Acta Scientific Dental Sciences (ISSN: 2581-4893)

Volume 5 Issue 3 March 2021

Review Article

Effect of Using Anterior Bite Plane in the Treatment of Growing Orthodontic Patients with Deep Overbite Malocclusion: A Systematic Review

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Received: January 18, 2021

Published: February 10, 2021

Abstract

Introduction: Correction of deep bite is one of the primary objectives of orthodontic treatment. Different treatment modalities could be used including anterior bite plane (ABP). The aim of this study was to evaluate the effect of ABP on treatment of deep overbite in growing patients.

Search Methods: Electronic search was done in five databases PUBMED, COCHRANE, LILACS, OVID AND SCOPUS, in addition to the gray literature.

Eligibility Criteria: Prospective, randomized and non-randomized control trials evaluating the effect of ABP on correction of deep overbite in growing patients were included.

Data Collection and Analysis: For the studies fullfiling the eligibility criteria, all outcomes data were extracted and tabulated; risk of bias was done using Downs and Black assessment tool for the included controlled clinical trials (CCTs).

Results: Three CCTs were included in the qualitative analysis. All of the included CCTs were found to have high risk of bias. Accordingly, No meta-analyses was performed. ABP was able to correct deep overbite by extrusion of molars especially lower first permanent molar. Additionally, an increase in mandibular plane angle and lower facial height was produced. Moreover, ABP reduced the muscular activity and there were insignificant favorable condylar changes.

Conclusions: ABP was able to correct deep overbite primarily by molar extrusion and improve masticatory muscle activity as well as condylar position. PROSPERO registration number: "CRD42016035970".

Funding: No funding nor conflict of interest to be affirmed.

Keywords: Anterior bite plane, deep bite, temporomandibular joint disorders, growing patients.

Abbreviations

TMD: Temporomandibular Disorders; TMJ: Temporomandibular Joint; RCTs: Randomised Control Trials; QUOROM: Quality of Reporting of Meta-analyses; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; GRADE: Grading of Recommendations Assessment, Development and Evaluation; CR: Centric Relation; CO: Centric Occlusion; SAM: School Articulator of Mack; LFH: Lower Facial Height; EMGs: Electromyography; HOP: Habitual Occlusal Position; BPOP: Bite Plane Induced Occlusal Position; FGB-D: Function Generating Bite for Deep Bite Correction; CBCT: Cone Beam Computed Tomography; PROSPERO: International Prospective Register of Systematic Reviews; CCTs: Controlled Clinical Trials; AJODO: American Journal of Orthodontics and Dentofacial Orthopedics; EJO: European Journal of Orthodontics; JCO: Journal of Clinical Orthodontics; KJO: Korean Journal of Orthodontics; WFO: World Federation of Orthodontics; DE: Dina Essrar; MK: Mohamed El Koussy; MS: Mona Salah; ABP: Anterior Bite Plane; MD: Mostafa El Dawlatly; L.I.H: Lower Incisor Height; U.I.H: Upper Incisor Height; L.M.H: Lower Molar Height; U.M.H: Upper Molar Height; C.V.M: Cervical Vertebrae Maturation.

Introduction

Deep bite has been considered one of the most common malocclusions and the most difficult to treat successfully [1]. It has been defined as "the overlapping of the upper anterior teeth over the lowers in the vertical plane" [3], with a prevalence of severe deep bite (overbite > 5mm) are found nearly in 20% of children and 13% of adults, representing about 95.2% of vertical occlusal problems [4].

Throughout the years, opinions have been controversial regarding the etiology of deep overbite and how it should be treated. Etiology of deep over bite is set to be either of dental origin or of skeletal origin. Dental origin could be due to deep curve of Spee, increased buccal root torque of the maxillary incisors [5-7], over erupted maxillary and mandibular anterior alveolar basal heights and under eruption of maxillary and mandibular posterior segments [2,8]. Moreover, extraction of mandibular incisors leads to collapse of the arch and deep bite development [8]. Nevertheless, skeletal origin could be due to discrepancy in the vertical position of the maxilla, mandible or their cant [9-11].

Different treatment modalities could be used to achieve the correction of deep over bite. Since, anterior bite plane is considered one of the most preferable lines of treatment for correction of deep overbite in growing patients [4], this systematic review was conducted to have a solid evidence-based prospective on the effects of the anterior bite plane on the treatment of deep overbite, as well as on the masticatory muscle activity and temporomandibular joint (TMJ).

Objectives

In order to answer the question; In growing patients with deep overbite malocclusion, what is the effect of anterior bite plane on the treatment of deep bite? A systematic review of the available orthodontic literature was required. The primary outcome measure was the effect of anterior bite plane upon treatment of deep over bite. The secondary measures were the effect of anterior bite plane on muscle activity and TMJ.

Materials and Methods

Protocol and registration

The protocol of the systematic review was registered on the National Institute of Health Research Database University of York (www.crd.york.ac.uk/prospero) with registration number of "CRD42016035970".

The "PICOS" of the current review was set so that the population (P) comprised growing patients with deep over bite malocclusion. The intervention (I) was restricted to deep bite treatment using Anterior Bite Plane (fixed and removable). The control (C) included non-treated group. The primary outcome (O) to be assessed was treatment of deep bite. While the secondary outcomes were its effect on muscle activity and TMJ. As for the study (S) designs, randomized, quasi-randomized and controlled clinical trials were included (Table 1).

Population (P)	Growing patients with deep over bite malocclusion.
Intervention (I)	Deep bite treatment using Anterior Bite Plane.
The control (C)	Non-treated group.
The primary outcomes (O)	Treatment of deep bite.
Study (S) designs	Randomized, quasi-randomized and controlled clinical trials.

Table 1: PICOS.

Eligibility criteria

The eligibility criteria of the current research were designed to address the study design, growth stage of the participants, the interventions, and the outcome measures. Prospective, randomized and non-randomized control trials were included. Concerning

the participants, growing patients (8-17 years old) having deep overbite malocclusion. The exclusion criteria comprised adult non-growing patients, prospective non controlled clinical trials, retrospective studies, case reports, case series', expert opinion, letters to the editor, systematic reviews, narrative reviews, in-vitro and animal studies.

Information Sources, search strategy and study selection

Five electronic databases were searched till December 2020, these were PUBMED, COCHRANE, LILACS, OVID AND SCOPUS. Hand searching of orthodontic journals; American Journal of Orthodontics and Dentofacial Orthopedics, Angle Orthodontists Journal, European journal of Orthodontics, Journal of Clinical Orthodontics, Korean Journal of Orthodontics, World Federation of Orthodontics and Clinical Trials.gov. The electronic central Library in Cairo University were searched for locating unpublished studies. There was no date restriction, but there was language restriction; where articles written in English only were included. The utilized key words in the PUBMED database search were 1) Anterior bite plane OR anterior bite plate OR anterior flat plane OR anterior flat plate OR anterior splints. 2) Deep bite OR over bite OR deep over bite OR increased over bite OR complete over bite OR traumatic over bite OR deep curve of Spee. 3) Temporomandibular joint OR temporomandibular disorders OR condylar positions. 4) Muscular activity OR muscle deprogramming OR clenching OR bruxism.

The exclusion process of the non-eligible articles for inclusion in the review was done by 2 reviewers, assessment of risk of bias, and extraction of data were performed independently by the same 2 investigators. If any divergence in the assessment of the resulted articles was present, it was resolved by discussion and consultation with a third author.

Data items and collection process

The data extraction sheet of the included study (Tables 2, 3, 4, 5 and 6) was developed by the same 2 reviewers independently and in case of disagreements, it was solved by consulting the third author.

Risk of bias/quality assessment in individual studies

Randomized clinical trials would be assessed by the Cochrane collaboration's tool [12] for assessing risk of bias. Quasi-randomized and Non-randomized would be assessed by Downs and Black tool [13]. These tools evaluate the study sequence generation, allocation concealment, blinding, and other sources of bias.

Summary measures and synthesis of results

The effect of the outcomes was considered as difference in means and standard deviation. Concerning heterogeneity, no measures were performed as no meta-analysis was conducted.

Risk of bias across the studies

For assessment of publication bias standard funnel plots to be used only when more than 10 studies included in the meta-analysis.

Additional analyses

No additional analyses were performed in the presented systematic review.

Results and Discussion

Results

Study selection and characteristics

According to the current search strategy it resulted in 1565 citations, after removal of the duplicates 800 articles remained to be assessed for eligibility criteria. Seven hundred and fifty-five studies were eliminated by title and abstract due to irrelevance to our review question and criteria. The main reasons for exclusion were; studies including adult patients, headgears or functional appliances were used in conjunction with the bite opening appliance. Also, case reports and in-vitro studies were salient reasons for the exclusion of some of the non-eligible studies. At last, 45 full texts were then read by both reviewers. Total of 3 studies met the inclusion criteria for the current search, where all the three studies were controlled clinical trials (CCTs) (Figure 1). They have been appraised by Downs and Black assessment tool [13].

A data extraction sheet was tailored for the studies by Forsberg and Hellsing (1984) [14], Labib (1988) [15] and Fayed (2003) [16], in order to aid in the process of qualitative analysis (Tables 2, 3, 4, 5 and 6).

Risk of bias within studies

Down's and black assessment tool was applied to these elected studies first by Forsberg and Hellsing (1984) [14], second by Labib (1988) [15] and third by Fayed (2003) [16] in order to check its methodological soundness and resulted in a score of 12, 12 and 13 respectively (Table 7).

Results of individual studies, meta-analysis and additional analyses

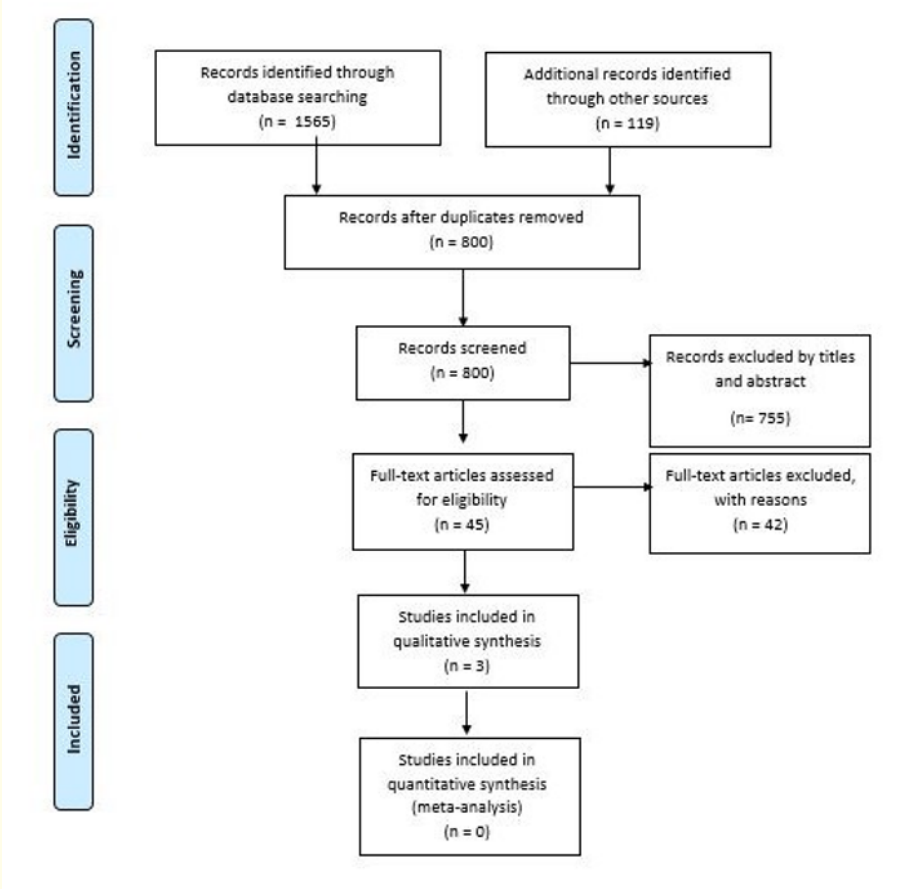

Figure 1: PRISMA Flow Diagram.

Authors	Publication Year	Country	Journal	Type of Study	Sample size (patients)	Gender	Age
Carl Forsberg., *et al*.	1984	Sweden	European Journal of Orthodontics	CCT	40	12 males, 8 females	9-13 yrs.
Labib	1988	Egypt	Master Thesis at Cairo University	CCT	30	13 males, 17 females	13-15 yrs.
Fayed	2003	Egypt	PhD Thesis at Cairo University	CCT	25	Females	12-15 yrs.

Table 2: Data Extraction Table: (Demographic).

Before Treatment																				
Authors	**TTT Duration**	**Vertical Overbite (Linear Cephalometric)**				**U.M.H (measured from cusp to PP)**				**L.M.H (Measured from MB cusp to MP)**				**U.I.H (measured from incisal edge to PP)**				**L.I.H (measured from incisal edge to MP)**			
		TTT Grp		Control Grp		TTT Grp		Control Grp		TTT Grp		Control Grp		TTT Grp		Control Grp		TTT Grp		Control Grp	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Forsberg and Hellsing (1984)	3 months	-	-	-	-	20.5	1.7	20.2	2.2	28	2.6	28.8	2.4	28	2.5	27.9	2	39.1	3	39.5	2.2
Labib (1988)	6 months	5.8	1.3	6.4	1	20.8	1.7	22.4	2.2	29	2.3	28.3	2.7	-	-	-	-	42.4	2.4	41.6	2.8
		Cast 4.7	Cast 1.2	Cast 5.7	Cast 1.1																

Table 3a: Data Extraction Table (Dental Measurements).

After Treatment																				
Authors	**TTT Duration**	**Vertical Overbite (Linear Cephalometric)**				**U.M.H (measured from cusp to PP)**				**L.M.H (Measured from MB cusp to MP)**				**U.I.H (measured from incisal edge to PP)**				**L.I.H (measured from incisal edge to MP)**			
		TTT Grp		Control Grp		TTT Grp		Control Grp		TTT Grp		Control Grp		TTT Grp		Control Grp		TTT Grp		Control Grp	
		mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD
Forsberg and Hellsing (1984)	3 months	-	-	-	-	21.8	1.7	21.2	2.3	29.4	2.5	29.5	2.5	28.1	2.5	28.2	1.9	39.2	3	40.4	2.3
Labib (1988)	6 months	3.1	1.2	6.5	1.1	22.3	1.6	22.4	2.1	30.7	1.9	28.7	2.4	-	-	-	-	42.4	2.3	41.7	2.6
		Cast 3.2	Cast 1.3	Cast 5.8	Cast 1																

Table 3b

Effect of ABP on Correction of Deep Overbite (1ry outcome)

Lower incisor to mandibular plane - in mm

Forsberg and Hellsing (1984) [14] measured the lower incisor to the mandibular plane before and after treatment in the treated group resulting in a mean difference of 0.1 +/- 0.5, while in the control group resulted in a mean difference of 0.9 +/- 0.7 (Table 4). While Labib (1988) [15] measured the lower incisor to the mandibular plane before and after treatment in the treated group resulting in a mean difference of 0.03 +/- 0.20, while in the control group resulted in a mean difference of 0.13 +/- 0.51. Also Labib (1988) [15] measured the difference between the two groups with a mean difference of 0.10 +/- 0.92. There was no statistically significant difference ($p > 0.05$) between the two groups regarding the lower incisor height (Table 4).

Upper incisors to palatal plane - in mm

Only Forsberg and Hellsing (1984) [14] measured the upper incisor to the palatal plane before and after treatment in the treated group resulting in a mean difference of 0.1 +/- 0.6, while in the control group resulted in a mean difference of 0.3 +/- 0.5 (Table 4).

Lower first permanent molar to mandibular plane - in mm

Forsberg and Hellsing (1984) [14] measured the lower first permanent molar to the mandibular plane before and after treatment in the treated group resulting in a mean difference of 1.4 +/- 0.7, while in the control group resulted in a mean difference of 0.7 +/- 0.6. These results showed significantly greater amount of eruption in treatment group than in control group (Table 4).

Labib (1988) [15] measured the lower first permanent molar to the mandibular plane before and after treatment in the treated group resulting in a mean difference of 1.65 +/- 0.78, while in the control group it resulted in a mean difference of 0.40 +/- 0.98. He also measured the difference between the two groups with a mean difference of -1.25 +/- 1.20. The mean value of the lower molar height increased in the treatment group which showed statistically highly significant results ($p < 0.001$) (Table 4).

Upper first permanent molar to palatal plane - in mm

Forsberg and Hellsing (1984) [14] measured the upper first permanent molar to the palatal plane before and after treatment in the treated group resulting in a mean difference of 1.3 +/- 0.6, while in the control group resulted in a mean difference of 1 +/- 0.5 (Table 4).

Labib (1988) [15] measured the upper first permanent molar to the palatal plane before and after treatment in the treated group resulting in a mean difference of 1.53 +/- 1.08, while in the control group resulted in a mean difference of 0.06 +/- 0.79. Also he measured the difference between the two groups with a mean difference of -1.46 +/- 1.31. Upper molar height showed statistically highly significant results ($p < 0.001$) (Table 4).

Authors	Labib (1988) Duration of TTT (6 months)						Forsberg and Hellsing (1984) Duration of TTT (3months)				
Parameters	Control Group (15)		Treated Group (15)		Mean Diff. of both Grps (30)		Control Group (20)		Treated Group (20)		Mean Diff. of both Grps (40)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean Diff.
Vertical Overbite (Study casts)	0.06	0.10	-1.46	0.78	1.52	0.77	-	-	-	-	-
Vertical Overbite (Linear Cephalometric)	0.10	0.43	-2.65	0.46	2.75	1.31	-	-	-	-	-
U.M.H (measured from MB cusp to PP)	0.06	0.79	1.53	1.08	-1.46	1.31	1.3	0.6	1	0.5	0.3
L.M.H (measured from MB cusp to MP)	0.40	0.98	1.65	0.78	-1.25	1.20	1.4	0.7	0.7	0.6	0.7
U.I.H (measured from incisal edge to PP)	-	-	-	-	-	-	0.1	0.6	0.3	0.5	-0.2
L.I.H (measured from incisal edge to MP)	0.13	0.51	0.03	0.20	0.10	0.92	0.1	0.5	0.9	0.7	-0.8

Table 4: Difference of the resulted Dental measures of the treated and control group in the two studies, and the mean difference between the two groups in each study.

Vertical overbite – in mm

Only Labib (1988) [15] measured the vertical overbite on the lateral cephalometric before and after treatment, resulting with a mean difference of -2.65 +/- 0.46 in the treated group and 0.10 +/- 0.43 in the control group. While the mean difference between the two groups was 2.75 +/- 1.31. This difference was found to be statistically highly significant ($p < 0.001$) (Table 4).

Labib (1988) [15] was the only one who measured the vertical overbite on the study casts before and after treatment, resulting with a mean difference of -1.46 +/- 0.78 in the treated group and 0.06 +/- 0.10 in the control group. While the mean difference between the two groups was 1.52 +/- 0.77. This difference was found to be statistically highly significant ($p < 0.001$) (Table 4).

Mandibular plane angle (MP/SN) - in degrees

Forsberg and Hellsing (1984) [14] recorded the mandibular plane angle before and after treatment, resulting with a mean difference of 0.6 +/- 0.8 in the treated group, and -0.3 +/- 1 in the control group. The mean difference between the two groups was 0.9, which was statistically significant ($p < 0.01$) (Table 6).

Labib (1988) [15] measured the mandible plane angle before and after treatment, resulting with a mean difference of 1.75 +/- 1.26 in the treated group, and -0.33 +/- 1.29 in the control group. While the mean difference between the two groups was -2.08 +/- 1.74, which was found to be statistically highly significant ($p < 0.001$) (Table 6).

Before Treatment																
Authors	**TTT Duration**	**Mandibular Plane Angle (MP/SN) (Angular)**				**Total Facial Height (T.F.H) (Linear)**				**Upper Facial Height (U.F.H) (Linear)**				**Lower Facial Height (L.F.H) (Linear)**			
		TTT Grp		**Control Grp**		**TTT Grp**		**Control Grp**		**TTT Grp**		**Control Grp**		**TTT Grp**		**Control Grp**	
		mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Forsberg and Hellsing (1984)	3 months	32	5.3	32.5	5.5	110.6	5.6	110.3	5.1	50.4	3.5	49.2	3.1	62	4.9	63.3	3.5
Labib (1988)	6 months	34.1	4.8	34.4	4.1	117	4.4	116.2	5.8	53.9	3.3	52.5	3.7	66.9	4	67.4	5.2
After Treatment																	
Authors	**TTT Duration**	**Mandibular Plane Angle (MP/SN) (Angular)**				**Total Facial Height (T.F.H) (Linear)**				**Upper Facial Height (U.F.H) (Linear)**				**Lower Facial Height (L.F.H) (Linear)**			
		TTT Grp		**Control Grp**		**TTT Grp**		**Control Grp**		**TTT Grp**		**Control Grp**		**TTT Grp**		**Control Grp**	
		mean	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**	**mean**	**SD**
Forsberg and Hellsing (1984)	3 months	32.6	5.2	32.2	5.9	113.9	5.8	113	5.4	50.8	3.5	50.5	3.1	64.9	4.9	64.5	3.8
Labib (1988)	6 months	35.9	4.9	34.1	4.1	121	4.6	116.5	5.6	54.5	3.2	52.5	3.9	70	4.5	67.4	5.1

Table 5: Data Extraction Table (Skeletal Measurements).

Authors	Labib (1988) Duration of TTT (6 months)						Forsberg and Hellsing (1984) Duration of TTT (3months)				
Parameters	Control Group (15)		Treated Group (15)		Mean Diff. of both Grps (30)		Control Group (20)		Treated Group (20)		Mean Diff. of both Grps (40)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean Diff.
Mandibular plane Angle (MP/SN) (Angular)	-0.33	1.29	1.75	1.26	-2.08	1.74	0.6	0.8	-0.3	1	0.9
Total Facial Height (T.F.H) (Linear)	0.33	1.39	4	1.78	-3.66	2.2	3.3	1.1	2.7	1.5	0.6
Upper Facial Height (U.F.H) (Linear)	0	0.92	0.68	0.81	-0.68	1.2	0.4	0.5	1.3	0.6	-0.9
Lower Facial Height (L.F.H) (Linear)	-0.06	1.09	3.12	1.51	-3.19	1.81	2.9	0.9	1.2	1.2	1.7

Table 6: Difference of the resulted Skeletal measures of the treated and control group in the two studies, and the mean difference between the two groups in each study.

Total facial height (N-Me) – in mm

Forsberg and Hellsing (1984) [14] evaluated the total facial height before after treatment resulting in mean difference 3.3 +/- 1.1 in the treated group, and 2.7 +/- 1.5 in the control group. The difference between the two groups was 0.6 (Table 6).

Labib (1988) [15] measured the total facial height before and after treatment, resulting with a mean difference of 4 +/- 1.78 in the treated group, and 0.33 +/- 1.39 in the control group. The mean difference between both groups was -3.66 +/- 2.2 which was statistically highly significant ($p < 0.001$) (Table 6).

Upper facial height (N-ANS) – in mm

Forsberg and Hellsing (1984) [14] detected the upper facial height before and after treatment with a mean difference 0.4 +/- 0.5 in the treated group, while in the control group the mean difference was 1.3 +/- 0.6. The mean difference (-0.9) between the treated and control group was found to be highly significant ($p < 0.001$) (Table 6).

Labib (1988) [15] measured the upper facial height before and after treatment, resulting in a mean difference of 0.68 +/- 0.81 in the treated group, and 0 +/- 0.92 in the control group. The mean difference (-0.68 +/- 1.2) between the two groups was said to be probably significant ($p < 0.05$) (Table 6).

Lower facial height (ANS-Me) – in mm

Forsberg and Hellsing (1984) [14] evaluated the lower facial height before and after treatment, showing a mean difference 2.9 +/- 0.9 in the treated group, while 1.2 +/- 1.2 in control group. The result of the mean difference (1.7) between the two groups was found to be statistically highly significant ($p < 0.001$) (Table 6).

Labib (1988) [15] measured the lower facial height before and after treatment, resulting in a mean difference of 3.12 +/- 1.51 in the treated group, and -0.06 +/- 1.09 in the control group. This increase in the lower facial height in the treated group was considered statistically highly significant ($p < 0.001$), with a mean difference between the two groups -3.19 +/- 1.81 (Table 6).

Question	Study		
	Forsberg and Hellsing (1984) [14]	Labib (1988) [15]	Fayed (2003) [16]
1	YES(1)	YES(1)	YES(1)
2	YES(1)	YES(1)	YES(1)
3	YES(1)	YES(1)	YES(1)
4	YES(1)	YES(1)	YES(1)
5	YES(1)	NO(0)	NO(0)
6	YES(1)	YES(1)	YES(1)
7	NO(0)	NO(0)	NO(0)
8	YES(1)	NO(0)	NO(0)
9	NO(0)	NO(0)	NO(0)
10	NO(0)	NO(0)	YES(1)
11	YES(1)	YES(1)	YES(1)
12	UTD(0)	UTD(0)	UTD(0)
13	NO(0)	YES(1)	YES(1)
14	UTD(0)	NO(0)	NO(0)
15	UTD(0)	NO(0)	NO(0)
16	YES(1)	YES(1)	YES(1)
17	NO(0)	YES(1)	NO(0)
18	UTD(0)	UTD(0)	YES(1)
19	NO(0)	NO(0)	UTD(0)
20	YES(1)	YES(1)	YES(1)
21	YES(1)	YES(1)	YES(1)
22	UTD(0)	UTD(0)	NO(0)
23	UTD(0)	NO(0)	UTD(0)
24	UTD(0)	UTD(0)	UTD(0)
25	NO(0)	NO(0)	NO(0)
26	NO(0)	UTD(0)	UTD(0)
27	YES(1)	YES(1)	YES(1)
Total	12	12	13

Table 7: Downs and Black checklist score for the included studies.

Effect of ABP on Muscular Activity and Temporomandibular Joint (2ry outcome)

Fayed (2003) [16] measured the effect of the anterior bite plane on the muscular activity and the condylar position of the temporomandibular joint by tomograms and electromyography, and concluded that:

- There was a significant reduction in temporalis and masseter muscle activities during clenching in the treated group. While in the control group, there was a significant increase in temporalis muscle activity.
- There was insignificant anterior condylar displacement in the treated group, however the displacement was in the opposite direction in the control group.

Risk of bias across studies

Tests for publication bias were not performed because only 2-3 studies were included in the meta-analyses.

Discussion

One of the most common malocclusion which is frequently seen in the orthodontic patients is deep over bite, which is defined as the excessive vertical overlap of the upper incisors on the labial surface of lower incisors when it exceeds the standard limit of 1-2 mm [17]. Deep overbite may lead to several problems such as anterior migration of the maxillary teeth, wear of the mandibular incisors and periodontal destruction that's why it should be treated successfully and as early as possible. Excessive overbite can cause vertical dimension problems, it is related to temporomandibular joint disorders (TMD) and increased muscle activity, it also affects esthetics, and thus, it is preferred to treat deep overbite in the growing period.

The exaggerated curve of Spee is a main factor in deep overbite malocclusion [5,6], where the lower incisors are retroclined and over-erupted. Treatment modalities for correction of deep overbite included lower incisor intrusion or by molars extrusion [14,15,18,19].

The anterior bite plane is one of the most popular appliances that is used for the treatment of deep overbite, also it is simple, easily constructed and could be adapted well by the patients. It is mainly recommended for growing patients.

Orthodontic literature encompasses large number of articles evaluating the effect of anterior bite plane for deep overbite correction. The effectiveness of this modality was swinging between promotors and opponents leaving the clinicians without a solid ground about its efficiency in deep overbite correction. To date there was no systematic reviews done to study the effect of the anterior bite plane on correction of deep overbite, as well as on its effects on muscle activity and TMJ changes mainly condylar position. Accordingly, in the presented systematic review a trial was achieved to reach a solid answer regarding the effect of anterior

bite plane on correction of deep overbite either by molars extrusion or incisors intrusion or even by both.

A strict inclusion criteria were set for this systematic review, it was limited to growing patients only as correction of deep bite utilizing the bite plane may involve molar extrusion with compensatory mandibular ramal growth which make it the feasible choice of treatment for this age group patients having deep bite [20]. Also, the study design was limited to randomized control trials, controlled clinical trials and quasi randomized controlled trials because this type of study design is of high quality than those of the retrospective studies, case report and case series studies. A control untreated group was essential to exclude any effects that could be attributed to growth rather than intervention effects.

Summary of evidence

In the current study and by using the Downs and black assessment tool, Forsberg and Hellsing (1984) [14], Labib (1988) [15], Fayed (2003) [16] were of poor quality. Fayed (2003) [16] was excluded from the results of the primary outcome because deep bite was assessed in her study by percentage only and not by linear measurements as in Forsberg and Hellsing (1984) [14] and Labib (1988) [15].

Since growth modification by compensatory mandibular ramal growth would be expected, then the best timing to use the bite plane would be around the pubertal growth spurt, therefore subjects younger than 11 years should be generally excluded [21]. The subjects (9 years) in Forsberg and Hellsing (1984) [14] were below the age range for the pubertal growth spurt, while in Labib (1988) [15] the age ranged from 13-15 years.

Since there are early and late growers (age ranged from 9-13 years) in the Forsberg and Hellsing (1984) [14], cervical vertebrae maturation index (CVM) would have been more accurate than chronological age to make sure that the sample is in the pubertal growth spurt [20].

Both Forsberg and Hellsing (1984) [15] and Labib (1988) [15] were included in the results for the primary outcome, having three similar dental measurements; upper first permanent molar height (measured from mesio-buccal cusp to palatal plane), lower first permanent molar height (measured from mesio-buccal cusp to mandibular plane) and lower incisors height (measured from incisal edge to mandibular plane). The upper incisor height measured from incisal edge to palatal plane was only measured by Forsberg and Hellsing (1984) [14]. On the other hand, Labib (1988) [15] was the only one to measure the vertical overbite from the study cast and lateral cephalogram.

According to Forsberg and Hellsing (1984) [14] the upper and lower first molars in the treated group showed a significantly greater amount of eruption than in the control group. The difference was greater in the lower jaw due to the greater eruption of the lower first molar than the upper one ($p < 0.01$). While the lower incisors showed very little changes in the treated group when compared to the control group with no statistically significant changes ($p > 0.05$).

As regard the posterior teeth height, the cephalometric evaluation in Labib (1988) [15] study showed increase in the height of the upper and lower first permanent molars, these changes were highly significant ($p < 0.001$). The super-eruption of lower first permanent molar was more than that of the upper, meanwhile, the height of the lower incisors almost showed no change, indicating absence of intrusion of the lower anterior incisors.

While the results for the skeletal measures regarding the mandibular plane angle, total facial height, upper facial height and lower facial height; Forsberg and Hellsing (1984) [14] found significant differences between the groups in the growth rotations of the jaws. An increase in the mandibular plane angle was highly significant ($p < 0.001$) in the treated group. The vertical development of the upper face was retarded in the treated group which indicated that the bite plane therapy had an inhibiting effect on the vertical development of the maxilla, whereas the lower facial height showed an increased rate of growth.

Forsberg and Hellsing (1984) [14] reported that the correction of deep overbite was achieved due to dental as well as skeletal changes. On the other hand, Labib (1988) [15] reported that the mandibular plane angle was found to be significantly increased after treatment of deep overbite with anterior bite plane. The mean difference was found to be statistically highly significant ($p < 0.001$).

As for the facial height, Labib (1988) [15] reported that the mean difference of the upper facial height was statistically significant ($p < 0.01$) for the treated patients. While for the total facial height and lower facial height there was significant increase in the patients under bite plane therapy than those in control group, this difference was found to be statistically highly significant ($p < 0.001$).

Regarding the secondary outcome, Fayed (2003) [16] was the only one that discussed the effect of the anterior bite plane on the muscular activity specially in temporalis and masseter muscles, and the condylar position in the TMJ. For the condylar position, the results showed no significant change in the condylar position after deep overbite correction with fixed anterior bite plane, and she stated that this result may be attributed to the assumption that, correction of deep overbite with fixed anterior bite plane was capable of establishing an occlusal vertical dimension that was in harmony with the postural vertical dimension, therefore there will be no mandibular overclosure in the maximum intercuspation, resulting that the condylar movement will be mainly rotatory, with minimal translation [16].

Also it may be attributed to the flat design of the bite plane, which didn't command a certain mandibular position in an anteroposterior direction, it only prevented posterior occlusal contact, unlike inclined plane or other functional appliances that produce protrusive movements of the mandible [16]. While in the control group, an insignificant condylar posterior displacement was found. This would indicate that the direction of condylar displacement with growth in deep overbite patients might be in a more posterior direction, which was found to be predisposing to TMJ disorders [16].

As for the muscular activity, her study showed that after the correction of the deep overbite with anterior bite plane, the temporalis and masseter muscles revealed a significant reduction during clenching, this could be caused due to the increase in vertical dimension caused by bite plane therapy.

On the other hand, in the control group, the muscular activity was significantly increased during rest in the left temporalis muscles, while there was insignificant increase during rest in the right temporalis, right and left masseter muscle activities. These results, represented that, untreated deep overbite patients would have an increase in muscle activity with time [16].

As a result from the provided data from the three included studies; Forsberg and Hellsing (1984) [14], Labib (1988) [15] and Fayed (2003) [16] in this systematic review, keeping in mind that they resulted in a poor scoring regarding the risk of bias assessment tool, it could be concluded that; anterior bite plane is an effective method in correction of deep overbite in growing patients by molar extrusion, especially the lower first permanent molars with no evidence that it could cause any lower incisors intrusion [14,15]. Also, the reduction of deep overbite by anterior bite plane was accompanied by an increase in the mandibular plane angle and in the lower facial height [14,15].

On the other hand, anterior bite plane is capable of reducing the masticatory muscle activity, thus providing a more healthy elevation musculature that overtime may prevent abnormal condylar position and contribute to a more stable, structurally compatible and properly functioning condylar position [16].

Limitations

All the included studies in this systematic review were CCTs. Absence of RCTs considered one of the limitations of the presented systematic review.

Since the two studies [14,15] reporting the primary outcome were found to be of poor quality and high risk of bias, a meta-analysis was not performed, as according to the recommendation of the Cochrane Handbook of systematic review of intervention [22] "Meta-analyses of studies that are at risk of bias may be seriously misleading. If bias is present in each (or some) of the individual studies, meta-analysis will simply compound the errors, and produce a 'wrong' result that may be interpreted as having more credibility".

As for the secondary outcomes, only one study [16] fitted the set criteria, thus no meta-analysis was done for them either.

Conclusion

- Evidence from high risk of bias studies is currently available regarding the effect of anterior bite plane on correction of deep overbite.
- Anterior bite plane is an effective method in correction of deep overbite in growing patients by molar extrusion, especially the lower first permanent molars.
- There was no evidence that the anterior bite plane could cause any lower incisors intrusion.
- The reduction of deep overbite by anterior bite plane was accompanied by:
    - Increase in the lower facial height.
    - Increase in the mandibular plane angle.
- Anterior bite plane is capable of reducing the masticatory muscle activity, thus providing a more healthy elevation musculature that overtime may prevent abnormal condylar position and contribute to a more stable, structurally compatible and properly functioning condylar position.

- Further randomized controlled clinical trials are recommended to evaluate the effects of anterior bite plane on correction of deep overbite.
- It is recommended also to conduct more studies on the effect of the anterior bite plane on the muscular activity and the temporomandibular joint.
- Another systematic review needs to be conducted on the effect of anterior bite plane on correction of deep overbite in adult patients.

Acknowledgements

I would like to thank all my supervisors and professors and colleagues in the department of Orthodontics, Faculty of Dentistry, Cairo University, for always being there when needed, for their support, great help and friendship. Besides, I would like to express my deepest appreciation and gratitude to my family for there great encouragement, valuable support and advice, continuous motivation and unlimited help throughout the journey of this work.

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