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Comparative Evaluation of Skeletal, Dental, Soft Tissue and Glenoid fossa Changes Induced by Fixed Functional (Rigid & Hybrid) and Myofunctional Appliances in Skeletal Class II patients

Dr. Rahul Paul[1], Dr. Deepti Yadav[2], Dr. Vandana Gulia[3], Dr. Ish Kumar Sharma[4], Dr. Uchit Gupta[5], Dr. Prakher Saini[6], Dr. Ratika Sawhney[7]

[1]Principal, Professor and Head of Department, Department of Orthodontics and Dentofacial Orthopaedics ,Inderprastha Dental College and Hospital, Ghaziabad.

[2]Professor, Department of Orthodontics and Dentofacial Orthopaedics ,Inderprastha Dental College and Hospital, Ghaziabad.

[3]Reader, Department of Orthodontics and Dentofacial Orthopaedics, Inderprastha Dental College and Hospital, Ghaziabad.

[4]Reader, Department of Orthodontics and Dentofacial Orthopaedics, Inderprastha Dental College and Hospital, Ghaziabad.

[5]Resident, Department of Orthodontics and Dentofacial Orthopaedics,Inderprastha Dental College and Hospital, Ghaziabad.

[6]Senior Lecturer, Department of Orthodontics and Dentofacial Orthopaedics, Inderprastha Dental College and Hospital, Ghaziabad.

[7]Resident, Department of Orthodontics and Dentofacial Orthopaedics,Inderprastha Dental College and Hospital, Ghaziabad.

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ABSTRACT

Functional appliances have been used for over a century to correct Class II malocclusion, producing both dental and skeletal effects to reduce overjet in growing patients. This study aimed to evaluate and compare skeletal, dental, soft tissue, and glenoid fossa changes induced by fixed functional (Powerscope and Forsus Fatigue Resistant) and myofunctional appliances in 60 subjects divided into three groups. Pre-treatment (T0) and 6-month post-treatment (T1) lateral cephalograms were manually traced and analyzed. Results indicated statistically significant improvements with all appliances, with Powerscope showing prominent dentoalveolar changes (e.g., incisal inclination, U6-PP), myofunctional appliances demonstrating superior skeletal effects (e.g., Ar-Go-Me angle), and Forsus Fatigue Resistant contributing most to condylar remodeling (AE-SN and AE-CP angles). The study concludes that while all three appliances effectively correct Class II malocclusion, their efficacy varies: As for dentoalveolar correction, Powerscope appliance shows the maximum results, myofunctional appliances works best for skeletal correction, and Forsus for condylar remodelling along with skeletal correction, suggesting appliance selection should align with specific treatment objectives.

Keywords: *Humans; Glenoid Cavity; Sample Size; Goals; Overbite, Malocclusion; Angle Class II.*

1. INTRODUCTION

Malocclusion is a widespread dental condition, ranking as the second most prevalent oral health issue among children and young adults in India, surpassed only by dental caries[1]. Among the various types of malocclusion, Class II malocclusion is particularly common, characterized by an abnormal anteroposterior relationship between the maxillary and mandibular teeth[2]. This condition can lead to functional impairments, aesthetic concerns, and psychosocial challenges. The prevalence of Class II malocclusion in India varies with age, affecting 6% of children aged 5–9 years and 14.6% of those aged 10–13 years[3], highlighting the need for early intervention during the mixed or early permanent dentition stages to optimize treatment outcomes by leveraging the patient's remaining growth potential[4].

In individuals with a normal skeletal pattern (Class I), maxillary and mandibular growth occurs harmoniously, resulting in balanced facial proportions[5]. However, in Class II malocclusion, the mandible is often retrognathic, contributing to a convex facial profile[6]. Functional appliances are widely used to correct such discrepancies by modifying mandibular position and muscle function, thereby stimulating favorable skeletal and dentoalveolar adaptations[7]. Beyond skeletal correction, these appliances also enhance oropharyngeal dimensions by advancing the mandible, hyoid bone, tongue, and soft palate, which may benefit airway function[8].

Functional appliances are broadly classified into removable, fixed, and hybrid types, each with distinct advantages and limitations[9]. Removable myofunctional appliances, such as activators and twin blocks, rely heavily on patient compliance, as they must be worn consistently to be effective[10]. They are particularly beneficial in growing patients, where they can induce favorable temporomandibular joint (TMJ) remodeling, improving mandibular projection and facial aesthetics[11]. However, their efficacy declines after the pubertal growth spurt, and inconsistent wear can compromise treatment success[12].

To address compliance issues, fixed functional appliances were developed, which are permanently bonded and require minimal patient cooperation[13]. The PowerScope, a rigid fixed appliance introduced in 2016, employs a telescoping mechanism to advance the mandible and has been shown to produce significant dentoalveolar changes, such as forward movement of mandibular molars and incisors[14]. In contrast, hybrid fixed appliances, like the Forsus Fatigue Resistant Device (FRD), combine rigid and flexible components, delivering continuous forces while allowing some mandibular movement for patient comfort[15]. Recent modifications, such as the E-Z Module, have simplified appliance placement and improved wearability[16,17].

Despite extensive research, key gaps remain in understanding the comparative skeletal, dental, and soft tissue effects of different functional appliances[18]. Some studies suggest that hybrid appliances like Forsus produce greater skeletal changes than rigid appliances like PowerScope[19], while others report no significant differences[20]. Additionally, the impact on the glenoid fossa, a critical component of TMJ function, remains poorly understood.

This study aims to bridge these gaps by conducting a comprehensive cephalometric evaluation of skeletal, dental, soft tissue, and glenoid fossa changes induced by myofunctional, rigid fixed, and hybrid fixed functional appliances. By comparing these outcomes, the research will provide evidence-based insights to guide clinicians in selecting the most effective treatment approach for Class II malocclusion, ultimately improving patient care and long-term stability.

2. MATERIAL AND METHODOLOGY

Study Design and Sample Selection

A prospective study was conducted with 60 patients (aged 10–21 years) from the Department of Orthodontics, Inderprastha Dental College and Hospital, India. Participants were selected based on:

Inclusion Criteria:

Cervical Vertebral Maturation Index (CVMI 3 & 4)[21]

Skeletal Class II malocclusion (SNB <80°, ANB 4–7°, overjet 5–10 mm)

Average mandibular plane angle (SN/GoGn 32±6°)

Angle’s Class II molar relationship

Exclusion Criteria:

IMPA >102°

Syndromic anomalies

Missing teeth (excluding third molars)

Group Allocation Patients were divided into:

-Fixed Functional Appliance Group (n=40):

Group A (PowerScope): 20 patients (CVMI 4, age 15–21)

Group B (Forsus FRD): 20 patients (CVMI 4, age 15–21)

-Myofunctional Appliance Group (n=20):

Group C: 20 patients (CVMI 3, age 10–14).

Table 1 :Criteria for appliance selection:

TYPE OF APPLIANCE	SKELETAL AGE	CHRONOLOGICAL AGE
MYOFUNCTIONAL (GROUP C)	CVMI 3	10-14 yrs

FIXED FUNCTIONAL(POWERSCOPE-GROUP A AND FORSUS FATIGUE RESISTANT-GROUP B)	CVMI 4	15-21 yrs

Sample Size Calculation

The sample size was determined using power analysis (80% power, 5% error, effect size 0.35), yielding 20 patients per group[22].

Methodology

Pre-therapeutic lateral cephalograms of all the chosen cases were recorded at baseline (T0). Cephalograms were manually traced by one investigator using a 0.3mm mechanical pencil on the tracing papers and all skeletal, dental , soft tissue and glenoid fossa parameters were noted.

In Group A and B, initial levelling and alignment was achieved using fixed mechanotherapy using the wire sequence of MBT with anchorage reinforced, once the wire was passively upgraded to 0.019 x 0.025 SS, pre-appliance preparation was done by incorporating lingual root torque in 0.019 x 0.025 SS wire of lower arch in anterior segment with V- bend given from canine to canine.

Group A underwent fixed functional treatment with the Powerscope appliance(FIGURE 2, 3) and Group B, received treatment with the Forsus Fatigue Resistant Apparatus (FIGURE 2, 4).

In Group C patients bite registration was done and myofunctional appliance(FIGURE 5) was delivered.

After 6 months post appliance placement (T1), lateral cephalograms were recorded(FIGURE 6). Treatment changes were evaluated using linear and angular measurements on the pre and post treatment lateral cephalograms of all skeletal , dental, soft parameters and also changes in the glenoid fossa relationship before and after the treatment between the 3 groups.

Cephalometric Analysis

Parameters evaluated:

- Skeletal: ANB, Ar-Go-Me, glenoid fossa relationships (horizontal/vertical distances), ramus height.
- Dental: U1-SN, IMPA, overjet, overbite.
- Soft Tissue: UL-S line, Z-angle, H-angle.

Statistical Analysis

Data analyzed using SPSS 27.0:

- Intragroup: Wilcoxon signed-rank test.
- Intergroup: Kruskal-Wallis test.

Ethical Approval

Approved by the institutional ethics committee.

Pilot Study

A preliminary study (n=6) confirmed significant skeletal changes in Groups B/C and dental changes in Group A, validating the methodology.

Validity and Reliability

This prospective cephalometric study ensured high validity and reliability through standardized protocols. Radiographs were taken using a Cs 8000c device (Carestream Health, Inc., France) at fixed settings (72 kV, 15 mA, 9.4s exposure, 0.027mm² pixel size) with patients in natural head position. Intra-examiner reliability was confirmed by calibrating landmark identification (10 randomly rechecked radiographs), supported by statistical validation. These measures align with the study's objectives, ensuring consistent and accurate results.

FIGURE 1: Instructions to patient regarding functional appliance therapy

(a) (b)

FIGURE 2: (a) POWESCOPE appliance assembly ,

(b) FORSUS FATIGUE RESISTANT appliance kit.

FIGURE 3: POWER SCOPE Fixed functional appliance(Right, Frontal, Left profile) .

FIGURE 4: FORSUS FATIGUE RESISTANT appliance(Right ,Frontal, Left profile).

FIGURE 5: Twin block myofunctional appliance(Right, Frontal, Left profile).

FIGURE 6: Tracing essentials.

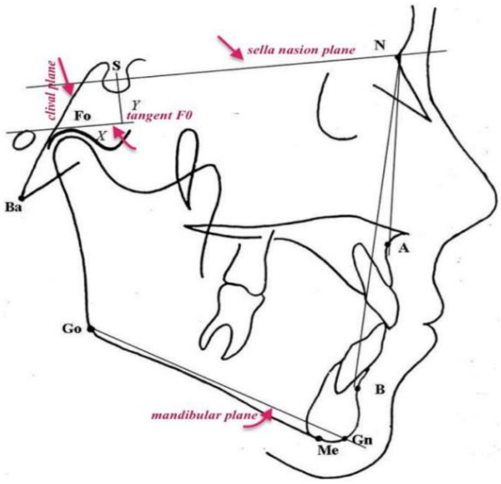


FIGURE 7: Cephalometric points and planes used to measure horizontal and vertical position of glenoid sossa

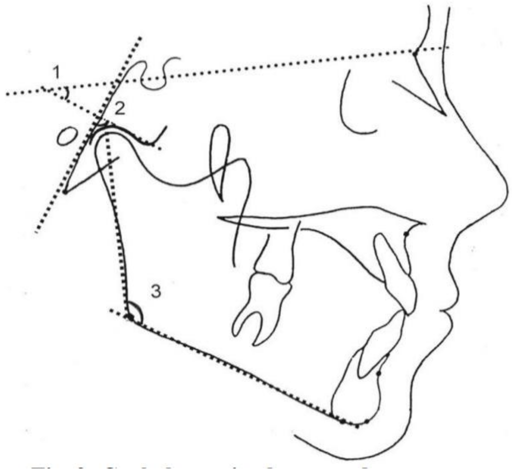


FIGURE 8: Cephalometric planes used to measure articular eminence inclination and gonial angle

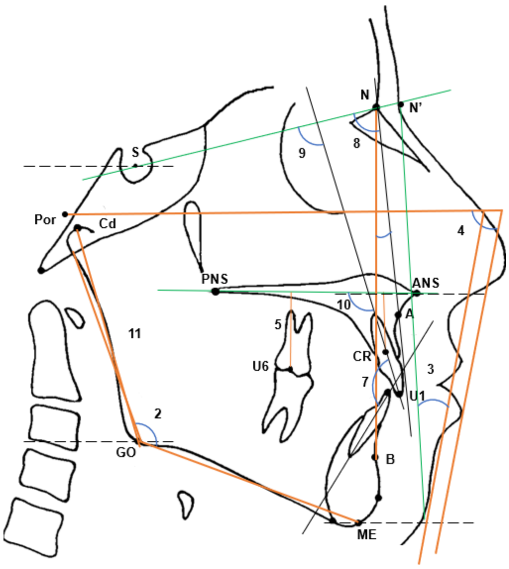


FIGURE 9 : CEPHALOMETRIC PARAMETERS:

1. ANB
2. Ar-Go-Me
3. H-angle
4. Z-angle
5. U6-PP
6. U1- NA

RESULTS:

The results obtained from the evaluation of skeletal, dental, and soft tissue changes produced by rigid fixed functional appliances (Powerscope), hybrid fixed functional appliances (Forsus fatigue) myofunctional appliances are summarized in Tables 2.

Table 2: Comparison of skeletal, dental and soft tissue changes between Group A, B and C.

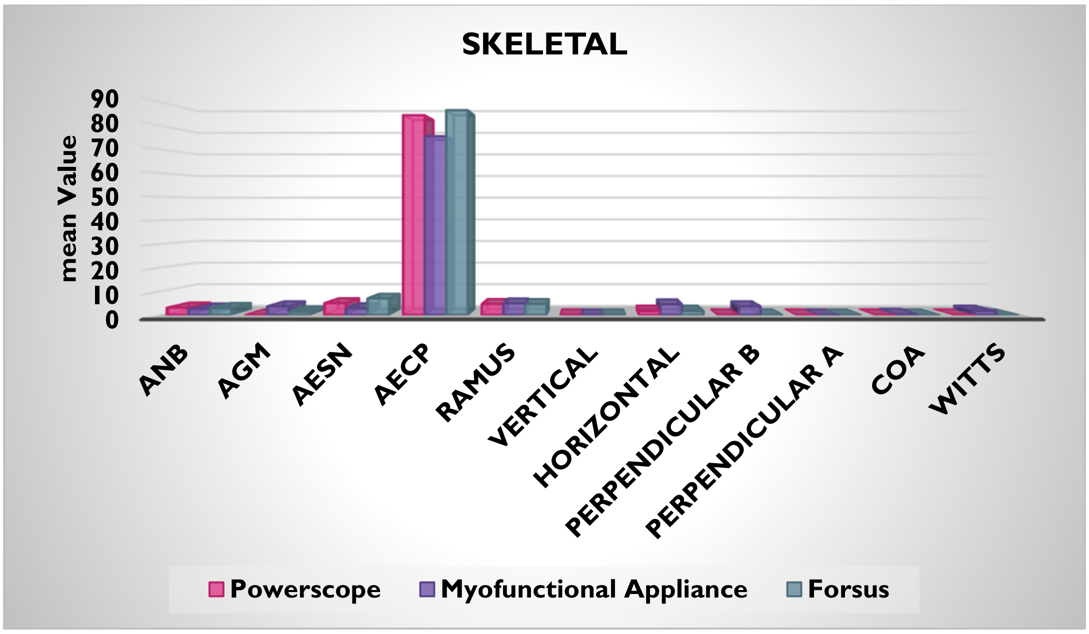
PARAMETERS		Mean difference	Std. Deviation	Chi-square value, Kruskal Wallis test	p-value,S/NS
SKELETAL					
ANB(degrees)	**GROUP A**	-3.1	1.774	0.689	0.709,NS
	GROUP C	-2.65	1.598		
	GROUP B	-2.9	1.618		
ArGoMe (degrees)	**GROUP A**	0	0	42.535	**<0.001,S**
	GROUP C	3.65	1.725		
	GROUP B	1.4	2.702		
AESN(degrees)	**GROUP A**	5	0	33.691	**<0.001,S**
	GROUP C	-2.8	1.239		
	GROUP B	7	2.991		
AECP(degrees)	**GROUP A**	84.4	7.394	18.835	**<0.001,S**
	GROUP C	-75.55	7.221		
	GROUP B	86.55	8.009		
WITTS(mm)	**GROUP A**	0	0	52.69	**<0.001,S**
	GROUP C	-1.7	0.732		
	GROUP B	0	0		
N-PERPENDICULAR DISTANCE- B(mm)	**GROUP A**	-0.05	0.223	53.177	**<0.001,S**
	GROUP C	-3.65	0.745		
	GROUP B	-0.05	0.223		

N-PERPENDICULAR DISTANCE -A(mm)	**GROUP A**	0	0	0	1.000,NS
	GROUP C	0	0		
	GROUP B	0	0		
VERTICAL SELLA DISTANCE(mm)	**GROUP A**	0	0	0	1.000,NS
	GROUP C	0	0		
	GROUP B	0	0		
HORIZONTAL SELLA DISTANCE(mm)	**GROUP A**	-1.7	1.417	21.871	**<0.001,S**
	GROUP C	-4.5	2.012		
	GROUP B	-1.7	1.417		
RAMUS HEIGHT(mm)	**GROUP A**	4.65	1.268	0.539	0.764,NS
	GROUP C	4.9	2.337		
	GROUP B	4.65	1.268		
Co-A(Maxillary Length)(mm)	**GROUP A**	0	0	2	0.368,NS
	GROUP C	0.25	1.118		
	GROUP B	0	0		
DENTAL					
U1SN(degrees)	**GROUP A**	-97.3	22.96	32.483	**<0.001,S**
	GROUP C	-48	2.092		
	GROUP B	-97.4	22.997		
U6PP(degrees)	**GROUP A**	-74.3	19.706	31.983	**<0.001,S**
	GROUP C	-53.5	2.719		
	GROUP B	-74.5	19.359		
IMPA(degrees)	**GROUP A**	-35.5	1.538	13.587	**0.001,S**
	GROUP C	-3.8	1.399		
	GROUP B	-1.95	1.571		

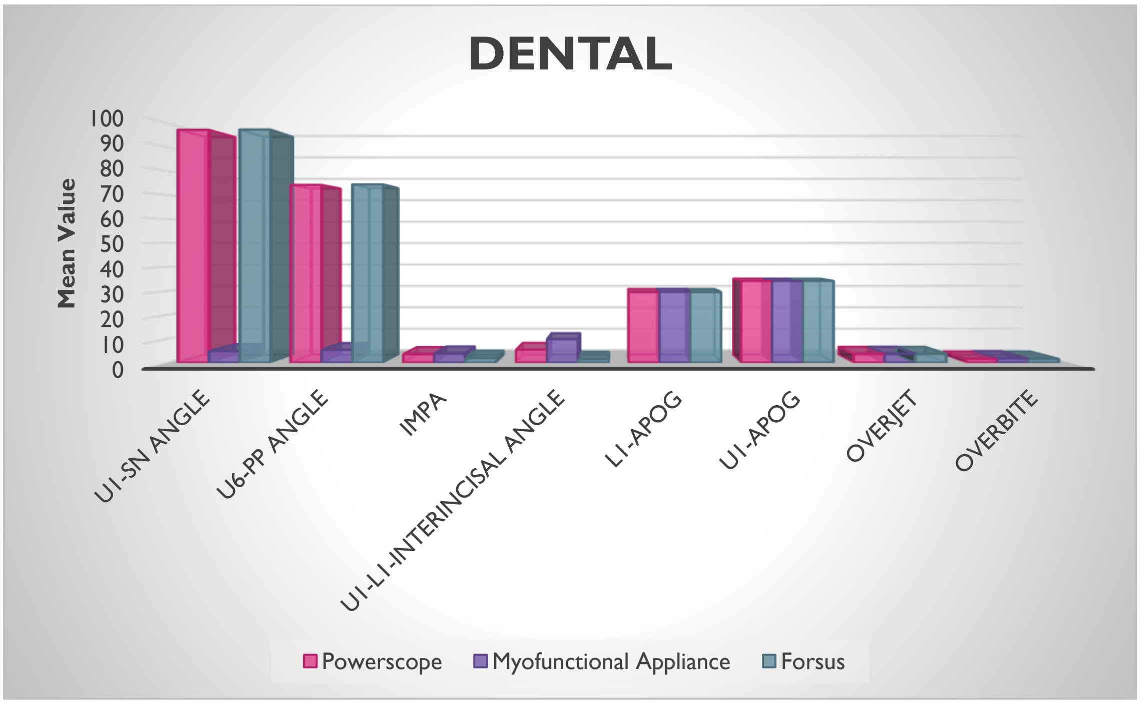
U1L1(degrees)	**GROUP A**	5.4	1.569	46.892	**<0.001,S**
	GROUP C	9.75	3.109		
	GROUP B	1.45	0.998		
L1-APog(degrees)	**GROUP A**	-29.5	2.544	0.123	0.940,NS
	GROUP C	-29.6	2.455		
	GROUP B	-29.5	2.544		
U1-APog(degrees)	**GROUP A**	-34.15	4.295	0.001	1.000,NS
	GROUP C	-34.15	4.183		
	GROUP B	-34.15	4.295		
OVERJET(mm)	**GROUP A**	-3.65	2.888	0.215	0.898,NS
	GROUP C	-3.7	2.617		
	GROUP B	-3.65	2.888		
OVERBITE(mm)	**GROUP A**	-1.55	1.394	0.337	0.845,NS
	GROUP C	-1.7	1.218		
	GROUP B	-1.55	1.394		
SOFT TISSUE					
UL-S plane(mm)	**GROUP A**	-3.6	0.94	0	1.000,NS
	GROUP C	-3.6	0.94		
	GROUP B	-3.6	0.94		
Z-angle	**GROUP A**	48.7	9.021	0	1.000,NS
	GROUP C	48.7	9.021		
	GROUP B	48.7	9.021		
LL-S plane(mm)	**GROUP A**	-23.3	6.611	0	1.000,NS
	GROUP C	-23.3	6.611		
	GROUP B	-23.3	6.611		
H angle	**GROUP A**	-4.25	1.916	0	1.000,NS
	GROUP C	-4.25	1.916		
	GROUP B	-4.25	1.916		

$p \leq 0.05$ – Significant, CI = 95 %

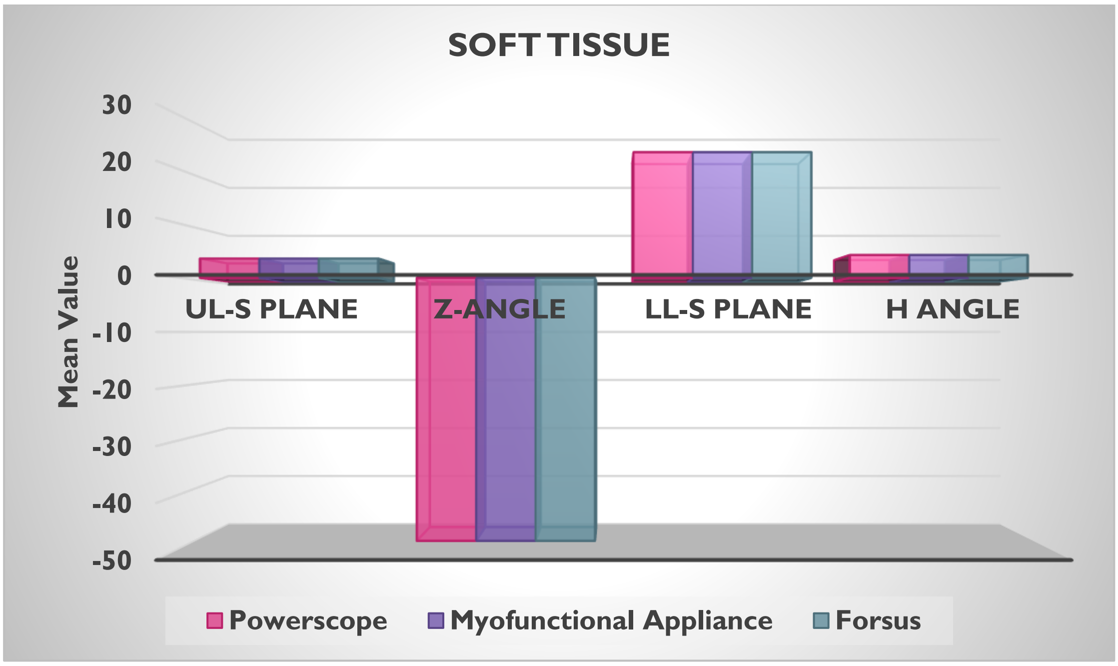
Graph 1: Comparison of skeletal changes between Group A, B and C.



Graph 2: Comparison of dental changes between Group A, B and C.



Graph 3: Comparison of soft tissue changes between Group A, B and C.



In Table 2, Graph 1-3 significant differences were observed in skeletal parameters such as ArGoMe , AE-SN angle, AE-CP angle, Horizontal Sella Distance, Perpendicular- B, and WITTS ($p < 0.001$). The Myofunctional Appliance showed the highest mean difference ArGoMe (3.65 ± 1.725) and horizontal sella distance changes (4.5 ± 2.012), while Forsus exhibited the highest mean difference in AE-SN (7 ± 2.991) and AE-CP (86.55 ± 8.009). Dental parameters like U1SN, U6PP, IMPA, and U1L1 also showed significant differences ($p < 0.001$), with Powerscope and Forsus having higher mean difference in angles U1SN (97.3 ± 22.96 and 97.4 ± 22.997) and U6PP (74.3 ± 19.706 and 74.5 ± 19.359) values compared to the Myofunctional Appliance. Soft tissue parameters (UL-S plane, Z-angle, LL-S plane, H angle) showed no significant differences ($p = 1.000$), indicating consistent effects across appliances. Non-significant findings ($p > 0.05$) included ANB, RAMUS, VERTICAL, PERPENDICULAR A, COA, L1DIFF, U1DIFF, OVERJET, and OVERBITE, suggesting these parameters were not significantly influenced by appliance type.

3. DISCUSSION

This comprehensive study systematically evaluated and compared the treatment outcomes of three distinct functional appliance modalities—the rigid fixed Powerscope, the hybrid fixed Forsus Fatigue Resistant Device, and removable myofunctional appliances—in addressing Class II malocclusions. The investigation focused on three key domains: skeletal modifications, dental changes, and soft tissue adaptations, providing critical insights into the mechanistic differences and clinical applications of each appliance type.

Skeletal Adaptations

The analysis of skeletal parameters revealed significant improvements across all three treatment groups, though with notable variations in efficacy and pattern. The reduction in ANB angle—a primary indicator of skeletal Class II correction—was most pronounced with myofunctional appliances, suggesting their superior capacity for mandibular advancement in growing patients. This finding corroborates the foundational work of **McNamara et al. (1985)**[23], who emphasized the growth-modifying potential of functional appliances. The Forsus appliance demonstrated intermediate skeletal effects, while the Powerscope, despite being a rigid fixed system, showed slightly less sagittal correction. Vertical skeletal parameters, particularly the ArGoMe angle, further highlighted these differences: myofunctional appliances induced the greatest increase in mandibular ramus height (3.65° vs. 1.4° for Forsus), reflecting their potent growth-stimulating properties. The condylar repositioning metrics (AE-SN and AE-CP angles) provided additional mechanistic insights, with Forsus exhibiting the most significant changes in condylar position within the glenoid fossa (AE-CP: 86.55°), indicative of its unique capacity for vertical control and fossa remodeling—a finding consistent with **Ruf and Pancherz's (1999)**[24] observations on fixed functional appliances.

Dental and Occlusal Changes

The dental effects varied substantially between appliance types, reflecting their distinct biomechanical actions. Fixed appliances (Powerscope and Forsus) produced marked dental changes, particularly in upper incisor retroclination (U1-SN: 97.3° and 97.4°, respectively) and molar distalization, attributable to their direct force application. In contrast, myofunctional appliances had negligible effects on incisor inclination (U1-SN: 48.0°), supporting **Tulloch et al.'s (2004)**[25] assertion that these devices primarily act through skeletal rather than dental mechanisms. The Forsus appliance's limited impact on lower incisor proclination (IMPA: 1.95°) contrasts with some prior studies (e.g., **Vogt, 2006)**[26], suggesting that its "hybrid" design may mitigate unwanted dental side effects while still achieving overjet reduction—a critical consideration for biomechanical efficiency.

Soft Tissue and Aesthetic Outcomes

All three appliances produced comparable and significant improvements in soft tissue profiles, including upper and lower lip retraction (UL-S and LL-S planes) and Z-angle enhancement. The absence of intergroup differences in these parameters ($p > 0.05$) implies that the choice of appliance may be less critical for aesthetic outcomes, provided skeletal and dental goals are met. These findings align with **Pancherz's (1982)**[27] classic work, which established that functional appliances uniformly improve facial balance through mandibular repositioning rather than direct soft tissue manipulation.

Clinical Implications and Limitations

The study's results underscore a fundamental principle: appliance selection must be tailored to the patient's specific needs. Myofunctional appliances excel in growing patients requiring maximal skeletal correction, while fixed systems (particularly Forsus) offer greater precision in vertical control and dental alignment. The observed discrepancies with earlier studies (e.g., **Franchi et al., 2004)**[28] likely reflect methodological variations, including sample age, treatment duration, and compliance rates—factors that clinicians must weigh when interpreting evidence.

4. CONCLUSION

1. Myofunctional appliance produced significant skeletal, dental, soft tissue, and glenoid fossa changes were seen, with pronounced mandibular growth.
2. Powerscope appliance produced significant skeletal, dental, soft tissue, and glenoid fossa changes were seen, with major dentoalveolar effects.
3. Forsus fatigue resistant appliance produced significant skeletal, dental, soft tissue, and glenoid fossa changes were seen, with major skeletal effects.
4. All three appliances on comparing effectively correct Class II malocclusion with Powerscope shows pronounced dentoalveolar changes (e.g., incisal inclination, U6-PP), Myofunctional appliances exhibited more noticeable skeletal effects, especially in mandibular growth and Forsus contributes the least to mandibular growth (Ar-Go-Me angle).
5. All appliances improve glenoid fossa relationship, with Forsus showing the most condylar remodeling, followed by Powerscope and Myofunctional.

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