

Cephalometric Evaluation of Effect of Forsus Fatigue Resistant Device (FFRD) on the Inclination of Occlusal Plane in Patients with Class II Malocclusion: A Cross-Sectional Study

Dr. Priyanjali Bharmal¹; Dr. Kishor Chougule²;
Dr. Sangeeta Golwalkar³; Dr. Vikranth Shetty⁴

¹Post-Graduate Student; ²Professor and Guide; ³Professor & HOD; ⁴Professor
^{1;2;3;4}Department of Orthodontics and Dentofacial Orthopedics, Tatyasaheb Kore Dental College and
Research Centre, Kolhapur, Maharashtra

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Abstract: Fixed functional appliances such as Forsus are widely used for Class II correction and produce both skeletal and dentoalveolar changes that may influence occlusal-plane inclination. The occlusal plane is an important determinant of dentofacial aesthetics and function, and Class II facial patterns generally exhibit a steeper inclination. Although both clockwise and anticlockwise occlusal-plane rotations have been reported, evidence regarding the specific effects of Forsus therapy remains limited.

➤ Method:

The sample comprised 70 subjects: 35 treated with Forsus FFRD combined with fixed orthodontic mechanotherapy and 35 treated with fixed mechanotherapy alone as controls.

Occlusal-plane inclination was assessed using OP-SN and OP-MP angular measurements.

Changes from T1 to T2 were evaluated to determine the effect of Forsus therapy on occlusal-plane inclination.

➤ Results:

In the Forsus group, SN-OP showed predominantly clockwise rotation (34/35), whereas OP-MP showed predominantly counterclockwise rotation (31/35).

In the Control group, SN-OP showed 18 counterclockwise, 13 clockwise, and 4 cases with no rotation, while OP-MP showed predominantly clockwise rotation (29/35).

The intergroup difference in the frequency and direction of occlusal-plane rotation was statistically significant ($p < 0.001$).

➤ Interpretation and Conclusion:

These findings indicate that Forsus treatment produced a consistent clockwise SN-OP and counterclockwise OP-MP rotational pattern, unlike the more variable control response.

Keywords: Forsus, Occlusal Plane.

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I. INTRODUCTION

Class II malocclusion is a common orthodontic problem that may adversely affect facial aesthetics, smile characteristics, and masticatory and respiratory functions.^{1,2} Skeletal Class II malocclusion is primarily associated with mandibular retrognathia, although maxillary prognathism may also contribute.³ Mandibular retrognathia has been reported as the most common underlying skeletal component of Class II malocclusion.⁴ Consequently, various functional appliances have been developed to promote mandibular advancement and improve the sagittal jaw relationship.

Fixed functional appliances are widely used for the correction of Class II malocclusion because they require minimal patient compliance and can be used concurrently with fixed orthodontic appliances.³ The Forsus Fatigue Resistant Device (FFRD; 3M Unitek, Monrovia, CA, USA) is a commonly used fixed functional appliance incorporating a semirigid telescoping mechanism that permits mandibular advancement while allowing some flexibility in mandibular position. Previous studies have demonstrated that Forsus therapy produces both skeletal and dentoalveolar effects, including reduction of overjet and overbite, retroclination of maxillary incisors, proclination and mesial movement of mandibular teeth, and changes in molar position.⁴ These treatment-related dental and skeletal changes may consequently influence the inclination of the occlusal plane.

The occlusal plane is an important determinant of dentofacial aesthetics and function and is associated with facial morphology, masticatory dynamics, and smile aesthetics.^{5,6} The inclination of the occlusal plane has also been related to facial type, with Class II facial patterns generally exhibiting a relatively steeper occlusal-plane inclination.⁶ Although changes in occlusal-plane inclination following fixed functional appliance therapy have been reported, both clockwise and anticlockwise rotations have been described in the literature.⁴ Evidence specifically evaluating the effect of the Forsus appliance on occlusal-plane inclination remains limited.

Therefore, the present study aimed to evaluate changes in occlusal-plane inclination in patients with Class II malocclusion treated with the Forsus Fatigue Resistant Device compared with patients undergoing fixed orthodontic treatment alone. The study also evaluated the associated skeletal and soft-tissue changes.

II. MATERIALS AND METHODS

A total of 70 subjects with skeletal Class II malocclusion on account of mandibular retrognathia were included in the present retrospective study. The case records were obtained from the Department of Orthodontics and Dentofacial Orthopaedics, TKDC and RC. The sample consisted of 35 subjects treated with the Forsus Fatigue Resistant Device (FFRD) in conjunction with fixed orthodontic mechanotherapy (Forsus group; 18 males and 17 females) and 35 subjects treated with fixed orthodontic mechanotherapy alone (control group). The sample size was

determined in consultation with a statistician, and subjects were selected using simple random sampling.

The inclusion criteria were as follows: (1) skeletal Class II malocclusion due to mandibular retrognathia, (2) positive visual treatment objective (VTO), (3) overjet of at least 7 mm, (4) age between 16 and 25 years, and (5) ANB angle greater than 5°. The exclusion criteria were: (1) vertical growth pattern, (2) temporomandibular joint disorders, (3) borderline Class II malocclusion with an overjet less than 5 mm, and (4) Class III malocclusion. Records of poor-quality radiographs were excluded from the study.

In the Forsus group, patients were treated with fixed orthodontic appliances and the Forsus FFRD. The appliance was placed when the patients were stabilized on 0.019 × 0.025-inch Stainless Steel archwires. The Forsus appliance was subsequently removed after completion of the functional appliance phase. The control group underwent fixed orthodontic mechanotherapy alone without the use of a functional appliance.

The effects of Forsus therapy were evaluated using lateral cephalometric radiographs obtained at two time points. For the Forsus group, T1 represented the pre-functional appliance stage, when the patient was on 0.019 × 0.025-inch Stainless Steel archwires and immediately before placement of the Forsus appliance. T2 represented the stage immediately after removal of the Forsus appliance. For the control group, T1 represented the stage when the patient was on 0.019 × 0.025-inch stainless steel archwires, and T2 represented the corresponding assessment after 6 months of fixed orthodontic treatment.

Standardized lateral cephalometric radiographs were obtained and digitally photographed using a Canon EOS 1500D digital SLR camera. The images were imported into OneCeph cephalometric software for tracing and analysis. Skeletal and soft-tissue landmarks were identified, and the relevant cephalometric measurements were recorded at T1 and T2.

The inclination of the occlusal plane was evaluated using two angular measurements: (1) the angle between the occlusal plane and the sella-nasion (SN) plane (OP-SN) and (2) the angle between the occlusal plane and the mandibular plane (OP-MP). Changes in these measurements between T1 and T2 were assessed to determine the effect of Forsus therapy on occlusal-plane inclination.

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS), version 19.0 (IBM, Armonk, NY). Continuous variables were expressed as mean ± standard deviation (SD). Changes between T1 and T2 within each group were evaluated using the paired t test, whereas comparisons between the Forsus and control groups were performed using the unpaired t test. The Mann–Whitney U test was used to compare the frequency of occlusal-plane rotation between the groups, and Fisher's exact test was used to assess the association between treatment group and

frequency of occlusal-plane rotation. A *P*-value <0.05 was considered statistically significant.

III. RESULTS

The changes in the skeletal and functional occlusal plane relationships between T1 and T2 in the Study group (Forsus) and Control group (fixed appliances) are presented in Tables 1–7.

The intergroup comparison of the change in SN-OP angle (T2–T1) revealed a statistically significant difference between the Study and Control groups. The mean difference between the two groups was 3.800°, which was statistically significant ($p < 0.001$; $t = 13.048$). Similarly, a statistically significant difference was observed in the change in OP-MP angle (T2–T1) between the two groups, with a mean difference of -3.771° ($p < 0.001$; $t = -6.375$).

Intragroup comparison of the SN-OP angle demonstrated a statistically significant change in the Study group, with a mean change of 3.514° between T1 and T2 ($p < 0.001$; $t = 10.684$). In contrast, the Control group showed a mean change of -0.286° , which was not statistically significant ($p = 0.625$; $t = -0.493$).

For the OP-MP angle, the Study group demonstrated a statistically significant mean change of -2.143° between T1 and T2 ($p < 0.001$; $t = -4.600$). The Control group also demonstrated a statistically significant change, with a mean increase of 1.629° ($p < 0.001$; $t = 4.467$).

A statistically significant association was observed between the type of rotation in the SN-OP angle (T2–T1) and the treatment groups ($p < 0.001$). Similarly, a statistically significant association was observed between the type of rotation in the OP-MP angle (T2–T1) and the treatment groups ($p < 0.001$).

Based on the direction of rotation, in the Study group, the SN-OP angle demonstrated counterclockwise (CCW) rotation in one case and clockwise (CW) rotation in 34 cases, with no cases showing absence of rotation. For the OP-MP angle in the Study group, 31 cases demonstrated counterclockwise rotation and 4 cases demonstrated clockwise rotation, while none showed absence of rotation.

In the Control group, the SN-OP angle demonstrated counterclockwise rotation in 18 cases, clockwise rotation in 13 cases, and no rotation in 4 cases. For the OP-MP angle, 3 cases demonstrated counterclockwise rotation, 29 cases demonstrated clockwise rotation, and 3 cases showed no rotation. Overall, the intergroup comparison demonstrated a statistically significant difference in the frequency and direction of rotation between the Study and Control groups ($p < 0.001$).

IV. DISCUSSION

The present study evaluated the effect of the Forsus Fatigue Resistant Device (FRD) on occlusal plane inclination

during correction of Class II malocclusion, with conventional fixed appliance therapy serving as the control. The findings demonstrated significant changes in both SN-OP and OP-MP angles in the Forsus group, with a distinct pattern of occlusal plane rotation compared with the control group. The results suggest that Forsus therapy produces significant dentoalveolar changes that influence the orientation of the occlusal plane during Class II correction.

A highly significant increase in the SN-OP angle was observed in the Forsus group, with a mean change of 3.514° ($p < 0.001$), indicating clockwise rotation of the occlusal plane relative to the cranial base. This finding was also clinically consistent, as 34 of 35 patients demonstrated clockwise rotation, while only one patient showed counterclockwise rotation. These findings are in agreement with Linjawi et al. (2018)¹, who reported a significant increase in occlusal plane inclination following Forsus therapy and suggested that the predominant effects of the appliance were dentoalveolar rather than skeletal. Similarly, Li et al. (2020)⁴ reported significant clockwise rotation of the functional occlusal plane following fixed functional appliance therapy, which was primarily attributed to mesial movement and extrusion of the mandibular molars, together with retroclination and extrusion of the maxillary incisors and proclination of the mandibular incisors.

Heinig and Göz (2001)⁷ also reported approximately 4.2° clockwise rotation of the occlusal plane following Forsus spring therapy. They suggested that the continuous forces generated by the appliance produce dentoalveolar changes that subsequently result in tipping of the occlusal plane. Similar findings were reported by Gunay et al. (2011)⁸, who observed approximately 5.33° clockwise rotation of the occlusal plane after Forsus treatment. Cacciatore et al. (2014)⁹ further demonstrated significant posterior rotation of the occlusal plane during the active Forsus phase, although this change was partially reversed by the end of comprehensive treatment, suggesting that the rotational effect may be influenced by the overall mechanics and timing of treatment.

The clockwise rotation observed in the present study may therefore be explained predominantly by the vertical and sagittal dentoalveolar effects of Forsus therapy. Previous studies have reported mesial movement and extrusion of the mandibular molars together with changes in maxillary and mandibular incisor inclination following Forsus treatment.^{4,10} These tooth movements can alter the inclination of the functional occlusal plane and account for the significant increase in SN-OP observed in the present study. The occlusal plane is influenced by tooth eruption, molar movement, incisor inclination, mandibular rotation and the surrounding muscular environment; therefore, even relatively small vertical tooth movements may result in clinically relevant changes in its inclination.^{11, 12}

In contrast to SN-OP, the OP-MP angle demonstrated a significant reduction of 2.143° in the Forsus group ($p < 0.001$), indicating a predominant counterclockwise change in the relationship between the occlusal and mandibular planes.

This finding was particularly evident from the distribution of rotational changes, with 31 of 35 Forsus-treated patients showing counterclockwise rotation and only four showing clockwise rotation. Thus, the Forsus appliance produced a different rotational response when the occlusal plane was evaluated relative to the mandibular plane than when it was evaluated relative to the cranial base.

The apparent difference between the SN-OP and OP-MP findings may be explained by the independent rotational behavior of the occlusal and mandibular planes. While Forsus produced a clockwise change in the occlusal plane relative to SN, growth-related or treatment-related mandibular rotation may have altered the OP-MP relationship. Sakuno et al. (2019)¹³ reported counterclockwise mandibular rotation following Forsus treatment despite clockwise rotation of the occlusal plane, supporting the possibility that occlusal and mandibular plane changes do not necessarily occur in the same direction. Similarly, Matthaios et al. (2022)¹⁴ reported that individual growth patterns and vertical dentoalveolar adaptations may modify mandibular rotation during Forsus therapy.

The control group demonstrated a significantly different response. The SN-OP angle showed no statistically significant intra-group change (-0.286° , $p = 0.625$), while the OP-MP angle increased significantly by 1.629° ($p < 0.001$). The distribution of rotational changes was also more variable in the control group. For SN-OP, 18 patients demonstrated counterclockwise rotation, 13 showed clockwise rotation and 4 showed no rotation. For OP-MP, 29 patients demonstrated clockwise rotation, 3 counterclockwise rotation and 3 showed no rotation. This greater variability may reflect the absence of a fixed functional appliance and the influence of conventional orthodontic mechanics, including leveling and alignment, incisor inclination, molar extrusion, archwire mechanics and anchorage changes.

The significant differences observed between the Forsus and control groups further emphasize the appliance-dependent nature of occlusal plane changes. The intergroup difference for SN-OP was 3.800° ($p < 0.001$), while the difference for OP-MP was -3.771° ($p < 0.001$). Moreover, a highly significant association was observed between treatment group and the direction of rotation for both SN-OP and OP-MP ($p < 0.001$). These findings indicate that Forsus therapy does not simply produce the same vertical changes associated with conventional fixed appliance treatment but establishes a characteristic rotational pattern of the occlusal plane.

The clinical significance of these findings lies in the relationship between occlusal plane inclination, mandibular position and facial esthetics. Changes in the occlusal plane can influence mandibular rotation, lower facial height, chin projection and overall facial balance. Bowman and

Johnston¹² emphasized that excessive changes in occlusal plane inclination may reflect inadequate vertical control and may have implications for treatment stability. Therefore, the significant clockwise rotation of SN-OP observed with Forsus should be considered during treatment planning, particularly in patients with a hyperdivergent growth pattern or increased lower facial height.

The predominantly counterclockwise OP-MP response observed in the Forsus group may, however, be favorable in selected patients because forward mandibular rotation can potentially improve chin projection and facial balance. The final clinical effect is likely to depend on the patient's underlying skeletal pattern, growth potential, vertical dentoalveolar changes and direction of appliance force. Thus, the rotational effects of Forsus should not be considered universally favorable or unfavorable but should be interpreted according to the individual skeletal and vertical characteristics of the patient.

The findings of the present study also have implications for vertical control during Forsus therapy. Previous evidence suggests that incorporation of skeletal anchorage can modify the dentoalveolar effects of Forsus and reduce undesirable vertical changes. Liu et al. (2021)¹⁵ reported that Forsus combined with temporary anchorage devices, particularly miniplates, may reduce intrusive/extrusive side effects and may facilitate a flatter or slightly counterclockwise occlusal plane. This highlights the potential value of careful anchorage and vertical control when treating patients in whom excessive clockwise rotation is undesirable.

Overall, the present findings support the concept that Forsus therapy produces significant and characteristic changes in occlusal plane inclination. The increase in SN-OP indicates predominantly clockwise rotation relative to the cranial base, whereas the reduction in OP-MP reflects a predominantly counterclockwise change relative to the mandibular plane. Compared with conventional fixed appliance therapy, Forsus demonstrated a significantly more consistent rotational pattern. These changes appear to be largely related to the dentoalveolar effects of the appliance, although individual growth and mandibular rotational changes may contribute to the final response.

V. LIMITATIONS OF THE STUDY

The study was limited by its relatively small sample size, short-term follow-up, and use of two-dimensional cephalograms, restricting generalizability and assessment of long-term and three-dimensional changes. Variations in appliance placement, activation, and concurrent orthodontic mechanics may also have contributed to individual differences in occlusal-plane rotation.



Fig 1 SN Plane and OP Plane

➤ Data of Study Group

Table 1 Data of Study Group

Study group (Forsus) cephalometric findings									
Patient ID	Age/Sex	SN-OP Angle				OP-MP angle			
		T1	T2	T2-T1	Rotation	T1	T2	T2-T1	Rotation
S01	24/M	10	14	4	CW	12	9	-3	CCW
S02	18/F	5	14	9	CW	15	6	-9	CCW
S03	21/M	13	16	3	CW	17	23	6	CW
S04	20/F	19	21	2	CW	10	8	-2	CCW
S05	22/M	11	15	4	CW	20	19	-1	CCW
S06	24/F	17	19	2	CW	16	15	-1	CCW
S07	25/M	13	16	3	CW	20	17	-3	CCW
S08	21/M	20	26	6	CW	20	11	-9	CCW
S09	19/M	9	6	-3	CCW	14	11	-3	CCW
S10	23/F	12	15	3	CW	18	16	-2	CCW
S11	25/M	14	18	4	CW	19	17	-2	CCW
S12	22/F	16	19	3	CW	15	14	-1	CCW
S13	20/M	11	14	3	CW	17	15	-2	CCW
S14	23/F	18	22	4	CW	21	19	-2	CCW
S15	25/M	15	19	4	CW	18	16	-2	CCW
S16	21/F	13	17	4	CW	17	19	2	CW
S17	25/M	17	24	7	CW	20	16	-4	CCW
S18	19/F	15	17	2	CW	18	13	-5	CCW
S19	25/M	16	20	4	CW	22	20	-2	CCW
S20	24/F	18	24	6	CW	21	17	-4	CCW
S21	22/M	18	23	5	CW	21	20	-1	CCW
S22	23/F	12	16	4	CW	17	18	1	CW
S23	20/M	14	18	4	CW	16	13	-3	CCW
S24	16/F	13	16	3	CW	17	15	-2	CCW
S25	23/F	15	20	5	CW	20	16	-4	CCW

S26	20/M	14	16	2	CW	17	14	-3	CCW
S27	22/F	13	15	2	CW	16	20	4	CW
S28	19/F	10	14	4	CW	16	13	-3	CCW
S29	17/M	8	13	5	CW	15	13	-2	CCW
S30	22/M	11	13	2	CW	17	14	-3	CCW
S31	16/F	16	18	2	CW	17	16	-1	CCW
S32	25/M	12	14	2	CW	15	14	-1	CCW
S33	18/F	12	15	3	CW	17	15	-2	CCW
S34	19/M	12	16	4	CW	16	13	-3	CCW
S35	24/F	13	15	2	CW	14	11	-3	CCW

➤ Data of Control Group

Table 2 Data of Control Group

Patient ID	Age/Sex	SN-OP angle				OP-MP angle			
		T1	T2	T2-T1	Rotation	T1	T2	T2-T1	Rotation
C01	17/M	16	9	-7	CCW	17	19	2	CW
C02	20/M	14	12	-2	CCW	17	19	2	CW
C03	25/M	18	14	-4	CCW	20	24	4	CW
C04	17/F	13	20	7	CW	16	18	2	CW
C05	21/F	13	17	4	CW	14	12	-2	CCW
C06	24/M	19	20	1	CW	8	12	4	CW
C07	22/F	24	20	-4	CCW	18	19	1	CW
C08	17/M	15	14	-1	CCW	8	10	2	CW
C09	21/M	12	20	8	CW	16	17	1	CW
C10	19/F	10	9	-1	CCW	17	20	3	CW
C11	24/F	14	14	0	NO ROTATION	11	11	0	NO ROTATION
C12	23/M	17	16	-1	CCW	13	15	2	CW
C13	19/M	14	12	-2	CCW	17	20	3	CW
C14	16/M	28	22	-6	CCW	22	24	2	CW
C15	25/F	9	9	0	NO ROTATION	9	10	1	CW
C16	17/F	20	15	-5	CCW	18	12	-6	CCW
C17	25/M	12	10	-2	CCW	14	15	1	CW
C18	20/M	24	20	-4	CCW	13	16	3	CW
C19	24/F	12	14	2	CW	8	9	1	CW
C20	24/F	13	14	1	CW	10	11	1	CW
C21	16/F	17	15	-2	CCW	20	24	4	CW
C22	23/M	14	14	0	NO ROTATION	20	20	0	NO ROTATION
C23	25/M	9	10	1	CW	8	11	3	CW
C24	23/F	8	14	6	CW	13	16	3	CW
C25	20/F	10	12	2	CW	15	16	1	CW
C26	20/M	13	17	4	CW	13	15	2	CW
C27	22/M	16	14	-2	CCW	15	17	2	CW
C28	25/M	15	15	0	NO ROTATION	9	9	0	NO ROTATION
C29	24/F	10	13	3	CW	9	11	2	CW
C30	22/F	11	12	1	CW	15	16	1	CW
C31	24/M	16	14	-2	CCW	12	14	2	CW
C32	20/M	15	14	-1	CCW	16	24	8	CW
C33	19/M	12	10	-2	CCW	12	11	-1	CCW
C34	22/M	16	13	-3	CCW	13	15	2	CW
C35	22/F	13	14	1	CW	11	12	1	CW

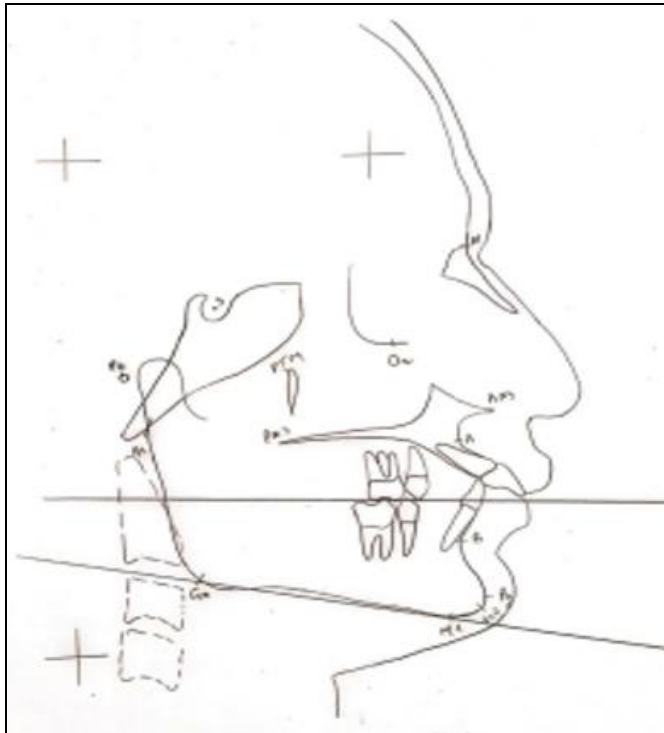


Fig 4 OP Plane and MP Plane

VI. CONCLUSION

Forsus treatment produced a consistent clockwise rotation of the occlusal plane relative to SN (SN-OP) and counterclockwise rotation relative to the mandibular plane (OP-MP), indicating differential changes in occlusal-plane inclination with respect to the cranial base and mandibular plane.

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