Linear distance between foramen spinosum plane and point ANS
Foramen Spinosum Pogonion	(ELSA-Pog)	Linear distance between foramen spinosum plane and point Pog
Axial Inclination of Upper Central Incisor	(U1/SN)	Angel between long axis of upper central and SN plane
Axial Inclination of lower Central Incisor	(L1/MP)	Angel between long axis of lower central and mandibular plane
Tipping of upper right first permanent molar	MD Tip - UR6 – FHP	Angel between long axis of upper right first molar and Frankfurt horizontal plane
Tipping of upper left first permanent molar	MD Tip - UL6 – FHP	Angel between long axis of upper left first permanent molar and Frankfurt horizontal plan
Tipping of lower left first permanent molar	MD Tip - LL6 – FHP	Angel between long axis of lower left first permanent molar and Frankfurt horizontal plane
Tipping of lower right first permanent molar	MD Tip - LR6 – FHP	Angel between long axis of lower right first permanent molar and Frankfurt horizontal plane
Upper Lip to Esthetic Plane	(Ls-E Plane)	Linear distance from Ls to E-line
Lower Lip to Esthetic Plane	(Li-E Plane)	Linear distance from Li to E-line.

Cast analysis

Stone casts were scanned using 3-shape R-750 scanner (3shape A/S. Copenhagen, Denmark) in the digital orthodontic center at Ain-Shams University, Analysis of the produced digital models was done using GOM Inspect 2019 software 3-shape software (Gom Inspect; Gom, Braunschweig, Germany)

After casts were scanned, the STL files were generated from the scanner, then imported into 3Shape Ortho Analyzer software all measurements were done on both arches except arch depth was done only on the maxillary casts table (2).

Table (2) *measurements of digital cast analysis*

Measurement	Abbreviation	Definition
Arch depth	AD	Linear measurement from the deepest point at the palate to a horizontal occlusal Plane connecting (molars cusp tips and incisal edges) (only on maxillary casts).
Inter Canine Width	IC	Linear measurement between cusp tips of deciduous canines bilaterally (For both arches).
Arch length	AL	Linear measurement from gingival midline (between central incisors) till line connecting between mesiobuccal cusps of right and left first permanent molars (For both arches).
Arch Perimeter	AP	Measuring total circumference of the arch by joining 4 lines; from mesial surface of right first permanent molar to cusp tip of right primary canine then from right primary canine to midline then again from midline to cusp tip of left primary canine and finally from cusp tip of left primary canine to mesial surface of left permanent first molar (For both arches).
Overbite	OB	Vertical Linear Distance from the centre of the incisal edge of upper central incisor to the centre of lower central incisors.
Overjet	OJ	Horizontal linear distance between labisl surface of upper central incisor to lingual surface of lower cenral incisor.
Molar rotation	MR	Angel formed between midsagittal lane and line connecting mesibuccal cusp and distolingual(palatal) cusp (for both archs R&L).

To reduce the error in the study, all measurements were done by the same orthodontist and after 2 weeks of the first analysis, 10 measurements were picked randomly and repeated by the same operator to determine intra-operator reliability also, another trained orthodontist performed all the measurements to determine inter-operator measurement reliability.

RESULTS

Results showed that there was a postoperative increase in all measured anteroposterior parameters that were statistically significant (p<0.05) except in case of B to N Perp & SNB at which there was a significant postoperative decrease (p<0.001) and (ELSA-B) & Cor-Gor, Col-Gol at which the difference was not significant (p=0.957) (p=0.110) respectively. The highest percentage change was seen in (ELSA-A) (3.09±3.53), while the lowest change occurred with A to N perp (-12.93±6.86). table (3)

Regarding the vertical changes there was a significant post-operative increase in (PP/MP) (p=0.001) and (PD) (p=0.012). While there was a significant decrease in (SN/MP) (p=0.002), (SN/PP) (p=0.001), Angle of the Mandible both left and right (p=0.034) table (4).

Concerning transverse measurements, results showed that there was a significant increase in both measured parameters (p<0.05), with the higher change occurring with SU (2.96±13.92).

The results of dental measurements showed that there was a significant post-operative increase in (U1/SN) (p=0.001), (MAL - UL6-MBC - SVer) (p <0.001) and (OJ) (p <0.001). While there was a significant decrease in (L1/MP) (p=0.001), (MD Tip - UL6 – FHP) (p=0.001), and (MD Tip - UR6 – FHP) (p=0.003). Also there was a significant increase in value measured post-operatively only in the case of (FUR-UL6 – FHP) (p=0.030) table (5).

Table (3) *skeletal anteroposterior measurements changes*

Skeletal measurements	Pre-operative	Post-operative	p-value	Difference	Percentage change
(ELSA-A)	65.48±2.75	68.26±3.00	<0.001*	2.03±2.29	3.09±3.53
(ELSA-ANS)	68.55±2.45	71.42±2.85	<0.001*	1.74±2.63	2.54±3.86
(ELSA-B)	66.56±4.45	66.51±5.45	0.957ns	0.33±5.05	0.65±8.36
(ELSA-Pog)	65.92±6.53	68.16±5.92	0.031*	0.03±5.84	0.27±9.89
A to N perp	0.90±0.49	2.36±1.01	<0.001*	-0.44±0.24	-12.93±6.86
ANB	-1.69±1.58	2.36±0.96	<0.001*	-0.04±0.79	3.54±7.3
B to N Perp	3.52±1.53	3.31±1.47	<0.001*	-0.21±0.16	-6.37±4.22
Col-Gol	107.93±4.91	107.62±5.90	0.046	0.68±1.26	0.60±1.16
Col to A point	85.03±3.30	86.63±3.94	<0.001*	1.60±1.38	1.87±1.60
Cor-Gor	108.02±5.68	108.61±5.43	0.110ns	0.59±1.38	0.56±1.28
Cor to A point	85.36±3.64	86.57±3.61	0.005*	1.21±1.46	1.43±1.74
SNA	79.32±2.12	82.48±1.74	<0.001*	3.16±2.48	1.09±3.17
SNB	82.47±2.55	79.63±2.83	<0.001*	-2.84±2.40	-0.46±2.99

**; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)*

Table (4) *skeletal vertical measurements changes*.

Skeletal measurements	Pre-operative	Post-operative	p-value	Difference	Percentage change
(ANS-Me)	56.12±4.75	56.47±4.99	0.550ns	0.34±2.24	0.65±3.94
(N-ANS)	45.29±3.05	46.14±3.68	0.053ns	0.86±1.63	1.86±3.64
(N-Me)	100.65±6.93	101.50±7.07	0.255ns	0.85±2.86	0.87±2.82
(PP/MP)	24.74±4.66	27.42±5.07	0.001*	2.61±2.82	0.62±8.9
(S-Go)	62.14±5.95	62.26±5.50	0.924ns	0.13±5.22	0.58±8.15
(SN/MP)	30.81±5.05	29.22±5.44	0.002*	-0.09±3.10	0.02±11.42
(SN/PP)	28.00±4.94	26.35±5.40	0.001*	-1.15±5.59	-0.82±21.52
Angle of the Mandible Left	122.94±4.79	121.84±4.43	0.034*	-1.10±1.89	-0.88±1.53
Angle of the Mandible Right	123.08±4.87	122.08±4.55	0.034*	-1.00±1.72	-0.79±1.43
PD	16.18±2.20	16.87±2.04	0.012*	0.69±0.97	4.60±6.16

**; significant ($p \leq 0.05$) ns; non-significant ($p>0.05$)*

Table (5) *dental measurements changes*.

Dental measurements	Pre-operative	Post-operative	p-value	Difference	Percentage change
(Vert. UL6)	32.07±4.92	34.09±3.48	0.244ns	2.03±6.68	9.03±22.41
(Vert. UR6)	30.52±4.42	33.73±3.49	0.054ns	3.21±6.14	13.29±23.39
FUR-LL6 – FHP	46.48±4.62	47.26±4.79	0.309ns	0.78±2.97	1.83±6.38
FUR-LR6 – FHP	46.89±4.47	47.39±4.55	0.527ns	0.50±3.11	1.25±6.61
FUR-UL6 – FHP	24.59±3.85	26.49±5.21	0.030*	1.90±3.17	7.67±12.88
FUR-UR6 – FHP	24.78±3.75	26.44±5.31	0.083ns	1.67±3.59	6.62±14.50

**; significant ($p <0.05$) ns; non-significant ($p>0.05$)*

Concerning soft tissue measurements Results showed that there was a significant post-operative increase in (Ls-E Plane) (p<0.001), (Ls-SnV) (p =0.003) and (H-Angle) (p=0.011). While there was a significant decrease in (Li-E Plane) (p<0.001), (Li-H Line), (p<0.001), (N'-Sn-Pog') (p=0.002) and (NLA) (p<0.001). The change in all other parameters was not statistically significant (p>0.05). Also measured (ILG) value significantly decreased post-operatively from (2.35±0.74) to (2.01±0.62) (p=0.031) with the percentage change being (-11.37±23.23) table (6).

Cast analysis:

Results showed that there was a significant post-operative increase of (AP) (p=0.022) and (IC) values (p<0.001). While the change in other parameters was not statistically significant (p>0.05). Also significant increase in all measurements (p<0.05) with the highest change occurring in (AL) (24.20±14.31) and the lowest in (IM) (4.07±5.16) table (7).

Table (6) *soft tissue measurement changes*

Soft tissue measurements	Pre-operative	Post-operative	p-value	Difference	Percentage change
(Li-E Plane)	2.82±1.33	1.71±1.29	<0.001*	-0.47±0.61	-17.48±18.11
(Li-H Line)	3.47±0.73	2.77±0.75	0.001*	-0.70±0.70	-19.27±17.53
(Li-SnV)	4.10±2.41	3.55±1.63	0.128ns	-0.55±1.36	-7.32±24.45
(Ls-E Plane)	-3.29±1.75	-1.40±0.94	<0.001*	-1.8±0.63	-12.44±16.51
(Ls-SnV)	2.06±1.53	3.17±2.12	0.003*	-0.42±0.93	-5.84±27.19
(N'-Sn-Pog')	168.27±4.38	165.06±4.95	0.002*	-3.21±3.33	-1.90±2.00
(NLA)	109.22±6.84	103.44±6.57	<0.001*	3.53±10.03	4.06±10.07
H-Angle	11.12±2.80	12.82±3.50	0.011*	1.69±2.33	16.56±19.82
Z-Angle	80.47±4.55	78.66±6.28	0.208ns	-1.81±5.49	-2.16±6.92
ILG	2.35±0.74	2.01±0.62	0.031*	-0.34±0.57	-11.37±23.23

*; significant (p ≤ 0.05) ns; non-significant (p>0.05)

Table (7) digital cast measurements changes

Upper arch	Pre-operative	Post-operative	p-value	Difference	Percentage change
AP	77.80±6.51	80.40±8.38	**0.022***	2.60±2.99	3.24±3.50
IM	48.90±4.58	50.80±4.98	**0.115ns**	1.90±3.45	4.07±7.20
AL	35.20±4.32	37.10±4.20	**0.076ns**	1.90±3.00	5.88±8.67
IC	28.70±1.95	34.00±3.30	**<0.001***	5.30±3.50	18.83±13.15
AP	73.30±9.07	84.30±9.32	**<0.001***	11.00±6.39	15.80±11.23
IM	51.30±4.81	53.30±4.67	**0.034***	2.00±2.54	4.07±5.16
AL	32.10±4.41	39.60±5.46	**<0.001***	7.50±4.28	24.20±14.31
IC	32.00±1.76	37.80±3.58	**0.002***	5.80±4.16	18.53±13.60

**; significant (p ≤ 0.05) ns; non-significant (p>0.05)*

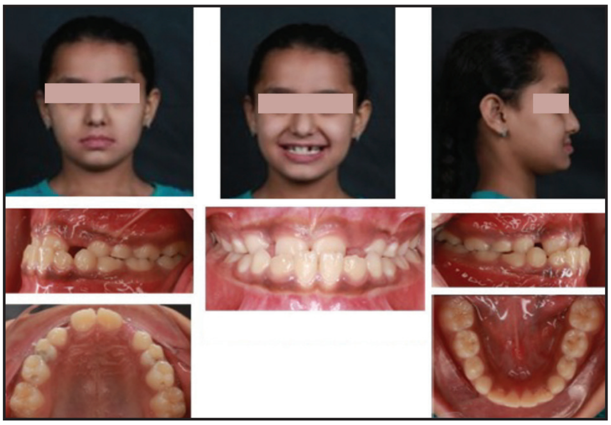

Figure (3) before treatment

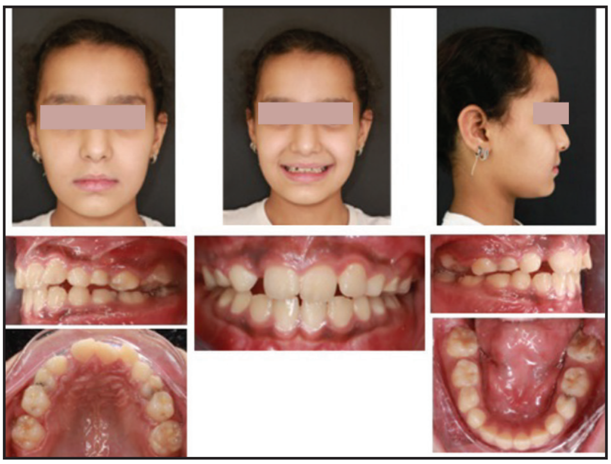

Figure (4) after treatment

DISCUSSION

Skeletal Class III malocclusion never stops to be challenging for many clinicians as the patient's growth pattern directly affects the treatment success on the long-term[7].

In orthodontic treatment, patients always have a proplem wearing extraoral appliances as easthetic demands have greatly increased nowday. So, the interest in intraoral appliances has been recently increased. Using extra-oral appliances decreases the patients co-operation as they refuse the appearance of the appliance also, pressure sores on the chin and forehead and poor esthetics due to the unaccepted physical appearance of the extra-oral appliance[8].

For that reason, this study was dedicated to evaluate three dimensionally The Tandem appliance for maxillary protraction in a trial to decrease the previously mentioned and known problems of extra oral appliances and 2D methods of assessment[9,10].

This study was carried on 22 Egyptian girls wit age range from 7 to 10 years old, this gender restriction during sample selection was done to standardize, exclude any differences in the treatment response between Class III males and females as in this skeletal age group there is a difference in growth curve between both genders which may affect results between them as reported by previous studies[11].

The protocol of elastics used in this study was augmented gradually starting with 150 gm per side at the beginning for two weeks, then 300 gm/side for 1 month and increased up to 450-500 gm/side till the end of the treatment. This protocol was affirmed by some authors to enhance patient compliance[12–14].

Regarding direction of the traction in this study, an angle of 30° was made to the patient occlusal plane to exert force in a downward and forward vector as was advocated by some authors [15,16] in order to minimize the counterclockwise rotation of maxilla.

However, it was found in this study that using this direction of pull did not reduce counterclockwise rotation of maxilla as there was a significant decrease in palatal plane angle (The difference was (-1.15±5.59) and percentage change was (-0.82±21.52).

It is worth mentioning that in this study, the skeletal effects were more prominent than the dental ones. So in order to analyze such outcome, there is a great number of combinations of factors from magnitude of force to duration of wearing elastics and of course the age[14,17–20].

The results of this study showed that the skeletal anteroposterior measurements revealed marked advancement of the maxilla as evident by the significant increase in the Maxillary AP length and Maxillo-mandibular measurement. The increase in the maxillary AP length proves that there was skeletal advancement of the maxilla, while the decrease in mandibular length can be attributed to autorotation, which in turn increased the muscle pull, these findings were in accordance with other study[13].

The maxillary-mandibular sagittal relationships showed a significant increase in ANB angle. This indicative improvement in the intermaxillary relationships, this could be attributed to forward advancement of the maxilla coupled with restraining of mandibular growth. This was in accordance to previous studies [14,20–24].

The skeletal maxillary transverse measurements showed significant increase in the inter-jugular width and suture width. This can be connected to the elastics pushing the cheeks, the buccinator and the Orbicularis Oris muscles away from the teeth and alveolar bone, thus, aiding in passive expansion equivalent results were reported while utilizing other surgical techniques to produce a skeletal effect as reported[25-27].

The dental measurements in the present study showed a noticeable proclination of the upper incisors as U1/SN angle was prominently increased. Regarding the lower incisor position, there was a retroclination of the lower incisors, as L1/MP angle was significantly decreased. Similar findings were reported in other studies [19–22,27].

The maxillary first molars revealed marked mesial movement and this could be linked to the advancement of the maxilla accompanied with the mesial drift of the molars within maxilla. Moreover, it's worth mentioning that there was marked mesial tipping of upper first molar as there was insignificant decrease of (MAL - UR6-MBRA – SVer), (MAL - UL6-MBRA - SVer)

Regarding the position of the lower molars, they demonstrated distal movement as there was a non-significant decrease in the distance between both the apices and cusps and S vertical plane. This could be explained by the reciprocal component of forces between upper and lower component of the Tandem appliance which had a distal vector directed to mandibular molars. In addition, there was a remarkable increase in angle between the long axis of mandibular molars and FH plane denoting a distal tipping of lower first molars

After digital cast analysis, not only was not there any significant mesio-lingual rotation of maxillary molars, but also mandibular molars exhibited a non-significant disto-lingual rotation. This could be credited to mesial force of traction and distal force applied to mandibular molars respectively.

The expansion in this study was Alternative Rapid Maxillary Expansion and Constriction (Alt-RAMEC) procedure introduced by Liou[6] as it was found that this protocol improves the manipulation as well as advancement of the maxillae relative to the surrounding sutures. Moreover, it enables protraction in less time and with better results as it produces more skeletal than dent alveolar results

Regarding soft tissue measurements, there was significant decrease in (Li-E Plane) and (Li-H Line) denoting an improvement of position of upper lip. Even more, there was significant increase in (Ls-E Plane) proving enhancement of position of lower lips. These results were confirmed with visual 3D superimpositions results which revealed an improvement in the overall soft tissue profile this was in accordance with [20].

CONCLUSION

1. The Tandem Appliance could be used effectively in management of skeletal Class III malocclusion with maxillary retrusion.
2. The Tandem appliance had a combination of skeletal and dental effects.
3. The Tandem Appliance enhanced soft tissue profile of the patients.

RECOMMENDATIONS

- Follow up the patients for extended time after the peak of growth to evaluate the effect of Tandem appliance on long term.
- Further studies are needed to increase the retention of the Hyrax appliance to decrease its de-bonding and loss.
- The Tandem appliance needs a more resilient design to prevent breakage.

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