Journal of Oral Biology and Craniofacial Research 14 (2024) 446–454

Contents lists available at ScienceDirect

Journal of Oral Biology and Craniofacial Research

journal homepage: www.elsevier.com/locate/jobcr

Cervical spine changes with functional appliance treatment: A systematic review and meta-analysis

Sandhya Murali, Annapurna Kannan *, Vignesh Kailasam

Department of Orthodontics and Dentofacial Orthopedics, Sri Ramachandra Dental College & Hospital, Sri Ramachandra Institute of Higher Education and Research (DU), Porur, Chennai, 600116, India

ARTICLE INFO

Keywords:
Orthodontic appliances
Cervical spine
Posture
Lordosis

ABSTRACT

Objective: Cervical spine posture is related to craniofacial morphology, airway, gait and body posture. This posture may be influenced by the changes in the mandibular position brought about by functional appliance therapy. Therefore, this systematic review aimed to assess the changes in the cervical spine posture with functional appliance treatment in Skeletal Class II subjects.

Methods: A search of studies in six electronic databases - Medline (via Pubmed), the Cochrane Library, OVID, LILACS, Scopus and Web of Science were performed until January 18, 2024 without any restriction in date or language of publication. Eligibility screening, study selection, and data extraction were performed by two reviewers independently. The risk of bias assessment of the included studies was performed with the Newcastle Ottawa scale and Cochrane RoB 2.0. Meta-analysis was performed using random effects model for assessment of changes in the cervical spine with removable and fixed functional appliances.

Results: Twelve articles that satisfied the eligibility criteria were included for systematic review and nine articles for meta-analysis. Five studies showed a low risk of bias, one as moderate and six as high risk of bias. GRADE assessment revealed a low quality evidence. Meta-analysis revealed a decrease of the upper cervical inclination by 1.16° (95 % CI of −2.68 to 0.35, $I^2 = 6$ %), an increase of the middle cervical inclination by 2.20° (95 % CI of 0.46–3.94, $I^2 = 49$ %), an increase in cervical curvature angle by 1.60° (95 % CI of 0.12–3.09, $I^2 = 89$ %) and a decrease in cervical lordosis angle by 1.54° (95 % CI of −4.16 to 1.08, $I^2 = 0$ %).

Conclusions: Minimal uprighting of the cervical spine was noted with functional appliances. Fixed functional appliances exerted a greater effect than removable functional appliances. Cervical hyperlordosis was reduced with removable functional appliance treatment. Though these changes are minimal, the clinical orthodontist should be aware that functional therapy also influences cervical spine posture. Due to the heterogeneity and low quality of evidence, the results are to be considered critically.

1. Introduction

The cervical spine and the associated muscles, ligaments and nerves function in close association with the stomatognathic system and contributes to overall body balance, gait and posture.[1] Untreated abnormalities of the cervical spine posture poses neck stresses with referred pain and loss of joint function.[2] The posture of the cervical spine is represented by the craniocervical angle which has been correlated to the development of mandible, lower face and pharyngeal airway and is also an important predictor of craniofacial growth.[3–5] The "soft tissue stretching hypothesis" by Solow and Kreiborg explains the observed negative correlation between mandibular length and cervical lordosis angle which is caused by the restricting forces of an extended head in the spinal cord on the mandible and maxilla.[6,7]

Hyperlordosis of the cervical spine with an extension of the head is reported in skeletal Class II individuals when compared to skeletal Class I and III individuals.[7–10] Functional appliances are orthodontic appliances that harnesses the orofacial muscle forces to alter the growth of the mandible and/or maxilla.[11] Apart from altering the growth of mandible, it may additionally influence the cervical spine posture indirectly affecting the airway and stomatognathic functions. This is of relevance to clinicians treating craniofacial abnormalities.

While a few studies have documented uprighting of the cervical spine with functional appliances,[12–14] some studies have reported

* Corresponding author.
E-mail addresses: D0421001@sriher.edu.in (S. Murali), annapurna@sriramachandra.edu.in (A. Kannan), vignesh.k@sriramachandra.edu.in (V. Kailasam).

https://doi.org/10.1016/j.jobcr.2024.05.015
Received 22 January 2024; Received in revised form 24 April 2024; Accepted 18 May 2024

unaltered cervical spine posture with functional appliance treatment.[15–17] The effects of maxillary expansion on the head and spine posture have been assessed as a systematic review,[18] but to the best of our knowledge, no systematic review exists in the literature to provide consensus on the impact of functional appliances on the cervical posture. Comprehending the impact of functional appliances on the cervical spine postural changes allows orthodontic practitioners offer a comprehensive, holistic care and broaden the scope of interdisciplinary practice.

The review question was "is there a change in the cervical spine posture following treatment with functional appliance?"

The primary objective was to evaluate the changes in the cervical spine posture following functional appliance treatment. The secondary objective was to compare the changes in the cervical spine posture with removable and fixed functional appliances.

2. Materials and methods

The systematic review was prepared as per the Preferred Reporting Items for Systematic Review (PRISMA) guidelines.[19] This systematic review was registered with PROSPERO under the ID number CRD42022310668.

Inclusion Criteria:

- Studies on orthodontic patients (with Skeletal Class II malocclusion) treated with functional appliance (removable or fixed)
- Patients with no history of previous orthodontic treatment/ interventions.
- Patients presented with Skeletal Class II malocclusion with ANB angle >4°
- Articles measuring craniocervical angle or head/neck posture or cervical spine posture following treatment with functional appliance.
- Availability of Lateral cephalogram data

Exclusion Criteria:

- Animal Studies
- Patients treated in combination with orthopaedic and functional appliances
- Patients with cervical spine anomalies and craniofacial malformations
- Studies conducted in patients with cleft lip and palate or other craniofacial syndromes
- Patients with TMJ disorders, obstructive sleep apnoea, history of trauma or surgery

2.1. Search strategy

A systematic search was performed until January 18th, 2024, across 6 electronic databases: Medline (via PubMed), the Cochrane Library, Scopus, Web of Science, OVID and LILACS. Grey literature search in ClinicalTrials, OpenGrey and Google Scholar was done. There were no limitations in the languages and year of publication for inclusion. Manual hand-searching of reference lists of the included articles was also performed. The search strategy comprised of the appropriate usage of MeSH keywords and Boolean operators "AND" and "OR". Table 1 provides details on the complete search strategy.

Table 1
Search strategy used in various databases.

(Functional appliance*) AND (cervical spine OR craniocervical angle OR posture OR body OR neck)	PubMed	716
(Functional appliance) AND (cervical spine OR posture OR neck OR head)	LILACS	9
(Functional appliance*) AND (cervical spine OR craniocervical angle OR posture OR body OR neck)	OVID	1273
(Functional appliance*) OR "orthodontic appliance*" AND "craniocervical angle" OR "spine posture" OR "neck posture" OR "cervical posture"	Cochrane Library	96
Functional appliance AND craniocervical angle	Scopus	179
(Functional appliance*) AND "craniocervical angle" OR "spine posture" OR "neck posture" OR "cervical posture"	Web of Science	694

2.2. Study selection

Study selection was performed by two investigators in two phases that included an independent initial screening of articles based on the research question and against the eligibility criteria. Titles and abstracts were screened in the initial screening process and followed by a full-text review in cases of incomplete information provided in the abstract and title. Furthermore, hand-searching of reference lists of the included articles was done to ensure no relevant articles were excluded. If there was an unclear or lack of information, the authors were contacted. Finally, the articles were assessed for eligibility for qualitative and quantitative reviews. The third reviewer handled any disagreements.

2.3. Data collection and analysis

The data collection was conducted independently by two authors using a standard, pre-defined table. The pre-defined data to be extracted were the name of the author(s), study type, age, gender, sample size, type of intervention, treatment duration, control group, craniocervical angle measurements. Any disagreements were resolved by a third reviewer (Table 2).

2.4. Risk of bias assessment in individual studies

Risk of Bias (RoB) assessment of individual studies was carried out using the Newcastle-Ottawa scale (NOS)[20] for case-control and cohort studies under the domains of – selection of samples, comparability and exposure/outcome. In NOS scoring, a maximum of four points for selection, two points for comparability and three points for the outcome were assigned. Studies that reached a score of seven or more were considered low RoB, five to six as moderate RoB and up to four as high RoB. Randomised controlled trials were assessed using Cochrane's RoB2.0 tool.[21] Risk of bias assessment of all included studies was carried out independently by two reviewers and disagreements were settled through discussion with the third reviewer.

2.5. Data synthesis

Data extraction and analysis were done by two reviewers independently and disagreements were resolved by discussion with the third reviewer. Data were analysed for meta-analysis using Revman software (version 5.4.) The continuous data of SN-OPT, SN-CVT, OPT/CVT and CVT/EVT angles were presented as the mean difference and 95 % confidence interval. Heterogeneity was assessed with the I^2 statistics, which ranged from 0 % to 100 %. Low heterogeneity was considered when I^2 was less than 25 %. More than 75 % would be indicative of considerable heterogeneity and between 25 % and 75 % represented average heterogeneity.[22]

3. Results

3.1. Study selection

After the search of six databases, 2967 articles were obtained, and one record was identified through other sources. After duplicates were removed 2105 records were screened based on title and abstract. 2045 articles were excluded and 60 articles were assessed by full-text review. Finally, twelve studies that met the eligibility criteria were included for

Table 2
Study characteristics of all included studies.

S. No	Article & Year	Study Design	Study group Sample Size	Study group age	Intervention received	Treatment duration	Control group & Sample size	Control group age	Outcomes measured
1.	Tecco et al., 2005[24]	Prospective	20 (0 M, 20 F)	8.4 ± 2.1 years	FR-2 (Standard)	24 months	Untreated Skeletal Class II (20 patients)	8.4 ± 2.1	SN-OPT, SN-CVT, CVT/EVT
2	Ohnmeis et al.,2014[12]	Retrospective	64 (28 M, 35F) 32 (Activator)	11 years 2 months	Activator	12 months and 7 days	Skeletal Class II treated with Bite jumping appliance (32 patients)	11 years and 2 months	SN-OPT
3	Aglarci, 2016[28]	Prospective	21 (10 M, 11F)	13.31 ± 0.92 years	Twin Block (Standard)	0.71 ± 0.22 years	No control group		SN-OPT, SN-CVT, OPT-CVT
4	Kamal et al.,2019[14]	Retrospective	30 (15 M,15F)	11.8 ± 1.5 years	Twin Block (No details of appliance)	11.83 ± 1.8 months	Untreated Skeletal Class II (30 patients)	11.6 ± 2.0 years	SN-OPT SN-CVT, OPT-CVT
5	Alsheiko et al., 2021[15]	Randomized controlled pilot trial	Twin Block (10) (5 M, 5F) Bionator (10) (5 M, 5F)	9–13 years	Twin Block (Standard) Bionator (Standard)	Not mentioned	Untreated Skeletal Class II (10 patients)	9–13 years	SN-OPT, SN-CVT, OPT/ CVT, CVT/EVT
6	Bhargavi (Grey literature) 2020[25]	Retrospective	Twin-Block (11 M, 9F) Herbst (13 M, 7F)	12.05 ± 1.43 years 13.0 ± 1.16 years	Twin Block Herbst	Not mentioned	Skeletal Class II treated by camouflage (20 patients)	12.90 ± 1.68 years	SN-OPT, SN-CVT, OPT/CVT
7	Malik et al., 2022[17]	Prospective	12 (6 M, 6F)	15 ± 1.3 years	Forsus	20–24 months	No control group		SN-OPT, SN-CVT, OPT-CVT
8	Gu et al., 2020[16]	Retrospective	17 (11 M, 6 F)	11.0 ± 1.4 years	Herbst (Standard)	19.2 ± 6.1 months	17 patients – Skeletal Class II treated with Headgear Activator	10.6 ± 1.5 years	SN-OPT
9	Ulusoy et al., 2014[23]	Retrospective	16 (8 M, 8F)	11.36 ± 0.77 years	Activator (Standard)	11 ± 3.4 months	Untreated Skeletal Class II (19 patients)	12.14 ± 0.65 years	SN-OPT, SN-CVT
10	Sharmila et al., 2022[27]	Prospective	16(8 M,8F)	10–13 years	Twin Block (Standard)	15months	No control group		SN-OPT, SN-CVT, OPT/ CVT, CVT/EVT
11	Buyukbayraktar and Camci, 2023[26]	Retrospective	36 (17 M, 19F) Twin Block (18)	12.14 ± 1.23 years	Twin Block (Expansion screw)	Not mentioned	Skeletal Class II treated with Myobrace (18 patients)	Not mentioned	SN-OPT, SN-CVT, OPT/CVT
12	Krishna et al., 2023[13]	Retrospective	57 Twin Block (19) Forsus (19) BSSO (19)	12–25 years	Twin Block (No details of appliance) Forsus	Not mentioned	No control group		SN-OPT, SN-CVT, OPT/CVT

systematic review and nine studies were included for meta-analysis. Out of which three were case-control studies, eight were observational studies and one was a pilot-RCT. Four studies were prospective and eight studies were retrospective in nature.

The entire search selection process is depicted in PRISMA flowchart (Fig. 1).

3.2. Study characteristics

The included studies were published between 2005 and 2023. Four out of twelve studies had an untreated control group.[14,15,23,24] Kamal and Fida[14] used Bolton-Brush Growth study as control group, whereas the other three studies had untreated control group. The removable functional appliances in the included studies were FR-2, Activator, Bionator and Twin Block. Twin Block was the most commonly studied appliance in the included studies. The fixed functional appliances in the included studies were Forsus and Herbst. The treatment duration was not mentioned in four of the included studies.[13,15,25,26] Tecco et al.[24]included female subjects only while other studies included both sexes. Six studies included treatment with one functional appliance.[14,17,23,24,27,28] Alsheiko et al.[15] included Twin Block and Bionator appliances. Bhargavi[25] included Twin Block and Herbst. Gu et al.[16] included Herbst and Headgear activator. Ohnmeis et al.[12] included Activator and Bite jumping appliance. Krishna et al.[13] included Twin block and Forsus (Table 2).

3.3. Risk of bias within studies

The risk of bias in the case-control and observational studies was assessed using the Newcastle Ottawa scale.[20] The Cochrane's Risk of Bias tool (RoB 2.0)[21] was used to assess the risk of bias for the pilot-RCT. The details of sample size calculation was mentioned in five studies.[13,14,23,25,26] As the study samples were representative of the population in eight studies, it was scored as low risk in the selection category.[12,14,16,17,23–25,28] In the comparability category, six studies were found to have a lack of study controls and hence was graded high risk.[12,13,17,26–28] All the included studies received a high risk score in the Outcome category, due to lack of follow-up data. Overall, five studies were graded as low RoB[14–16,24,25] one study as moderate RoB[23] and six studies as high RoB.[12,13,17,26–28] The risk of bias assessment is presented in Tables 3 and 4 and Fig. 2.

4. Results of individual studies

The craniocervical angle parameters included were SN-OPT and SN-CVT angles which indicate the upper and middle cervical inclination respectively. OPT/CVT and CVT/EVT angles indicate the cervical curvature and cervical lordosis angle of the cervical spine respectively. The

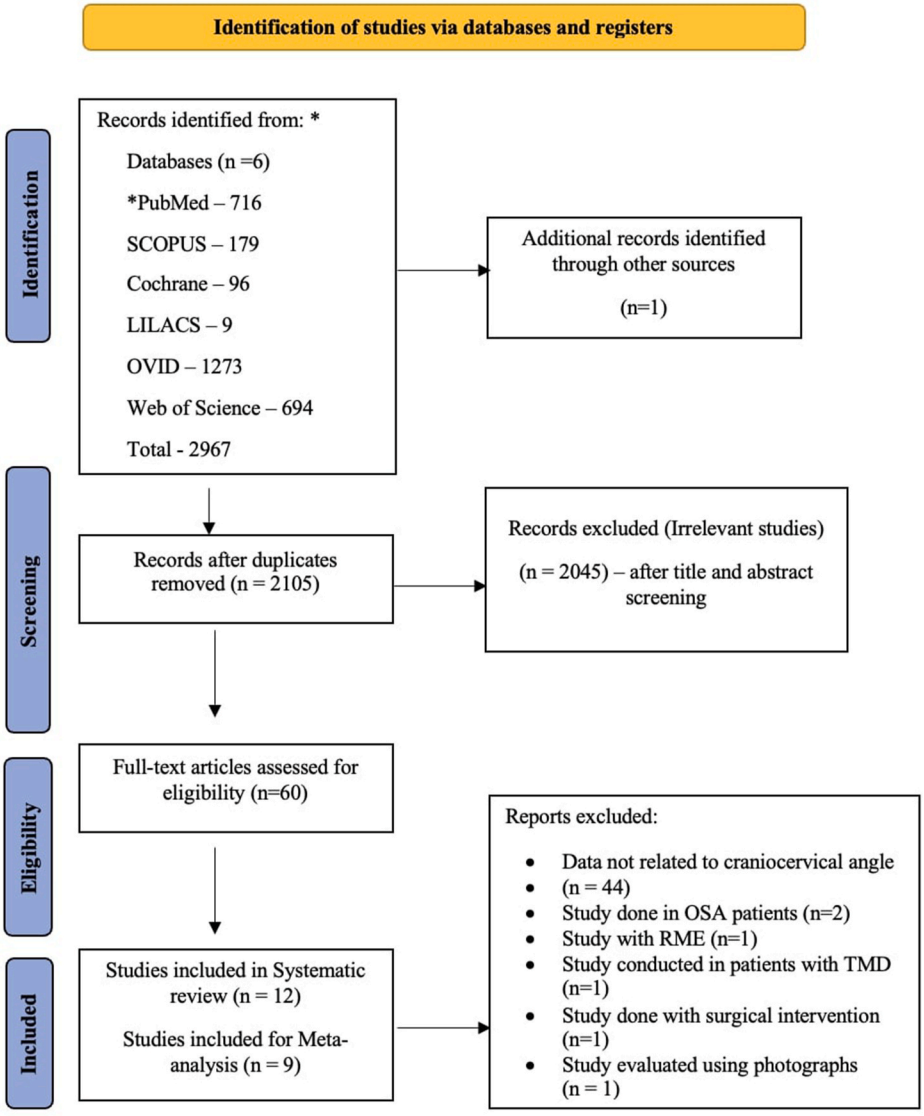

Fig. 1. PRISMA flowchart.

Table 3
Risk of bias of included studies - New Castle Ottawa Scale for cohort studies.[18]

Author	Selection				Comparability	Outcome			Overall
	Representative-ness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at the start of the study	Comparability of cohorts on the basis of design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur?	Adequacy of follow-up of cohorts	
Ohnemeis et al., 2014[12]	b	Not applicable	a	a	Not applicable	a	b	d	4 (high)
Aglarci, 2016[28]	a	Not applicable	a	a	Not applicable	a	b	d	4 (high)
Bhargavi, 2020[25]	b	a	a	a	a,b	a	b	d	7 (low)
Gu et al., 2020[16]	b	a	a	a	a,b	a	a	d	8 (low)
Malik et al., 2022[17]	b	Not applicable	a	a	Not applicable	a	b	d	4 (high)
Sharmila et al., 2022[27]	d	Not applicable	a	a	Not applicable	a	b	d	3 (high)
Buyukbayratkar and Camci, 2023[26]	d	Not applicable	a	a	Not applicable	a	b	d	3 (high)
Krishna et al., 2023[13]	d	Not applicable	a	a	Not applicable	a	b	d	3 (high)

Table 4
Risk of bias of included studies - New Castle Ottawa Scale for case-control studies.[18]

Author	Selection				Comparability	Exposure			Overall
	Is the case definition adequate	Representativeness of the cases	Selection of controls	Definition of controls	Comparability of cases and controls on the basis of design or analysis	Ascertainment of exposure	Same method of ascertainment for cases and controls	Non-response rate	
Tecco et al., 2005[24]	a	a	a	a	a,b	a	a	Not applicable	8 (low)
Kamal et al., 2019[14]	a	a	a	a	a,b	a	a	Not applicable	8 (low)
Ulusoy et al., 2014[23]	a	b	a	a	a	a	b	Not applicable	5 (moderate)

SN-OPT angle was measured in all twelve studies. The SN-CVT angle was measured in ten studies. The OPT/CVT angle was measured in eight studies. The CVT/EVT angle was measured in three studies. A total of 280 patients were included in this systematic review to assess the changes in the cervical spine following functional appliance treatment.

The meta-analysis was done to assess the changes in SN-OPT, SN-CVT, OPT/CVT and CVT/EVT angles with functional appliance therapy. Nine studies were included in the meta-analysis. One study by Kamal et al.[14] was not included in the meta-analysis as median data for the craniocervical parameters were mentioned. Ohnmeiss et al.[12] was also excluded due to lack of continuous data. Tecco et al.[24] study was excluded from meta-analysis as it included only female subjects. Random effects model was appropriate considering the heterogeneity and availability of greater number of included studies.

4.1. Upper cervical spine

A decrease in SN-OPT angle i.e., backward inclination of the upper cervical spine was reported in four studies.[13,14,23,24] Two out of four studies were judged as low RoB.[14,24] Non-significant changes in the upper cervical spine have been reported in six studies.[15–17,23,27,28] Ohnmeiss et al.[12] reported changes in the upper cervical spine but attributed to a combination of growth and functional appliances due to lack of control group. Ulusoy et al.[23] study was the only one to measure after a mean retention period of 2.5 years and reported a non-significant increase in SN-OPT angle in the post-retention phase.

Meta-analysis revealed an overall mean decrease in SN-OPT angle by 1.16° (95 % CI of −2.68 to 0.35, $I^2 = 6$ %) with low heterogeneity. This minimal change with a wide confidence interval was not clinically and statistically significant. Sub-group analysis revealed a decrease by 0.96° (95 % CI of −3.15 to 1.23) and 1.49° (95 % CI of −4.16 to 1.18) with removable and fixed functional appliances respectively (Fig. 3).

4.2. Middle cervical spine

Backward inclination of the middle cervical spine was reported in one study.[28] Significant increase in SN-CVT angle was reported in five studies with an overall high RoB in four studies.[13,17,24,26,27] Non-significant changes in the middle cervical spine inclination were reported by three studies with two studies having a low risk of bias and one with a high risk of bias.[15,17,23] However, patients included in two studies were older compared to other studies.[13,17]

Meta-analysis revealed an overall mean increase of SN-CVT angle by 2.20° (95 % CI of 0.46–3.94, $I^2 = 49$ %) with average heterogeneity. This change could be clinically relevant and was statistically significant. The data of Krishna et al.[13] contributed to the average heterogeneity. Sub-group analysis reported an increase of 1.90° (95 % CI of −0.09 to 3.90) and 2.66° (95 % CI of −0.97 to 6.29) with removable and fixed functional appliances respectively (Fig. 4).

4.3. Cervical curvature angle

Cervical curvature (OPT/CVT angle) was reported in seven studies.[13,15,17,23,25,26,28] Three studies reported a significant increase in cervical spine curvature.[25,26,28] However, all three studies did not include an untreated control group to only attribute the changes to the appliance. Non-significant changes were reported by the other studies with an overall moderate RoB.[15,17,25,27]

Meta-analysis revealed an increase of OPT-CVT angle by 1.60° (95 % CI of 0.12–3.09, $I^2 = 89$ %). The change could be clinically significant and was statistically significant. High heterogeneity was noted, primarily from the data of one study by Krishna et al.[13] Sub-group analysis showed an increase of 1.26° (95 % CI of −0.71 to 3.23) and 2.25° (95 % CI of −0.34 to 4.83) with removable and fixed functional appliances respectively (Fig. 5).

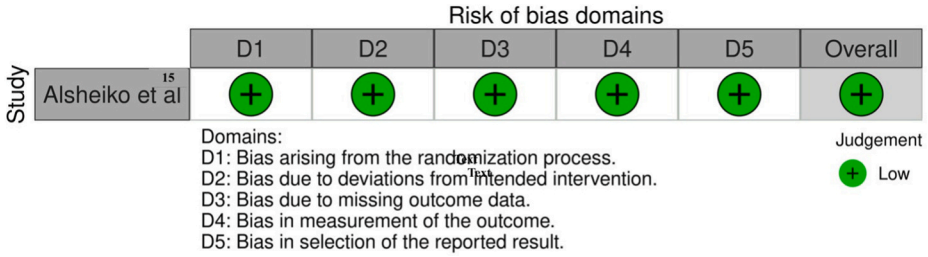

Fig. 2. Risk of bias using Cochrane RoB 2.0.

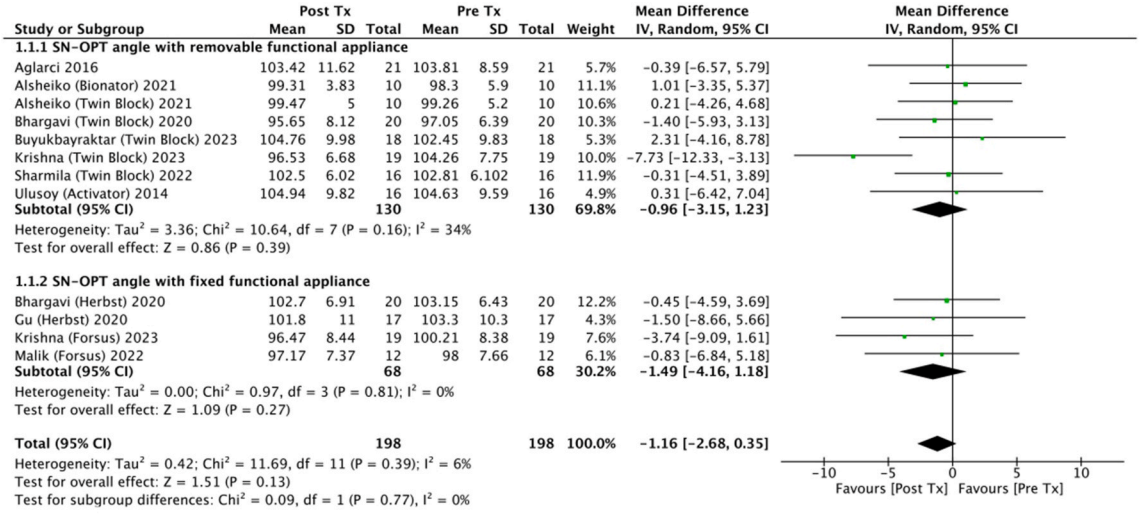

Fig. 3. Comparison of upper cervical inclination with functional appliance treatment.

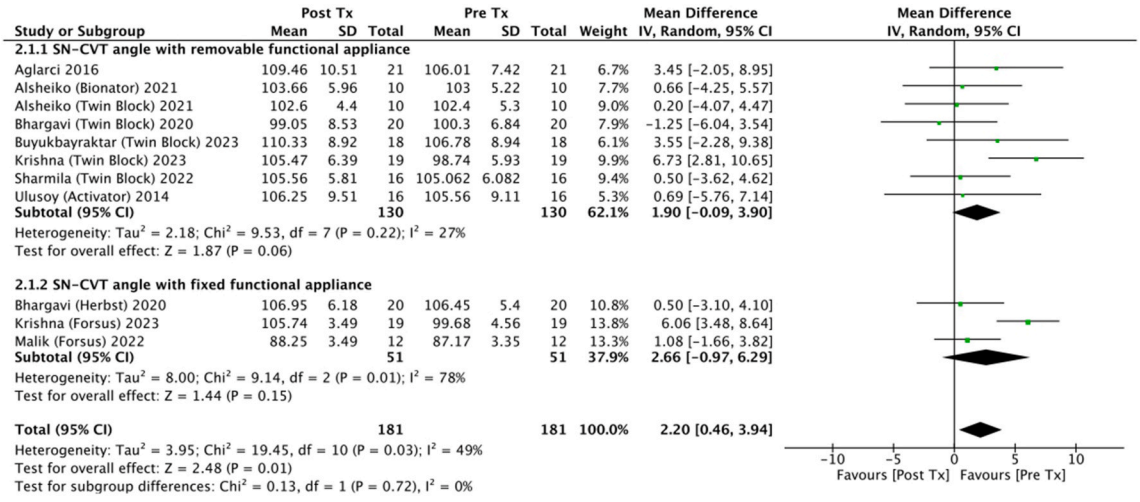

Fig. 4. Comparison of middle cervical inclination with functional appliance treatment.

4.4. Cervical lordosis angle

Cervical lordosis angle (CVT/EVT) was reported in three studies with removable functional appliances only.[15,24,27] Tecco et al.[24] study reported a significant increase in cervical lordosis angle. However, the study included only female subjects and the treatment duration was longer compared to other studies. Therefore, it was not included in the meta-analysis. Non-significant changes in lordosis angle were reported by the other two studies judged as low and high RoB.[15,27]

Meta-analysis revealed a decrease in CVT-EVT angle by 1.54° (95 % CI of −4.16 to 1.08, $I^2 = 0$ %). This change could be clinically significant but was not statistically significant. I^2 value revealed zero heterogeneity (Fig. 6).

4.5. Grading the quality of evidence

The quality of evidence was assessed using Grading of Recommendations, Assessment, Development and Evaluations (GRADE).[29] The quality of evidence is low for the upper and middle cervical inclination. Very low for cervical curvature angle and moderate for cervical lordosis

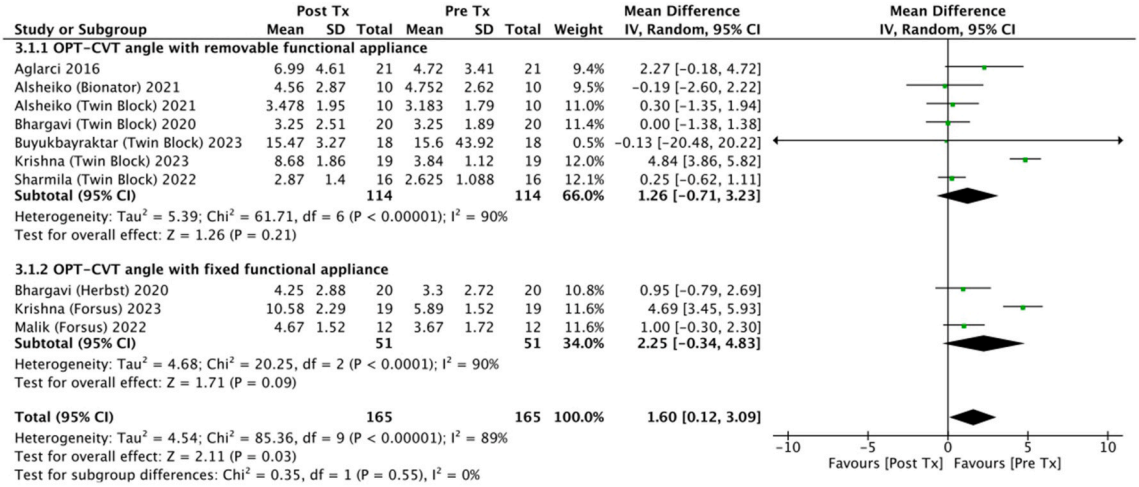

Fig. 5. Comparison of craniocervical curvature angle with functional appliance treatment.

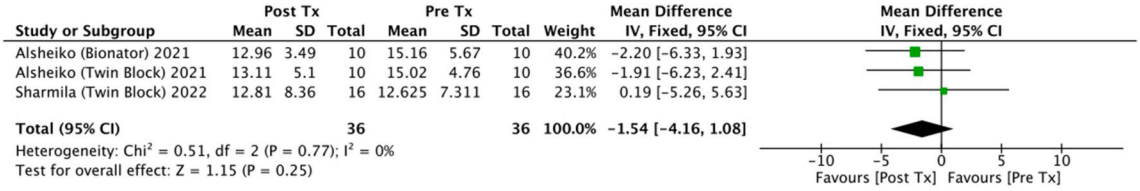

Fig. 6. Comparison of cervical lordosis angle with functional appliance treatment.

angle. Low represented that further research was likely to change the estimate. Very low indicated that the estimated effect was uncertain. Moderate indicated the possibility that true effect was close to the effect estimate. The details of the study's quality of evidence are presented in Table 5.

4.6. Heterogeneity assessment

Low heterogeneity was found with the comparison of pre and post-treatment changes in upper cervical spine inclination and cervical lordosis angle ($I^2 = 6$ % and 0 % respectively). Average heterogeneity was found for middle cervical spine inclination ($I^2 = 49$ %). High heterogeneity was found for cervical curvature angle ($I^2 = 89$ %)

5. Discussion

To the best of our knowledge, this is the first systematic review and meta-analysis evaluating the effects of functional appliance treatment on cervical spine postural alterations. This review clearly reported that the upper cervical spine was not significantly altered by functional appliances. The significant increase was noted only with middle cervical spine inclination.

The decrease of upper cervical inclination and increase in middle cervical inclination suggests uprighting or straightening of the cervical spine. This was supported by the studies of Kamal and Fida,[14] Krishna et al.,[13] and Smailiene et al.[30] who reported uprighting of the cervical spine with Twin Block appliance. Anatomically, the upper cervical spine borders the nasopharynx, while the middle and lower cervical spines enclose the oropharynx and hypopharynx. The decrease in upper cervical inclination can be correlated with the minimal changes noted in nasopharyngeal airway with functional appliance treatment. The increase in middle cervical inclination noted in this review can be linked to the increase in oropharynx and hypopharynx with functional appliance treatment as supported by previous systematic reviews.[31–33] The increase in cervical curvature with functional appliance treatment ranged from 0.1° to 3.1°. Meta-analysis revealed high heterogeneity for cervical spine curvature. However, on removal of the data from one study[13] the heterogeneity became low. (Supporting file 1) Minimal reduction of cervical lordosis angle was beneficial in Class II patients due to the presence of hyperlordosis. Although it was measured in three studies with removable functional appliances only, the certainty of evidence was moderate with low heterogeneity.

Meta-analysis of the cervical spine inclination, curvature and lordosis angles revealed varying heterogeneity from low to high. Low heterogeneity in upper cervical inclination and lordosis angle was probably due to similarity in the methodology of the included studies. Therefore, these findings can be generalized. However, caution should be exercised when interpreting the results of middle cervical inclination (moderate heterogeneity) and curvature angle (high heterogeneity), due to the wider confidence interval in the data presented in one study.[13] Additionally, funnel plot analysis revealed minimal publication bias, with skewness seen only from the data by one study.[13] (Fig. 7).

The GRADE assessment was scored from very low to moderate for the cervical spine parameters. Very low quality of evidence was given to cervical curvature angle as the overall quality of included studies was moderate, presence of historical control group and wider confidence interval limiting the applicability of the estimated effect. The evidence for cervical lordosis angle was considered moderate as the quality of included studies was moderate and there were no notable discrepancies in all the other domains. Low evidence was assigned for upper and middle cervical inclination due to considerable heterogeneity and moderate quality of the included studies (Table 5).

It should be highlighted that greater change occurred with fixed functional appliances than removable, which may be attributed to the full-time wear of the fixed functional appliance. However, the mean daily wear duration of the removable functional appliances was reported in the only one of the included studies.[14] The overall treatment duration was not mentioned in four studies.[13,15,25,26] Gender variation of the cervical spine posture has been mentioned in literature, where males exhibited a straight cervical spine curvature compared to females.[34]

Table 5
Quality assessment using GRADEpro.

Author(s):

Question: Changes in SN-OPT angle with functional appliance treatment

Setting:

Bibliography: Cervical spine changes with functional appliance treatment

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Changes in SN-OPT angle with functional appliance		Relative (95% CI)	Absolute (95% CI)		
SN-OPT angle with functional appliance												
12	1 randomised trial + 11 observational studies	serious[a]	not serious	serious[b]	not serious	none	198	198	-	MD **1.16 lower** (2.68 lower to 0.35 higher)	⊕⊕◯◯ Low	
SN-CVT with functional appliance												
10	1 randomised trial + 9 observational studies	serious[a]	not serious	serious[b]	not serious	none	181	181	-	MD **2.2 higher** (0.46 higher to 3.94 higher)	⊕⊕◯◯ Low	
OPT-CVT with functional appliance												
8	1 randomised trial + 7 observational studies	serious[c]	serious[d]	serious[b]	serious[e]	none	165	165	-	MD **1.6 higher** (0.12 higher to 3.09 higher)	⊕◯◯◯ Very low	
CVT-EVT with functional appliance												
3	1 randomised trial + 2 observational studies	serious[f]	not serious	not serious	not serious	none	36	36	-	MD **1.54 lower** (4.16 lower to 1.08 higher)	⊕⊕⊕◯ Moderate	

CI: confidence interval; **MD:** mean difference

Explanations

a. Six studies graded as high risk of bias

b. Historical control group used in one study

c. Five studies graded as high risk of bias

d. High heterogeneity noted with wider confidence intervals

e. Unexplained wide confidence interval in one study

f. Two studies with high risk of bias

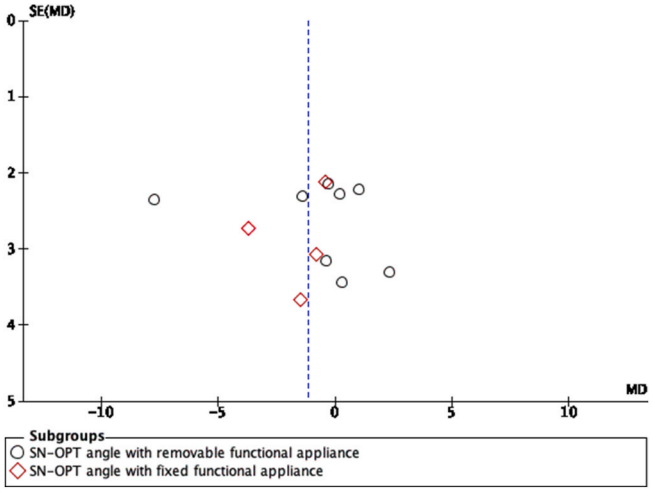

Fig. 7. Funnel plot.

Because Tecco's study exclusively included female subjects, it was not included in the meta-analysis.

It is important to understand the impact of functional appliance to the cervical spine. Reduction of cervical lordosis angle as a consequence of functional appliance treatment offers application of functional appliance for the management of cervical hyperlordosis. While oral appliances have been utilized to treat obstructive sleep apnea and orofacial pain, the therapeutic utility of oral appliances in management of cervical spine postural abnormalities remains unexplored. The potential application of functional appliances in the management of cervical spine hyperlordosis and alignment is highlighted in this systematic review.

6. Limitations and future directions

The limitations of the systematic review include lack of studies with long term follow up data. Only one study by Ulusoy et al.[23] study measured cervical spine inclination changes at the post-retention phase. The cervical spine postural changes were evaluated with a two-dimensional representation such as a lateral cephalogram in all the included studies. A three-dimensional radiograph of the cervical spine can aid in precise estimation of the cervical spine posture and rotational/lateral changes. Due to higher radiation dose, they are not routinely prescribed for orthodontic patients. Moreover, more research providing gender-specific data can yield an accurate estimation of the gender variability in cervical postural responses. The overall quality of studies were moderate and included a smaller sample size. Future research implicates to identify more high-quality, randomized controlled and multi-centric trials with larger samples and gender specificity along with long-term follow-up data to substantiate the results. Additionally, original research on the changes of cervical lordosis angle with fixed functional appliance are required.

7. Conclusion

On careful consideration of the quality of evidence and heterogeneity, the following conclusions were made.

Minimal uprighting of the cervical spine was noted with functional

appliances. Fixed functional appliances exerted a greater effect than removable functional appliances. Cervical hyperlordosis was reduced with removable functional appliance treatment. Though these changes are minimal, the clinical orthodontist should be aware that functional therapy also influences cervical spine posture. Due to the heterogeneity and low quality of evidence, the results are to be considered critically.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jobcr.2024.05.015.

References

1. Arumugam P, Padmanabhan S, Chitharanjan AB. The relationship of postural body stability and severity of malocclusion. *APOS Trends Orthod*. 2016 Jul;6:205–210. https://doi.org/10.4103/2321-1407.186436.
2. Cailliet R. Pain in the neck and arm. Diagnosis by history and examination. *Calif Med*. 1968;108(2):99–103.
3. Solow B, Siersbaek-Nielsen S. Cervical and craniocervical posture as predictors of craniofacial growth. *Am J Orthod Dentofacial Orthop*. 1992 May;101(5):449–458. https://doi.org/10.1016/0889-5406(92)70119-u.
4. Solow B, Sandham A. Cranio-cervical posture: a factor in the development and function of the dentofacial structures. *Eur J Orthod*. 2002 Oct;24(5):447–456. https://doi.org/10.1093/ejo/24.5.447.
5. Solow B, Siersbaek-Nielsen S, Greve E. Airway adequacy, head posture, and craniofacial morphology. *Am J Orthod*. 1984 Sep;86(3):214–223. https://doi.org/10.1016/0002-9416(84)90373-7.
6. Solow B, Kreiborg S. Soft-tissue stretching: a possible control factor in craniofacial morphogenesis. *Scand J Dent Res*. 1977 Sep;85(6):505–507. https://doi.org/10.1111/j.1600-0722.1977.tb00587.x.
7. Festa F, Tecco S, Dolci M, et al. Relationship between cervical lordosis and facial morphology in Caucasian women with a skeletal class II malocclusion: a cross-sectional study. *Cranio*. 2003 Apr;21(2):121–129. https://doi.org/10.1080/08869634.2003.11746240.
8. D'Attilio Michele, Caputi Sergio, Epifania Ettore, Festa Felice, Tecco Simona. Evaluation of cervical posture of children in skeletal class I, II, and III. *Cranio*. 2005 Jul;23(3):219–228. https://doi.org/10.1179/crn.2005.031.
9. Peng H, Liu W, Yang L, et al. Does head and cervical posture correlate to malocclusion? A systematic review and meta-analysis. *PLoS One*. 2022 Oct;17(10), e0276156. https://doi.org/10.1371/journal.pone.0276156.
10. Huggare J. Postural disorders and dentofacial morphology. *Acta Odontol Scand*. 1998;56(6):383–386. https://doi.org/10.1080/000163598428374.
11. Bishara SE, Ziaja RR. Functional appliances: a review. *Am J Orthod Dentofacial Orthop*. 1989;95(3):250–258. https://doi.org/10.1016/0889-5406(89)90055-3.
12. Ohnmeiß M, Kinzinger G, Wesselbaum J, Korbmacher-Steiner HM. Therapeutic effects of functional orthodontic appliances on cervical spine posture: a retrospective cephalometric study. *Head Face Med*. 2014 Mar;10:7. https://doi.org/10.1186/1746-160X-10-7.
13. Krishna SSS, Shashikumar B, Naik RD. Evaluation and comparison of cervical spine posture in class II division I patients treated with twin block appliances, Forsus appliances, and bilateral sagittal split osteotomy: a cephalometric study. *Contemp Clin Dent*. 2023;14(2):157–165. https://doi.org/10.4103/ccd.ccd_459_22.
14. Kamal AT, Fida M. Evaluation of cervical spine posture after functional therapy with twin-block appliances: a retrospective cohort study. *Am J Orthod Dentofacial Orthop*. 2019 May;155(5):656–661. https://doi.org/10.1016/j.ajodo.2018.06.012.
15. Alsheikho HO, Jomah DH, Younes M, Tizini M, Hassan H, Khalil F. Evaluation of head and cervical spine posture after functional therapy with Twin-Block and Bionator appliances: a pilot randomized controlled trial. *Cranio*. 2021 Apr;11:1–10. https://doi.org/10.1080/08869634.2021.1909455.
16. Gu M, Savoldi F, Chan EYL, et al. Changes in the upper airway, hyoid bone and craniofacial morphology between patients treated with headgear activator and Herbst appliance: a retrospective study on lateral cephalometry. *Orthod Craniofac Res*. 2021 Aug;24(3):360–369. https://doi.org/10.1111/ocr.12442.
17. Malik N, Fernandes BA, Ramamurthy PH, Anjum S, Prakash A, Sinha A. Cephalometric evaluation of the cervical spine posture following fixed functional therapy with Forsus™ appliance. *J Indian Soc Pedod Prev Dent*. 2022 Jan-Mar;40(1):81–85. https://doi.org/10.4103/jisppd.jisppd_173_21.
18. Carbajal-Rodriguez G, Langer ME, Yaya-Beas M, Liñán-Durán C, Lagravère M, Gianoni-Capenakas S. Effects of rapid maxillary expansion on head and cervical posture in growing patients: a systematic review. *Int Orthod*. 2022 Sep;20(3), 100658. https://doi.org/10.1016/j.ortho.2022.100658.
19. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021 Mar;29:372. https://doi.org/10.1136/bmj.n71.
20. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol*. 2010 Sep;25(9):603–605. https://doi.org/10.1007/s10654-010-9491-z.
21. Sterne JAC, Savović J, Page MJ, et al. Rob 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019 Aug, l4898. https://doi.org/10.1136/bmj.l4898.
22. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med*. 2002 Jun;21(11):1539–1558. https://doi.org/10.1002/sim.1186.
23. Ulusoy C, Bavbek NC, Tuncer BB, Tuncer C, Turkoz C, Gencturk Z. Evaluation of airway dimensions and changes in hyoid bone position following class II functional therapy with activator. *Acta Odontol Scand*. 2014 Nov;72(8):917–925. https://doi.org/10.3109/00016357.2014.923109.
24. Tecco S, Farronato G, Salini V, et al. Evaluation of cervical spine posture after functional therapy with FR-2: a longitudinal study. *Cranio*. 2005 Jan;23(1):53–66. https://doi.org/10.1179/crn.2005.009.
25. Bhargavi KG. *Cervical Spine Postural Changes Following Fixed and Removable Functional Appliance Therapy – A Comparative Study*. Sri Ramachandra Institute of Higher Education and Research; 2021 [Dissertation].
26. Buyukbayraktar ZC, Camci H. Dentoalveolar, skeletal, pharyngeal airway, cervical posture, hyoid bone position, and soft palate changes with Myobrace and Twin-block: a retrospective study. *BMC Oral Health*. 2023 Jan 30;23(1):53. https://doi.org/10.1186/s12903-023-02773-x.
27. Sharmila R, Balashanmugam B, Jain S, Nandhini A. Assessment of correction of cervical hypolordosis in class II skeletal patients with mandibular retrognathism after twinblock therapy. *Int. J. Innov. Sci. Technol* . 2022 May;7(5):217–227.
28. Aglarci C. Evaluation of cervical spine posture after functional therapy with twin-block appliances. *J Orthod Res*. 2016 Jan;4:6–12.
29. Guyatt GH, Oxman AD, Vist GE, et al. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008 Apr;336(7650):924–926.
30. Smailienė D, Intienė A, Dobradziejutė I, Kušleika G. Effect of treatment with twin-block appliances on body posture in class II malocclusion subjects: a prospective clinical study. *Med Sci Mon Int Med J Exp Clin Res*. 2017;23:343–352. https://doi.org/10.12659/msm.899088. Published 2017 Jan 20.
31. Anusuya V, Jena AK, Sharan J. Effects of functional appliance treatment on pharyngeal airway passage dimensions in Class II malocclusion subjects with retrognathic mandibles: a systematic review. *APOS Trends Orthod*. 2019 Jul-Sep;9(3):123–148. https://doi.org/10.25259/APOS_59_2019.
32. Ganesh G, Tripathi T. Effect of fixed functional appliances on pharyngeal airway dimensions in Skeletal Class II individuals - a scoping review. *J Oral Biol Craniofac Res*. 2021 Oct-Dec;11(4):511–523. https://doi.org/10.1016/j.jobcr.2021.07.004.
33. Kannan A, Sathyanarayana HP, Padmanabhan S. Effect of functional appliances on the airway dimensions in patients with skeletal class II malocclusion: a systematic review. *J Orthod Sci*. 2017 Apr-Jun;6(2):54–64. https://doi.org/10.4103/jos.JOS_154_16.
34. Visscher CM, de Boer W, Naeije M. The relationship between posture and curvature of the cervical spine. *J Manip Physiol Ther*. 1998 Jul-Aug;21(6):388–391.