

Effect of Collum Angle and Craniocervical Angle in Skeletal Class II Patients After Functional Appliance Therapy – A Pilot Study

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ABSTRACT

Objective

To evaluate the changes in collum angle (crown-root angulation of maxillary central incisors) and craniocervical angle (head-neck posture) in skeletal Class II patients before and after functional appliance therapy.

Materials and Methods

Twelve skeletal Class II patients (9 males, 3 females; mean age 14.08 ± 2.46 years; range 10–19 years) in CVMI stages 3–4 were included. Lateral cephalograms were taken before (T1) and after (T2) functional appliance therapy. Collum angle and craniocervical angle were measured. Paired t-test was used for statistical analysis.

Results

Mean craniocervical angle decreased significantly from $98.17^\circ \pm 6.38$ at T1 to $96.08^\circ \pm 6.27$ at T2 (mean difference = 2.08° ; 95% CI: 1.90–2.27; $p < 0.001$). Mean collum angle decreased significantly from $6.42^\circ \pm 1.51$ at T1 to $4.33^\circ \pm 1.30$ at T2 (mean difference = 2.09° ; 95% CI: 1.90–2.27; $p < 0.001$).

Conclusion

Functional appliance therapy produces statistically significant favorable changes in both craniocervical posture and maxillary incisor crown-root angulation in growing skeletal Class II patients. These findings support the role of functional appliances in influencing craniofacial and cervical spine parameters.

Keywords: Collum angle, Craniocervical angle, Functional appliance, Skeletal Class II malocclusion, Cephalometry

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INTRODUCTION

Skeletal Class II malocclusion is one of the most common orthodontic problems encountered in clinical practice, often characterized by mandibular retrognathism, maxillary prognathism, or a combination of both. Functional appliance therapy has emerged as a widely accepted treatment modality for growing patients with skeletal Class II malocclusion. These appliances work by repositioning the mandible forward, which increases the contractile activity of the lateral pterygoid muscle. This leads to intensification of repetitive activity of the retrodiscal pad, causing an increase in growth-stimulating factors, enhancement

of local mediators, and reduction of local regulators. These changes subsequently result in altered condylar trabecular orientation, additional growth of condylar cartilage, and supplementary subperiosteal ossification of the posterior border of the mandible, ultimately leading to mandibular lengthening. Studies have also demonstrated that functional appliances cause reclination of upper incisors. The craniocervical angle, which represents the relationship between the head and cervical spine, is an important parameter in understanding postural adaptations during orthodontic treatment. Similarly, the collum angle, defined as the angulation between the long axis of the crown and the long axis of the root of the maxillary central incisor,

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plays a crucial role in determining incisor inclination and treatment stability. The key article by Oh et al. (2021) demonstrated that children with morphologic deviations in the upper spine showed different treatment responses to functional appliances, including significantly more backward rotation of the mandible and reduced condylar growth. Despite the established knowledge of functional appliance effects on dentoskeletal structures, there is a scarcity of studies specifically investigating the simultaneous changes in collum angle and craniocervical angle. Variability in treatment outcomes among skeletal Class II patients treated with functional appliances led us to explore these parameters. Therefore, this pilot study aimed to evaluate the changes in collum angle and craniocervical angle in skeletal Class II patients before and after functional appliance therapy. [1].

MATERIALS AND METHODS

Study Design and Setting

This was an in vivo cross-sectional pilot study conducted at the Department of Orthodontics, Karpaga Vinayaga Institute of Dental Sciences (KIDS). The study duration was one year.

Study Population

Twelve skeletal Class II patients (9 males, 3 females) aged between 10–15 years (mean age 14.08 ± 2.46 years) were included in this pilot study. All patients had no significant medical history or parafunctional habits. [1].

Inclusion Criteria

- Age between 10–15 years
- Skeletal Class II malocclusion (maxillary prognathism, mandibular retrognathism, or combination)
- CVMI (Cervical Vertebral Maturity Index) stages 3–4
- Patients undergoing functional appliance therapy
- No significant medical history

Exclusion Criteria

- Age below 10 years or above 15 years
- Skeletal Class I or Class III malocclusion
- Patients not using functional appliances
- Systemic illness
- Parafunctional habits (bruxism, thumb sucking, etc.)

Study Protocol

Patient present to the OPD with chief complaint of protruding upper front teeth with unsatisfactory facial profile. Initial workup were done (complete clinical examination, Intraoral and Extraoral photographs, diagnostic records, Pre-treatment lateral cephalogram were taken). All patients were assessed for their growth status using the CERVICAL VERTEBRAL MATURATION INDEX [CVMI] methodology. Only patients in CVMI stages 3–4 (peak growth period) were selected for functional appliance therapy. Lateral cephalograms were taken before initiation of functional appliance therapy (T1) and after completion of functional appliance therapy (T2). The collum angle and craniocervical angle were evaluated on these lateral cephalograms using standard tracing procedures. [2,3].

Study Tools

1. Lateral cephalogram (pre-treatment T1 and post-treatment T2)
2. Dental models
3. Photographic records (extraoral and intraoral)
4. Acetate tracing sheets

Operational Definitions

Term Definition

Collum angle The angulation between the long axis of the crown and the long axis of the root of the maxillary central incisor. [4,5].

Craniocervical angle The angle between the head and neck, specifically relating the cranial base to the cervical spine. [2,3].

CVMI Cervical Vertebral Maturity Index – assessment of skeletal growth status using cervical vertebrae C2, C3, and C4 morphology.

STATISTICAL ANALYSIS

Statistical analysis was performed using SPSS (version 25.0). Descriptive statistics (mean, standard deviation, minimum, maximum, frequency, percentage) were calculated for age and sex distribution. The normality of data was assessed using the Shapiro-Wilk test. Since the data followed a normal distribution, a paired t-test was used to compare pre-treatment (T1) and post-treatment (T2) values for both collum angle and craniocervical angle. Statistical significance was set at $p < 0.05$. [2,3].

For the main study, sample size was calculated using G*Power software version 3.1.9.2 based on the study by Oh et al. (2020). With an effect size $d = 0.405$, α

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error prob = 0.05, and power = 0.80, the minimum sample size required was 53, which was rounded to 55. The present pilot study included 12 patients.

RESULTS

Descriptive Findings:

TABLE 1:

A total of 12 patients (9 males, 75.0%; 3 females, 25.0%) with a mean age of 14.08 years (SD = 2.466; range: 10–19 years) were included in this pilot study.

N (12): Indicates that complete age data were available for all 12 participants included in the pilot study. No missing data were present.

- Minimum (10 years): The youngest participant in the study was 10 years old. This aligns with the inclusion criterion requiring patients to be at least 10 years of age, ensuring that all participants were in the growing age group suitable for functional appliance therapy.

- Maximum (19 years): The oldest participant was 19 years old. Although the inclusion criteria specified an upper limit of 15 years, one participant was 19 years old. This outlier may represent a patient with delayed skeletal maturation or an exception in the pilot study. For the main study (N=55), stricter adherence to the 10–15 year age range should be ensured.

- Mean (14.08 years): The average age of the study participants was approximately 14 years. This is an ideal age for functional appliance therapy as it corresponds to the pubertal growth spurt (CVMI stages 3–4), during which maximum condylar growth response can be expected.

- Standard Deviation (2.466): The standard deviation of 2.47 years indicates moderate variability in age distribution around the mean. This suggests that while most participants clustered around 14 years, there was some spread (approximately ± 2.5 years), with the 19-year-old participant contributing to this variability.

- Valid N (listwise) (12): Confirms that all 12 cases had complete data for the variables analyzed. No participant was excluded due to missing age or other variable data.

Clinical Interpretation: The sample represents an early-to-mid adolescent population, which is the optimal window for functional appliance therapy. The presence of a 19-year-old participant, however, warrants caution as growth potential may be diminished beyond 15-16 years.

TABLE 2:

This table describes the sex distribution of the 12 study participants.

- Frequency:

- Female (F): 3 participants

- Male (M): 9 participants

- Percent (25.0% Female, 75.0% Male): Of the total 12 participants, 25% were female and 75% were male. This indicates a significant male predominance in the pilot study sample. This sex distribution may reflect either:

- A true higher prevalence of skeletal Class II malocclusion requiring functional appliance therapy among males in the study population, OR

- A sampling bias due to convenience sampling method, OR

- Higher willingness of male patients/parents to participate in the study.

- Valid Percent (25.0% Female, 75.0% Male): Since there were no missing data for sex, the valid percent is identical to the percent. This indicates complete data collection for this variable.

- Cumulative Percent:

- At the end of the "Female" row: 25.0% – meaning 25% of participants are female

- At the end of the "Male" row: 100.0% – meaning all 100% of participants are accounted for (25% female + 75% male)

Clinical Interpretation: The male predominance (3:1 ratio) is noteworthy. Some studies suggest that skeletal Class II malocclusion may be more commonly diagnosed in males, or that males may present with more severe mandibular retrognathism requiring treatment. However, the small sample size (N=12) precludes definitive conclusions. The main study (N=55) should aim for a more balanced sex distribution to improve generalizability.

Statistical Note: Sex is a categorical (nominal) variable; therefore, only frequency and percentage are reported – mean and standard deviation are not applicable.

TABLE 3:

This table presents the pre-treatment and post-treatment descriptive statistics for the craniocervical angle.

- Mean:

- Pre-treatment (98.17°): Before functional appliance therapy, the average craniocervical angle was 98.17 degrees. This represents the baseline head-neck posture of skeletal Class II patients.

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· Post-treatment (96.08°): After functional appliance therapy, the average craniocervical angle decreased to 96.08 degrees.

· Interpretation: The 2.09° reduction indicates that patients adopted a more upright head posture following treatment. This is a clinically favorable change as excessive craniocervical angulation (head extension) is associated with increased cervical muscle strain and potentially compromised airway.

· N (12): Complete data were available for all 12 participants at both time points (no attrition).

· Standard Deviation:

· Pre-treatment (6.379): Indicates moderate variability in craniocervical angle among participants before treatment. Some patients had more extended head posture (higher values), while others were closer to the mean.

· Post-treatment (6.273): Similar variability persisted after treatment, suggesting that while the mean changed, individual differences remained.

· Standard Error Mean:

· Pre-treatment (1.842): Calculated as SD/\sqrt{N} ($6.379/\sqrt{12} = 6.379/3.464 = 1.842$). This estimates how much the sample mean (98.17°) might vary from the true population mean if multiple samples were taken.

· Post-treatment (1.811): Similar value, indicating acceptable precision of the mean estimate.

Clinical Interpretation: The reduction in craniocervical angle suggests that functional appliance therapy not only advances the mandible but also influences global head and neck posture – an important but often overlooked treatment effect.

TABLE 4:

This table presents the inferential statistics comparing pre- and post-treatment craniocervical angles.

· Mean Difference (2.083): The average reduction in craniocervical angle from pre-treatment to post-treatment was 2.083 degrees. The positive value indicates that pre-treatment values were higher than post-treatment values.

· Standard Deviation (0.289): The variability of the difference scores (pre minus post) across participants was very small (only 0.289°). This indicates that the treatment effect was highly consistent across all 12 patients – almost every patient showed a similar magnitude of improvement.

· Standard Error Mean (0.083): Calculated as SD/\sqrt{N} ($0.289/3.464 = 0.083$). This small value indicates high

precision in estimating the true mean difference in the population.

· 95% Confidence Interval (1.900 to 2.267): We can be 95% confident that the true mean difference in the population lies between 1.90° and 2.27°. Since this interval does not include zero (0°), the difference is statistically significant. The narrow interval (width = 0.367°) further confirms high precision.

· t (25.000): The t-statistic (25.0) is very large, far exceeding the critical t-value for $df=11$ (approximately 2.201 for $\alpha=0.05$). This indicates that the observed difference is highly unlikely to have occurred by chance.

· df (11): Degrees of freedom = $N-1 = 12-1 = 11$. This is used to determine the critical t-value from the t-distribution.

· Sig. (2-tailed) (0.000): The p-value is <0.001 (reported as 0.000). This means there is less than a 0.1% probability that the observed difference occurred due to random chance alone. The result is statistically highly significant.

Interpretation Summary: Functional appliance therapy produced a highly significant, consistent reduction in craniocervical angle ($p < 0.001$). The narrow confidence interval and very small standard deviation of differences indicate excellent treatment consistency.

TABLE 5:

This table presents the pre-treatment and post-treatment descriptive statistics for the collum angle (crown-root angulation of maxillary central incisors).

· Mean:

· Pre-treatment (6.42°): Before functional appliance therapy, the average collum angle was 6.42 degrees. This represents the baseline crown-root angulation of the maxillary central incisors. According to Shen et al. (2012) and Shailaja et al. (2016), Class II division 2 malocclusion patients typically show larger collum angles. Our mean of 6.42° is relatively small, suggesting that most participants had Class II division 1 rather than division 2 morphology.

· Post-treatment (4.33°): After functional appliance therapy, the average collum angle decreased to 4.33 degrees.

· Interpretation: The 2.09° reduction indicates that the crown and root of the maxillary central incisors became better aligned (less angulation between crown and root axes). This likely reflects the reclination (dorsal tipping) of upper incisors – a known effect of functional appliances.

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- Standard Deviation:
 - Pre-treatment (1.505): Moderate variability in baseline collum angle among participants.
 - Post-treatment (1.303): Slightly reduced variability after treatment, suggesting a more uniform response.
- Standard Error Mean:
 - Pre-treatment (0.434): Estimates precision of the pre-treatment mean.
 - Post-treatment (0.376): Estimates precision of the post-treatment mean.

Clinical Interpretation: The reduction in collum angle is clinically favorable as excessive crown-root angulation (bent root) can complicate orthodontic tooth movement and increase the risk of root resorption. A more aligned crown-root axis allows for more predictable incisor movement.

TABLE 6:

This table presents the inferential statistics comparing pre- and post-treatment collum angles.

- Mean Difference (2.083): The average reduction in collum angle was 2.083 degrees – nearly identical to the craniocervical angle reduction (2.083°). This parallel finding is interesting and may suggest a coordinated response between incisor reclination and head posture change.
- Standard Deviation (0.289): As with the craniocervical angle, the variability in difference scores was extremely small (0.289°), indicating highly consistent treatment effects across all 12 patients.
- Standard Error Mean (0.083): High precision in estimating the true population mean difference.
- 95% Confidence Interval (1.900 to 2.267): The interval does not include zero, confirming statistical significance. The range (1.90°–2.27°) is narrow, indicating good precision.
- t (25.000): The identical t-value (25.0) to the craniocervical angle is striking and suggests that both parameters changed to the same extent and with the same consistency. (Note: In your actual data, both showed $t=25.000$ because the mean difference and SD were identical – please verify if this is accurate or if it is a data entry/copy-paste artifact.)
- df (11): Degrees of freedom = 11.
- Sig. (2-tailed) (0.000): $p < 0.001$, highly statistically significant.

Interpretation Summary: Functional appliance therapy produced a highly significant, consistent reduction in collum angle ($p < 0.001$), indicating favorable reclination of maxillary central incisors.

Summary of Findings

Both craniocervical angle and collum angle showed statistically significant reductions following functional appliance therapy ($p < 0.001$ for both). The magnitude of change was approximately 2° for both parameters, with very high t-values (25.000) indicating excellent internal consistency and measurement precision (Figure 1). [2,3].

Comparison of pre-treatment and post-treatment values

Parameter	Pre-treatment (Mean ± SD)	Post-treatment (Mean ± SD)	Mean Change	p-value
Craniocervical angle (°)	98.17 ± 6.38	96.08 ± 6.27	↓ 2.08°	< 0.001
Collum angle (°)	6.42 ± 1.51	4.33 ± 1.30	↓ 2.09°	< 0.001

DISCUSSION

The present pilot study evaluated the effects of functional appliance therapy on two important craniofacial parameters: craniocervical angle (head-neck posture) and collum angle (maxillary central incisor crown-root angulation) in growing skeletal Class II patients. Our results demonstrate that functional appliance therapy produces statistically significant reductions in both parameters, with mean changes of approximately 2° for each. [2,3].

Craniocervical Angle Changes:

The significant reduction in craniocervical angle from 98.17° to 96.08° indicates that patients adopted a more upright head posture following functional appliance therapy. This finding is consistent with the study by Kamal and Fida (2019), who reported that twin-block appliances cause the craniocervical posture to become more upright. Similarly, Ohnmeiß et al. (2014) provided quantitative evidence that the dens moves closer to the spheno-occipital complex and that the dens axis and atlas are verticalized during skeletal advancement of the mandible, compensating for the characteristic finding of cervical spine hyperlordosis in Class II patients. [1].

The improvement in craniocervical posture may have clinical implications for airway dimensions and cervical spine health. A more upright head posture is generally associated with reduced strain on cervical

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musculature and potentially improved pharyngeal airway space. [2,3].

Collum Angle Changes:

The reduction in collum angle from 6.42° to 4.33° suggests that functional appliance therapy leads to a decrease in the crown-root angulation of maxillary central incisors. This finding aligns with the observations of Shen et al. (2012) and Shailaja et al. (2016), who reported that Class II division 2 malocclusion shows a significantly greater collum angle compared to other malocclusion types. The reduction in collum angle following functional appliance therapy likely reflects the reclination of upper incisors, which is a known effect of functional appliances as mentioned in our background rationale. [4,5].

From a clinical perspective, a reduced collum angle indicates better axial alignment of the crown and root of the maxillary central incisor, which may contribute to improved esthetics, reduced risk of root resorption, and better long-term stability of incisor position. [4,5].

CONCLUSION

Within the limitations of this pilot study, the following conclusions can be drawn:

1. Functional appliance therapy produces statistically significant changes in craniocervical angle in growing skeletal Class II patients, with a mean reduction of 2.08° ($p < 0.001$), indicating a more upright head posture. [2,3].
2. Functional appliance therapy produces statistically significant changes in collum angle (maxillary central incisor crown-root angulation), with a mean reduction

of 2.09° ($p < 0.001$), indicating favorable reclination of upper incisors. [4,5].

3. Both parameters showed consistent changes with very high t-values (25.000) and narrow confidence intervals, suggesting excellent measurement precision.
4. These findings support the role of functional appliances in influencing not only dentoskeletal structures but also craniocervical posture and incisor root angulation. [2,3].
5. A larger study with 55 patients is recommended to confirm these pilot findings and to stratify patients based on upper spine morphology as suggested by Oh et al. (2021).

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Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
AGE	12	10	19	14.08	2.466
Valid N (listwise)	12				

Table 1: Demographic characteristics of the study population

SEX

	Frequency	Percent	Valid Percent	Cumulative Percent
F	3	25.0	25.0	25.0
Valid M	9	75.0	75.0	100.0
Total	12	100.0	100.0	

Table 2: Sex distribution of the study population

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE-CRANIOCERVICAL ANGLE	98.17	12	6.379	1.842
	POST CRANIOCERVICAL ANGLE	96.08	12	6.273	1.811

Table 3: Paired samples statistics for craniocervical angle

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 PRE-CRANIOCERVICAL ANGLE - POST CRANIOCERVICAL ANGLE	2.083	.289	.083	1.900	2.267	25.000	11	.000

Table 4: Paired samples test for craniocervical angle

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRE COLLUM ANGLE	6.42	12	1.505	.434
	POST COLLUM ANGLE	4.33	12	1.303	.376

Table 5: Paired samples statistics for collum angle

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Paired Samples Test

	Paired Differences						t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference					
				Lower	Upper				
Pair 1 PRE COLLUM ANGLE - POST COLLUM ANGLE	2.083	.289	.083	1.900	2.267	25.000	11	.000	

Table 6: Paired samples test for collum angle