"A COMPARATIVE ASSESSMENT OF TONGUE POSTURE AND PHARYNGEAL AIRWAY IN CLASS II DIVISION 1 PATIENTS TREATED WITH FUNCTIONAL APPLIANCE AND CAMOUFLAGE TREATMENT: A RETROSPECTIVE CEPHALOMETRIC STUDY".

By

REG. NO. II0222001

Dissertation

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Head of Department

Dr Rohan Hattarki M. D.S.
Professor & Head,
Department of Orthodontics and Dentofacial Orthopaedics,
KLE Vishwanath Katti Institute of Dental Sciences,
KAHER, Belagavi.

Date : 19/4/25
Place: Belagavi

Principal

Dr Alka Kale M. D.S.
Principal,
KLE Vishwanath Katti Institute of Dental Sciences,
KAHER, Belagavi.

PRINCIPAL
KLE V.K. Institute of Dental Sciences
Nehru Nagar, BELAGAVI-590010.

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☎: 0831-2470362 **Web: http://www.kledental-bgm.edu.in**
FAX: 0831-2470640 **E-mail:principal@kledental-bgm.edu.in**

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UG / PG / Ph.D / Staff : PG
Batch & Year : 2022-2025
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BIOSTATISTICS CLEARANCE CERTIFICATE

KLE
VISHWANATH KATTI
INSTITUTE OF DENTAL SCIENCES

(Constituent College of K.L.E. University, Belgaum)
J.N.M.C. Campus, Nehru Nagar, Belgaum-590 010, Karnataka, India

☎ 0831-2470362
FAX: 0831-2470640

Web: http://www.kledental-bgm.edu.in
E-mail: principal@kledental-bgm.edu.in

Biostatistics Clearance Certificate

This is to certify that Biostatistics aspect of the Dissertation/Research work of **REG. NO. II0222001** **it Graduate Student**, under the guidance of **ır, Department of Orthodontics**, entitled **"A comparative assessment of tongue posture and pharyngeal airway in Class II division1 Patients treated with functional appliance and camouflage treatment:A Retrospective cephalometric study."** has been done under my guidance and completed satisfactorily.

Place: Belagavi
Date:

Name & Signature of Biostatistician

Dr. S. B. Javali. Ph.D.
Professor In Statistics
Department of Community Medicine
USM KLE International Medical ...
BELAGAVI-...

LIST OF ABBREVIATIONS

UPW	-	Upper pharyngeal width
MPW	-	Middle pharyngeal width
LPW	-	Lower pharyngeal width
OSA	-	Obstructive Sleep Apnoea
UARS	-	Upper Airway Resistance Syndrome
SDB	-	Sleep Disordered Breathing
FRD	-	Fatigue Resistant Device
TB	-	Twin Block
NHP	-	Natural Head Position
PAS	-	Pharyngeal Airway Space
CBCT	-	Cone Beam Computed Tomography
MRI	-	Magnetic Resonance Imaging
°	-	degree

ABSTRACT

INTRODUCTION:

Skeletal Class II malocclusion, predominantly marked by mandibular retrognathism, is a prevalent orthodontic concern with complex etiology encompassing hereditary, environmental, and neuromuscular factors. Low tongue posture in such cases disrupts muscular equilibrium, leading to constricted dental arches, high palatal vaults, and compromised pharyngeal airway dimensions, heightening risks of upper airway resistance syndrome (UARS) and obstructive sleep apnea (OSA). The pharyngeal airway, intricately linked to tongue posture, plays a crucial role in breathing and craniofacial development. Treatment options for Class II malocclusion range from growth modification with functional appliances to dental camouflage via extractions. While functional appliances aim to advance the mandible and optimize airway patency, the effects of extraction therapy on tongue posture and airway dimensions remain less understood. This study aims to comparatively evaluate these two treatment modalities to enhance orthodontic treatment planning.

MATERIALS AND METHODS:

This retrospective cephalometric study analysed 40 lateral cephalograms (pre- and post-treatment) of patients treated with either functional appliances (n=20) or camouflage extractions (n=20) from the Department of Orthodontics. Inclusion criteria included skeletal Class II malocclusion with ANB $\geq 4°$ and AO-BO > 2 mm, with age stratification: 10–15 years for functional therapy, and 16–40 years for camouflage. Exclusion criteria covered respiratory disorders, craniofacial anomalies, and prior surgeries. Cephalometric measurements assessed pharyngeal airway widths

(upper, middle, lower) following Ozbek et al., and tongue posture parameters (Tg1–Tg7, TgH, TgL) based on Rakosi's landmarks. Data were analysed using independent and paired t-tests with $p < 0.05$ as significance level.

RESULTS:

Functional appliance therapy demonstrated statistically significant improvements in the upper airway dimension ($p = 0.0139$) and middle airway ($p = 0.0318$) between groups, while extraction therapy showed reductions in upper ($p = 0.0308$) and lower airway ($p = 0.0450$) intra-group post-treatment. In tongue posture assessment, functional therapy led to significant improvement in total tongue length TgL ($p = 0.0091$ intra-group; $p = 0.0009$ inter-group), indicating enhanced oral cavity space and forward tongue positioning. Tg1 (anterior-posterior tongue dimension) also showed favourable inter-group significance ($p = 0.0447$). Conversely, extraction therapy resulted in significant intra-group reduction in TgL ($p = 0.0278$), implying possible tongue space restriction. Other tongue parameters showed non-significant trends.

CONCLUSION:

The findings underscore that functional appliances positively influence tongue posture and airway dimensions, particularly benefiting growing patients. Functional therapy promotes forward mandibular positioning and tongue advancement, contributing to improved airway patency and potentially mitigating risks of airway-related dysfunctions. In contrast, extraction-based camouflage, while effective dentally, may compromise airway space and tongue posture, especially in non-growing individuals. These insights highlight the importance of airway-centric

orthodontic planning, advocating functional appliances as the preferred modality in suitable cases.

KEYWORDS: Class II malocclusion, functional appliances, extraction therapy, tongue posture, pharyngeal airway, cephalometric analysis, airway patency, orthodontic treatment planning

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INTRODUCTION

Class II skeletal malocclusion represents a prevalent sagittal discrepancy in orthodontics, typically characterized by mandibular retrognathism, maxillary prognathism, or both, with mandibular retrusion being the most frequently encountered combination[1]. According to Proffit's equilibrium theory, the resting posture of orofacial muscles, particularly the tongue, plays a pivotal role in maintaining dental and skeletal harmony[2]. In a normal scenario, the tongue exerts a gentle, expansive pressure against the palate, aiding transverse maxillary development and maintaining arch width[3,4]. However, in Class II patients with low tongue posture, this balance is disturbed, allowing unchecked inward forces from the cheeks and lips to constrict the arch, resulting in a high, narrow palate and compromised arch length and width[5]. The growth of the mandible is restricted transversely or the mandible is not able to catch up due to the constricted and V-shaped maxillary arch. Additionally, a lower tongue position affects pharyngeal airway dimensions, contributing to reduced oropharyngeal space and increasing the risk of functional sequelae such as compromised breathing, altered swallowing patterns, and instability post-treatment[6,7]. The disruption in muscular equilibrium thus has far-reaching consequences not only on dental arch form but also on airway patency and long-term orthodontic stability[8]. The etiology is multifactorial, involving hereditary patterns, environmental factors, and neuromuscular imbalances[9,10].

Anatomically, the pharyngeal airway is a complex muscular tube divided into nasopharynx, oropharynx, and hypopharynx, while the tongue, a muscular hydrostat, functions intricately in breathing, mastication, swallowing, and speech[11]. In Class II malocclusion, mandibular retrusion and posterior tongue displacement can encroach upon this airway space[12], predisposing individuals to upper airway resistance syndrome (UARS) and obstructive sleep apnea (OSA), especially during sleep when muscle tone is reduced[13]. The compromised airway space not only affects respiratory efficiency but also exacerbates craniofacial growth disturbances, potentially perpetuating a cycle of dysfunction[14]. Studies have shown that Class II patients with narrow airways often present clinical symptoms such as snoring, mouth breathing, and daytime somnolence, underlining the clinical relevance of assessing airway dimensions during orthodontic diagnosis[15].

Skeletal Class II Division 1 patients typically exhibit features such as convex facial profile, increased overjet, maxillary protrusion, mandibular retrusion, and a retrognathic chin[16]. Dental manifestations include proclined maxillary incisors and retroclined mandibular incisors, while soft tissue features often present as lip incompetence and an acute nasolabial angle[17]. These skeletal and soft tissue patterns influence tongue posture and airway configuration, further complicating the clinical picture[18].

Treatment strategies for Class II malocclusion include functional appliance therapy, camouflage treatment involving extractions, or orthognathic surgery[19]. Functional appliances like the Twin Block are most effective in growing patients, leveraging residual mandibular growth to posture the mandible forward, enhancing skeletal correction and airway dimensions[20,21]. Conversely, camouflage treatment, typically used in non-growing individuals, relies on dental compensations such as premolar extractions to manage protrusion without altering the skeletal base[22]. In severe skeletal cases or post-growth phases, orthognathic surgery becomes necessary for comprehensive correction[23]. Treatment decisions are guided by the patient's age, growth potential, severity of malocclusion, and airway considerations[24].

During adolescence, normal pharyngeal airway dimensions vary with age, sex, and ethnicity, with males generally exhibiting larger airway volumes than females[25].

Growth spurts during puberty result in increased airway dimensions, while post-pubertal growth stabilization leads to minor variations thereafter[26]. Racial differences also influence craniofacial and airway morphology, necessitating population-specific norms for accurate assessment[27]. Similarly, tongue volume and posture exhibit age-related changes, peaking during adolescence and stabilizing in adulthood, although variations persist due to anatomical and functional factors[28].

Several imaging modalities aid in evaluating tongue posture and airway dimensions. These include CBCT, MRI, and acoustic pharyngometry, with lateral cephalometry remaining the most accessible and widely used in orthodontics[29]. Despite being two-dimensional, cephalometry provides reliable data on sagittal airway space, tongue posture, and related craniofacial structures[30]. Parameters such as PAS (posterior airway space), distance from the dorsum of the tongue to the palate, and the position of the hyoid bone have been validated as key indicators of functional changes following orthodontic intervention[31].

Given the intricate relationship between mandibular position, tongue posture, and pharyngeal airway, understanding the impact of different treatment modalities is crucial. While functional appliances aim to improve both skeletal and airway dimensions, camouflage approaches may not address airway concerns effectively[32]. Therefore, this retrospective cephalometric study, aims to provide a comparative evaluation of these parameters, offering insights to refine treatment planning and enhance both esthetic and functional outcomes[33]. Very few studies have been conducted on the effect of anterior retraction on tongue posture and its effect on pharyngeal airway in Class II skeletal malocclusion camouflage cases and its comparison to treatment by functional appliances and therefore this study has been undertaken.

AIMS AND OBJECTIVES

AIM- Assess tongue posture and pharyngeal airway in Class II division 1 patients treated with functional appliance and camouflage orthodontic treatment.

OBJECTIVES:

- To assess the treatment changes in tongue and pharyngeal airway in functional orthodontic treatment.
- To assess the treatment changes in tongue and pharyngeal airway in camouflage orthodontic treatment.
- To compare the treatment changes in tongue and pharyngeal airway in functional and camouflage orthodontic treatment.

REVIEW OF LITERATURE

1. **Dedhiya N, Pradhan T, Sethia A (2020)[33]**

   A retrospective cephalometric study evaluated how the hyoid bone position and airway dimensions changed in Class II patients receiving Forsus Fatigue Resistant Device and Fixed Twin Block treatment. Cephalograms before and after treatment were examined. The forward hyoid bone placement and airway dimensions were greatly enhanced by both devices. The Fixed Twin Block group saw a statistically significant shift in the upper part of airway in contrast to the group using the Forsus Fatigue Resistant Device.

2. **Rajput R, Daokar S (2020)[7]**

   Twin Block and Forsus appliances were tested in this randomized clinical trial for patients with skeletal Class II malocclusion. Changes in the area of the tongue and the position of the hyoid bones were examined in cephalograms taken before and after therapy. The hyoid bone was displaced forward and upward in both groups, and the tongue area significantly increased, suggesting better airway space and tongue posture. Twin Block exhibited more skeletal effects, but both appliances were effective.

3. **Afzal E, Fida M (2019)[12]**

   This study evaluated how the Twin Block appliance affected the hyoid bone position and tongue posture in skeletal Class II patients. Prior to and following treatment, lateral cephalograms revealed anterior repositioning of the hyoid bone and forward tongue movement, indicating that in addition to improving airway dimensions, functional appliances can also enhance tongue position.

There were statistically significant variations in the tongue position between the pre- and post-functional values.

4. **Shinde S, Sethi S, Vasa D, et al. (2023)[5]**

A comparative cephalometric study examined tongue position in skeletal Class II Division 1 and Division 2 malocclusions. Results indicated statistically significant differences in tongue posture between divisions, with Class II Division 1 showing a lower tongue posture. This highlights the role of tongue position in malocclusion severity and treatment planning.

5. **Chhabra S, Khanna P, Munjal P (2021)[6]**

The size and position of the tongue were assessed in this cephalometric study in connection to skeletal Class I and II patterns. Results indicated that the tongue posture of skeletal Class II people was statistically significantly lower and more posterior than that of Class I, indicating that tongue posture has a role in sagittal disparities. This might affect the size of the airways.

6. **Gohilot A, Pradhan T and Keluskar KM (2014)[34]**

In order to determine velopharyngeal incompetency in patients with unilateral cleft lip and palate, this cephalometric study assessed the adenoids, upper airway, maxilla, velum length, and need ratio. Findings emphasized that reduced upper airway dimensions, retruded maxilla and altered velum length contribute to velopharyngeal incompetency. Though focused on cleft patients, the methodology offers insight into airway analysis relevant to Class II studies.

7. **Kaur R, Garg AK, Gupta DK, Singla L and Aggarwal K (2022)[35]**

   Twin Block and Forsus appliances were compared prospectively in patients with Class II malocclusion. Hyoid bone and airway alterations were evaluated by cephalograms before and after treatment. Both appliances improved hyoid positioning and airway dimensions, but the Twin Block showed slightly better anterior movement and airway space gain. Following functional mandibular realignment using a twin block appliance, the findings of the tongue space measures revealed an increase in mean tg7 and TGH readings, which were found to be statistically significant. Both modalities were effective in managing airway dimensions.

8. **Gu M, Savoldi F, Chan EYL, et al. (2021)[36]**

   Changes in the upper airway between individuals treated with Herbst appliances and headgear activators were compared in a retrospective cephalometric research. When compared to the headgear activator group, the Herbst group's upper airway dimensions significantly improved. Appliances that work showed a favorable effect on the size of the pharynx after Class II correction.

9. **Ali B, Shaikh A and Fida M (2015)[14]**

   Class II patients' oro-pharyngeal airway alterations following Twin Block therapy were assessed in this study. Pharyngeal airway dimensions significantly increased after treatment, according to lateral cephalograms taken before and after the procedure.

10. Hu Z, Yin X, Liao J, Zhou C, Yang Z and Zou S (2015)[22]

A systematic review assessed the impact of premolar extraction on upper airway dimensions. They were categorized into three groups according to their indications for extractions, namely anteroposterior discrepancy (group 1), crowding (group 2), and unspecified indications (group 3). In group 1, enrolled patients were diagnosed with class I bimaxillary protrusion and had four first premolars extracted, with a statistically significant decrease in upper airway dimension. In group 2, increase in the upper airway dimension was reported in patients who were diagnosed with class I crowding and four first premolars extracted. In group 3, all patients were adolescents and no significant change in the upper airway dimension was observed. Results indicated that extraction therapy could reduce airway dimensions, particularly when associated with significant incisor retraction. Findings raise concerns regarding potential airway compromise following camouflage treatment in Class II malocclusion.

11. El H, Palomo JM (2011)[25]

This study evaluated oropharyngeal (OP) and nasal passage (NP) airway volumes in 140 subjects aged 14–18 with Class I, II, or III skeletal patterns using CBCT scans. Results showed a statistically significant smaller oropharyngeal volumes in Class II patients, especially those with retruded mandibles (low SNB angle). The results indicate that mandibular position significantly influences airway size, highlighting its relevance in orthodontic diagnosis and planning.

12. **Li L, Liu H and Cheng H (2014)[27]**

This comparative CBCT study evaluated changes in upper airway morphology in Class II Division 1 patients treated with the Twin Block appliance. Post-treatment scans showed significant improvements in airway volume and mandibular advancement. Functional appliances contribute effectively to airway enhancement in growing patients.

13. **Bidjan D, Sallmann R, Eliades T and Papageorgiou SN (2020)[32]**

A systematic review and meta-analysis examined the impact of orthopedic treatment for Class II malocclusion with functional appliances on upper airway dimensions. The study concluded that functional appliances significantly enlarge upper airway dimensions in growing patients, supporting early orthopedic intervention.

14. S Bhatia , B Jayan , S S Chopra(2016)[37]

This study assessed 22 adults with Class I bimaxillary protrusion undergoing orthodontic treatment with premolar extractions and maximum incisor retraction. Pre- and post-treatment lateral cephalograms were analysed. Significant reductions were found in velopharyngeal and glossopharyngeal airway dimensions and posterior movement of the hyoid bone. The amount of lower incisor retraction correlated with airway narrowing. Conclusion: Maximal incisor retraction reduced pharyngeal airway space and altered hyoid position, suggesting clinicians should consider airway impact when planning extractions in similar patients.

15. Jain I, Pradhan T, Sethia A (2024)[11]

This study evaluated pharyngeal airway changes after mandibular setback, advancement, and bimaxillary surgeries using cephalometric analysis. Mandibular advancement significantly increased oropharyngeal space and moved the hyoid bone and tongue forward. Mandibular setback reduced airway space and caused posterior-inferior hyoid movement. Bimaxillary surgery increased nasopharyngeal space and minimized negative airway impact compared to setback alone. Overall, airway dimensions were most favorably affected by advancement and least by setback. The study highlights the need to assess airway implications in surgical planning.

MATERIALS AND METHODS

Study Design:

Retrospective cephalometric study

Source of data/laboratory details:

40 pre and post-treatment functional and camouflage treated lateral cephalograms obtained from the record data base of patients who underwent orthodontic treatment in Department of Orthodontics and Dentofacial Orthopedics, KAHER, KLE VK Institute of Dental Sciences, Belagavi, Karnataka, India.

Inclusion criteria:

- Skeletal Class II malocclusion with mandibular retrognathism
- ANB> or = 4 degree and AO-BO>2mm
- Age: functional 10-15years, camouflage-16-40 years
- The cephalometric records of good quality

Exclusion criteria:

- Patients suffering from respiratory disorders
- Past medical history of jaw and adenoidal trauma or surgery (Quincy)
- A history of nasal stenosis, cleft lip and palate, or any other systemic condition that interferes with normal growth

Sample size estimation:

<u>Formula</u>

$n= [(Z_{1-\alpha/2}+ Z_{1-\beta})^2\ (SD1^2+SD2^2)] / (x_1- x_2)^2$

SD1 = 2.45

SD2 = 1.80

x_1 = 10.73

x_2 = 8.73

α = 0.05

$1 – \beta$ = 0.85

$Z_{1-\alpha/2}$ = 1.96

$Z_{1-\beta}$ = 1.037

SD1: Standard deviation in the 1st group

SD2: Standard deviation in the 2nd group

x_1 : Mean of 1st group

x_2 : Mean of 2nd group

α : Level of significance

$1 – \beta$: Power

Estimated sample size for each group, $n = 20$

The sample size was estimated to be 20 in each group at a power of 0.85 with a 0.05 alpha error (Ghodke et al,2014). Therefore, this study included a sample size of 20 in each group, accounting to a total sample size of 40.

Materials and methodology with flowchart:

The materials required-

- Pre and post treatment lateral cephalograms of subjects
- 0.35mm mechanical lead pencil for tracing of radiographs
- Illuminated view box for tracing of radiographs
- Acetate matte sheets
- Scale
- Setsquares
- Protractor

Fig 1: 0.35 mm lead pencil, protractor, divider, ruler, coloured pencils

Fig 2: Lateral cephalogram on illuminated view box

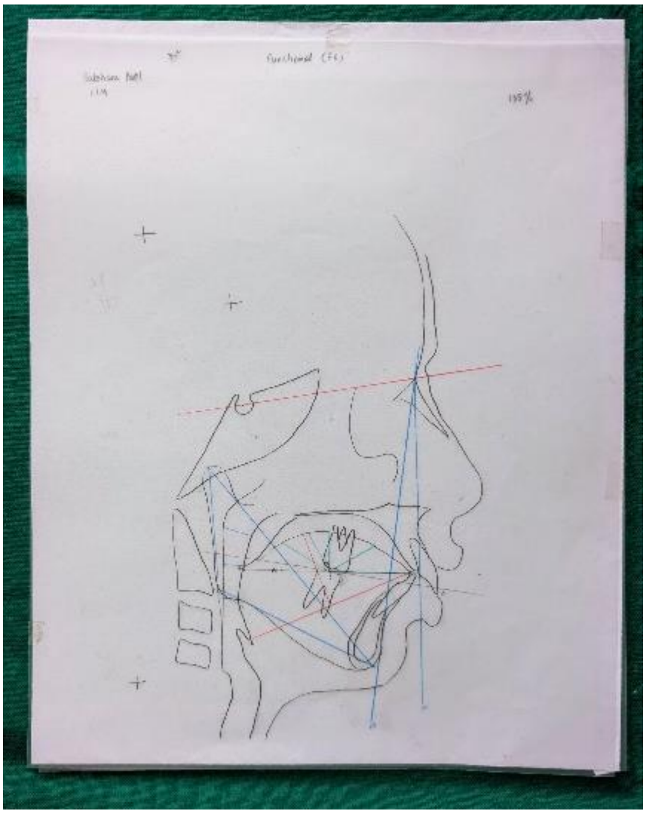
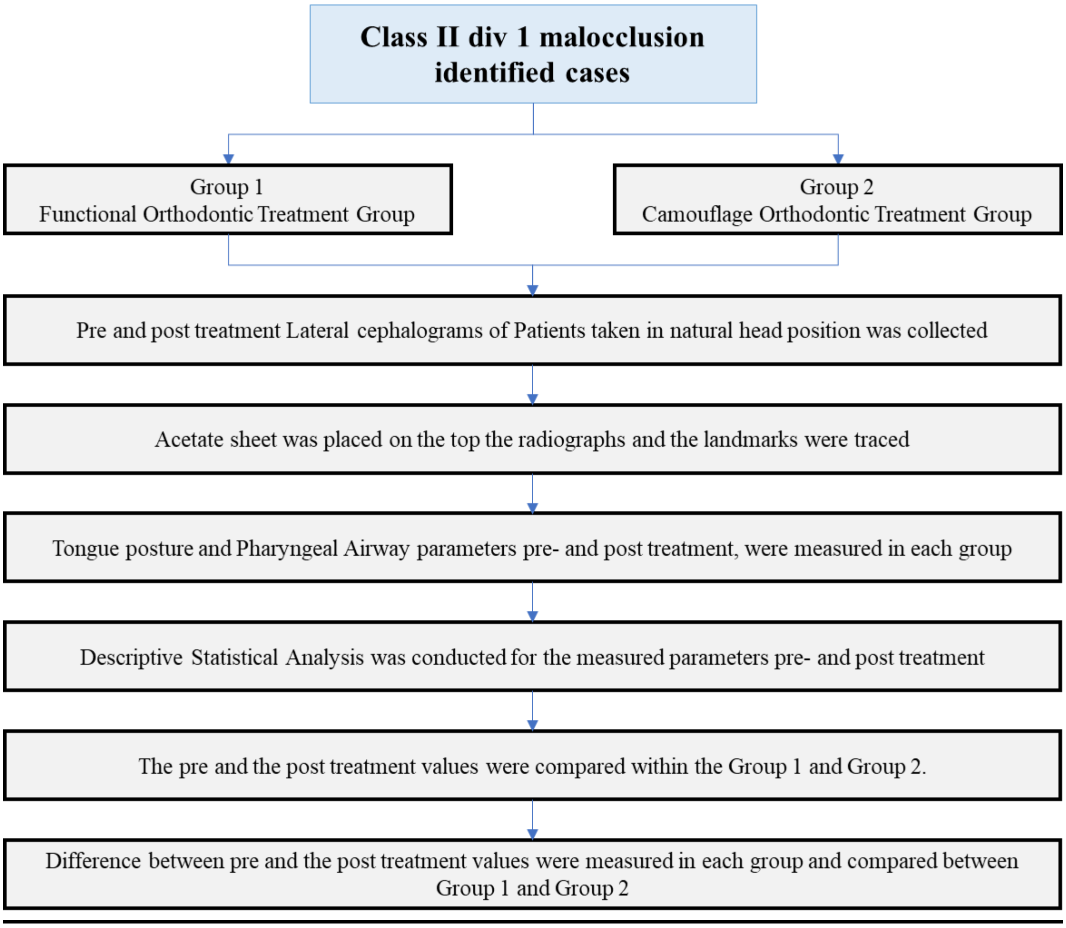


Fig 3: Tracing on acetate matte sheet

Methodology



Pharyngeal airway space: linear measurements

(According to measurements taken by Ozbek et al[39])

1. Upper pharyngeal width: Smallest distance between the posterior border of the soft palate to the closest point on the posterior pharyngeal wall.

2. Middle pharyngeal airway: Smallest distance between the posterior border of the tongue to the closest point on the posterior pharyngeal wall, through the tip of the soft palate.

3. Lower pharyngeal width: Smallest distance from the intersection of posterior border of tongue and inferior border of the mandible to the closest point on the posterior pharyngeal wall.

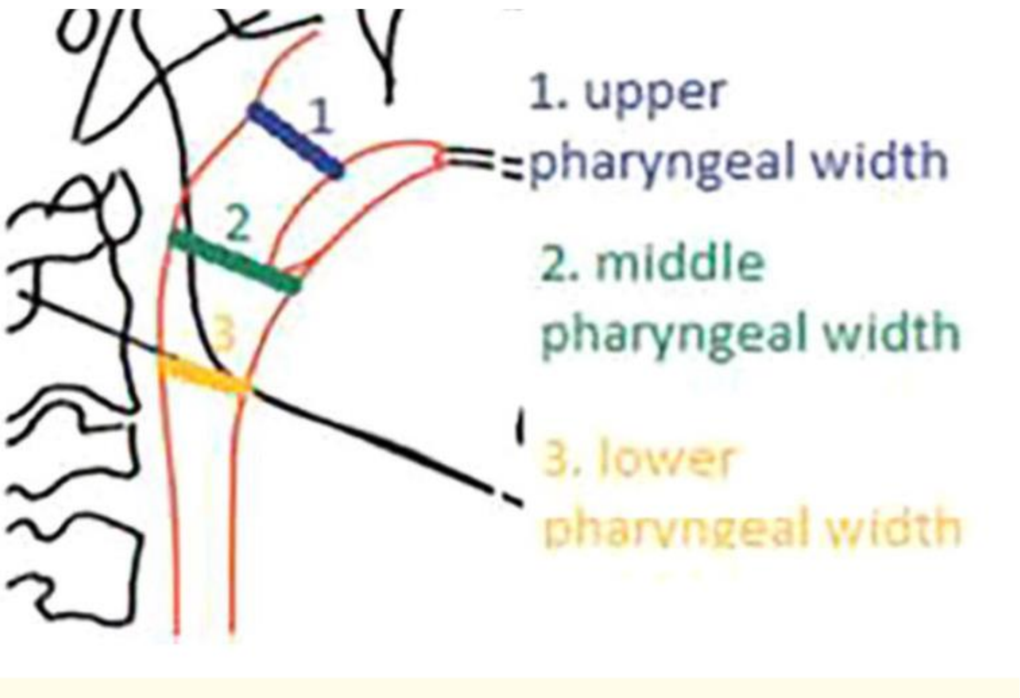


Fig. 4 Showing the linear measurement of the pharyngeal airway space

Tongue analysis

Landmarks as given according to Bjork, Lowe et al., Rakosi, Ingervall and Schmoker(16,40)

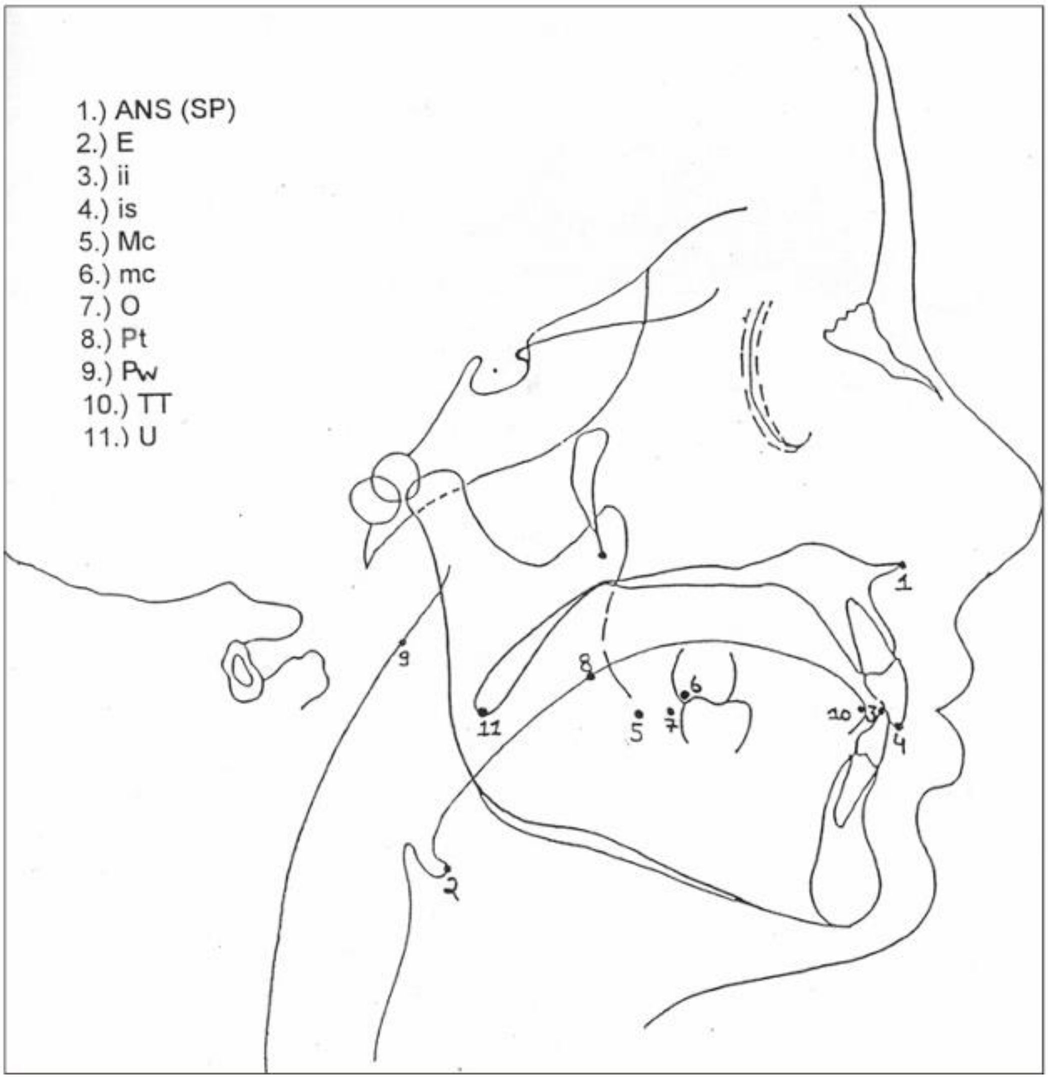
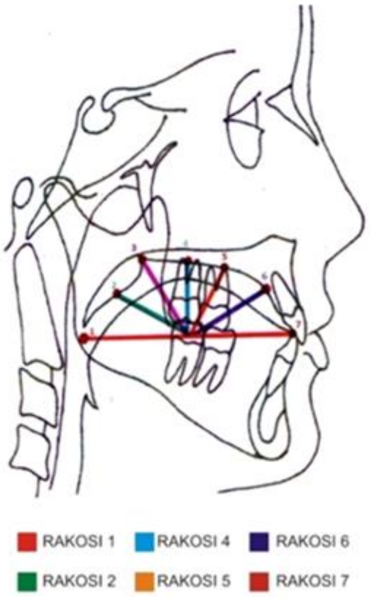


Fig. 5 Showing the landmarks used in tongue analysis

LANDMARK	DESCRIPTION
A.N.S.	The anterior nasal spine's apex
E	The epiglottis's most anterior and inferior points
Ii	Most prominent mandibular incisors' incisal tip
Is	The tip of the most noticeable maxillary incisor
Mc	A location on the cervical distal third of the final permanent molar to erupt
mc	Distobuccal cusp tip of the first permanent molar in the maxilla
O	The midpoint of the linear distance U-ii on the Mc-ii line
TT	Tongue tip
U	Uvula projection on the Mc-ii line or its tip

Parameters as given according to According to Rakosi, 1982 and Lowe et al., 1986[16,40]



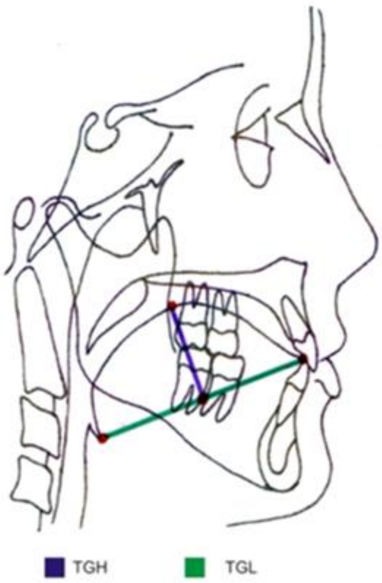


Fig 6: Showing the parameters measured in tongue analysis- tg1 to tg7 (Left)

Fig 7: Showing the parameters measured in TGH and TGL (Right)

PARAMETERS	DESCRIPTION
tg1	The tongue's length at its posterior region, or root. Line constructed through the O and ii.
tg2	The tongue's partial length in the dorsum's posterior area. Line constructed on O at 30° Mc-ii line.
tg3	The tongue’s partial length of the dorsum's middle length. Line constructed on O at 60° Mc-ii line.
tg4	The partial length of the tongue in the center of the its dorsum. Line constructed on O at 90° Mc-ii line.
tg5	The partial length of the tongue in the center of its dorsum. Line constructed on O at 120° Mc-ii line.
tg6	The partial length of the tongue in the anterior area.Line constructed on O at 150° Mc-ii line.
tg7	The partial length of the tongue in the tip area.Line constructed on O at 180° Mc-ii line.
TgH	The tongue's height during centric occlusion and rest.
TgL	Whole length of the tongue.

RESULTS

- The study was done to assess tongue posture and pharyngeal airway in Class II division 1 patients treated with functional appliance and camouflage orthodontic treatment.
- This is a retrospective cephalometric study.
- A total of 40 pre and post treatment samples (20 in Functional appliance group and 20 in Extraction/ Camouflage group) were collected and the tongue and airway parameters were measured.

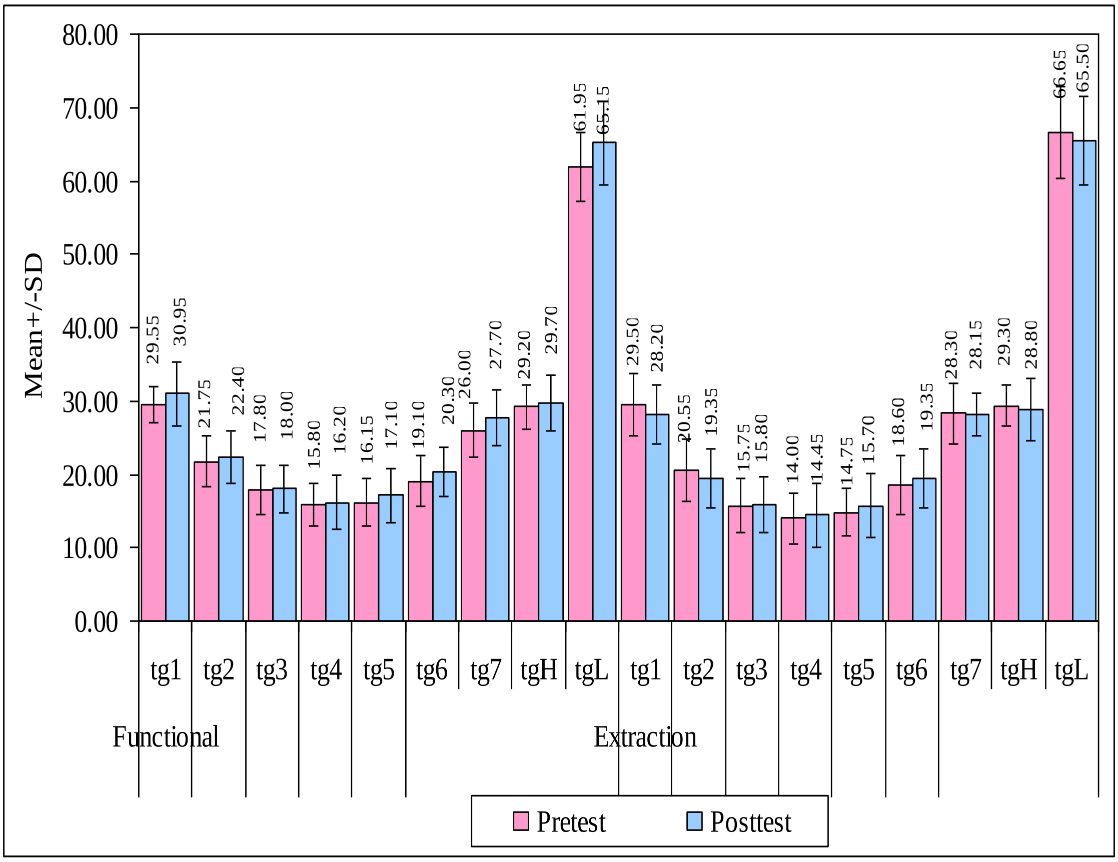
TONGUE ANALYSIS

Table 1: Comparison of pre-treatment and post-treatment values (in mm) of tongue related parameters in functional and camouflage treatment groups by dependent t test

Group	Parameters	Pretest		Post-test		Mean Diff.	% of change	t-value	p-value
		Mean	SD	Mean	SD				
Functional group	tg1	29.55	2.44	30.95	4.26	-1.40	-4.74	-1.6286	0.1199
	tg2	21.75	3.39	22.40	3.56	-0.65	-2.99	-0.8345	0.4144
	tg3	17.80	3.33	18.00	3.32	-0.20	-1.12	-0.2564	0.8004
	tg4	15.80	2.91	16.20	3.69	-0.40	-2.53	-0.4573	0.6527
	tg5	16.15	3.25	17.10	3.70	-0.95	-5.88	-1.1784	0.2532
	tg6	19.10	3.54	20.30	3.31	-1.20	-6.28	-1.6330	0.1189
	tg7	26.00	3.67	27.70	3.71	-1.70	-6.54	-1.7608	0.0944
	tgH	29.20	3.02	29.70	3.81	-0.50	-1.71	-0.4880	0.6312
	tgL	61.95	4.73	65.15	5.75	-3.20	-5.17	-2.9047	0.0091*
Extraction group	tg1	29.50	4.29	28.20	3.96	1.30	4.41	1.3316	0.1988
	tg2	20.55	4.31	19.35	4.04	1.20	5.84	1.0799	0.2937
	tg3	15.75	3.65	15.80	3.76	-0.05	-0.32	-0.0560	0.9559
	tg4	14.00	3.48	14.45	4.31	-0.45	-3.21	-0.5057	0.6189
	tg5	14.75	3.24	15.70	4.35	-0.95	-6.44	-1.0468	0.3083
	tg6	18.60	4.01	19.35	4.04	-0.75	-4.03	-0.8679	0.3963
	tg7	28.30	4.18	28.15	2.96	0.15	0.53	0.1784	0.8603
	tgH	29.30	2.79	28.80	4.32	0.50	1.71	0.4610	0.6500
	tgL	66.65	6.22	65.50	6.12	1.15	1.73	2.3823	0.0278*

*p<0.05

Graph 1: Comparison of pre-treatment and post-treatment values of tongue related parameters in functional and camouflage treatment groups



<u>**INTERPRETATION (Table 1 and Graph 1)**</u>

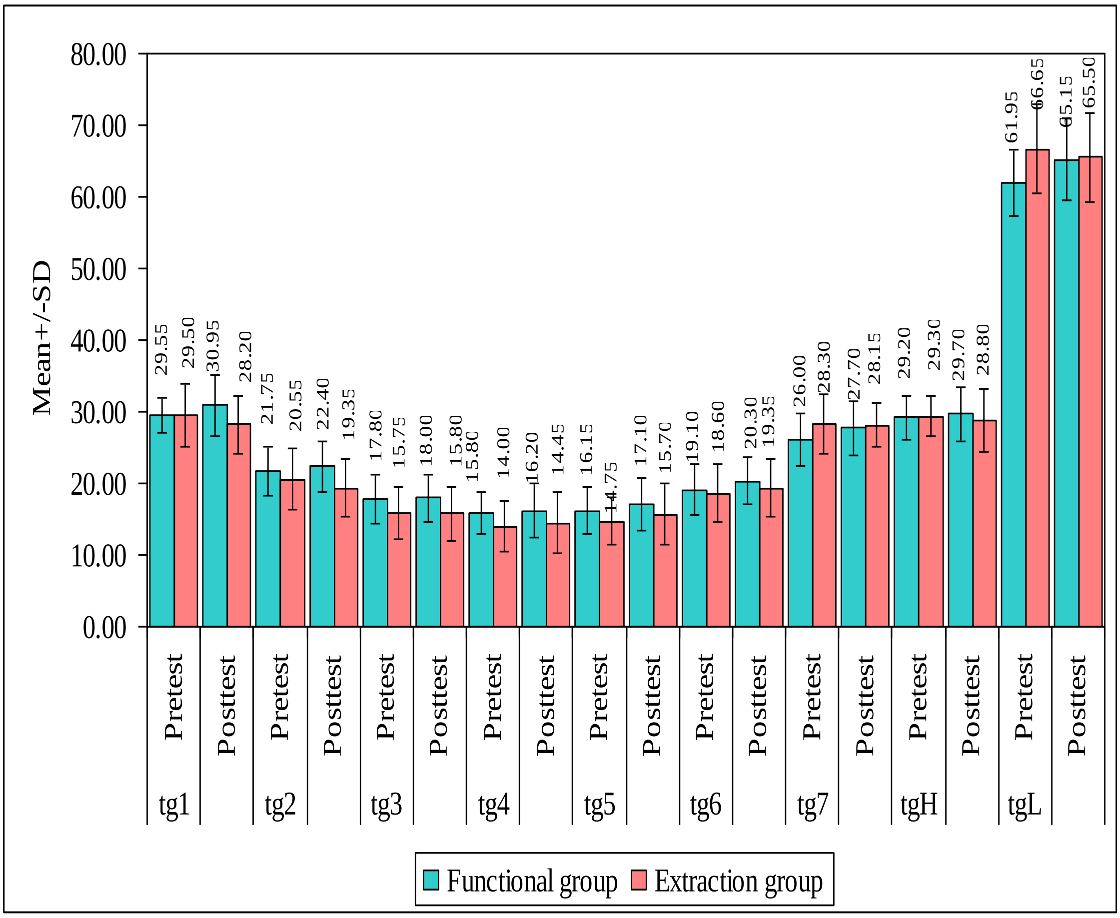
Table 1 depicts changes within functional and camouflage group. In the functional group, tgL showed statistically significant difference (Pre → 61.95 ± 4.73; Post → 65.15 ± 5.75; p = 0.0091), suggesting an improvement in overall tongue posture and space. While tg1 and tg7 showed improvement, they did not reach statistical significance. In the extraction group, tgL showed statistically significant difference (66.65 ± 6.22 (Pre) and 65.50 ± 6.12 (Post); p = 0.0278), indicating a potential reduction in tongue space following extraction and retraction. All other parameters across both groups remained statistically non-significant, suggesting limited change in mid and posterior tongue posture from treatment alone.

Table 2: Comparison between Functional appliance treatment group and Camouflage treatment group of tongue related parameters by Independent t test

Parameters	Time points	Functional group		Extraction group		Effect size	t-value	p-value
		Mean	SD	Mean	SD			
tg1	Pretest	29.55	2.44	29.50	4.29	0.02	0.0453	0.9641
	Posttest	30.95	4.26	28.20	3.96	1.39	2.1155	0.0410*
	Difference	-1.40	3.84	1.30	4.37	-1.24	-2.0756	0.0447*
tg2	Pretest	21.75	3.39	20.55	4.31	0.56	0.9792	0.3337
	Posttest	22.40	3.56	19.35	4.04	1.51	2.5321	0.0156
	Difference	-0.65	3.48	1.20	4.97	-0.74	-1.3633	0.1808
tg3	Pretest	17.80	3.33	15.75	3.65	1.12	1.8533	0.0716
	Posttest	18.00	3.32	15.80	3.76	1.17	1.9591	0.0575
	Difference	-0.20	3.49	-0.05	3.99	-0.08	-0.1265	0.9000
tg4	Pretest	15.80	2.91	14.00	3.48	1.03	1.7740	0.0841
	Posttest	16.20	3.69	14.45	4.31	0.81	1.3788	0.1760
	Difference	-0.40	3.91	-0.45	3.98	0.03	0.0401	0.9682
tg5	Pretest	16.15	3.25	14.75	3.24	0.86	1.3640	0.1806
	Posttest	17.10	3.70	15.70	4.35	0.64	1.0960	0.2800
	Difference	-0.95	3.61	-0.95	4.06	0.00	0.0000	1.0000
tg6	Pretest	19.10	3.54	18.60	4.01	0.25	0.4184	0.6780
	Posttest	20.30	3.31	19.35	4.04	0.47	0.8131	0.4212
	Difference	-1.20	3.29	-0.75	3.86	-0.23	-0.3967	0.6938
tg7	Pretest	26.00	3.67	28.30	4.18	-1.10	-1.8487	0.0723
	Posttest	27.70	3.71	28.15	2.96	-0.30	-0.4236	0.6742
	Difference	-1.70	4.32	0.15	3.76	-0.98	-1.4451	0.1566
tgH	Pretest	29.20	3.02	29.30	2.79	-0.07	-0.1087	0.9140
	Posttest	29.70	3.81	28.80	4.32	0.42	0.6982	0.4893
	Difference	-0.50	4.58	0.50	4.85	-0.41	-0.6702	0.5068
tgL	Pretest	61.95	4.73	66.65	6.22	-1.51	-2.6906	0.0105*
	Posttest	65.15	5.75	65.50	6.12	-0.11	-0.1864	0.8531
	Difference	-3.20	4.93	1.15	2.16	-4.03	-3.6166	0.0009*

*$p<0.05$

Graph 2: Comparison between Functional appliance treatment group and Camouflage treatment group using pre-treatment and post-treatment values of tongue related parameters



<u>INTERPRETATION (Table 2 and Graph 2)</u>

Table 2 compares tongue posture measurements between the functional and extraction groups. Statistically significant differences were observed in tg1 and tgL. Post-treatment tg1 increased in the functional group (30.95 ± 4.26) but decreased in the extraction group (28.20 ± 3.96), resulting in a significant difference. This suggests forward positioning of the tongue in functional cases. Similarly, tgL, which represents total tongue length, increased in the functional group (from 61.95 ± 4.73 to 65.15 ± 5.75) and decreased in the extraction group (from 66.65 ± 6.22 to 65.50 ± 6.12), with a statistically significant difference, indicating that extraction therapy restrict tongue length due to reduced oral volume. Other parameters such as tg2–tg7 and tgH did not show statistically significant inter-group differences ($p > 0.05$), indicating stability in those regions regardless of treatment modality.

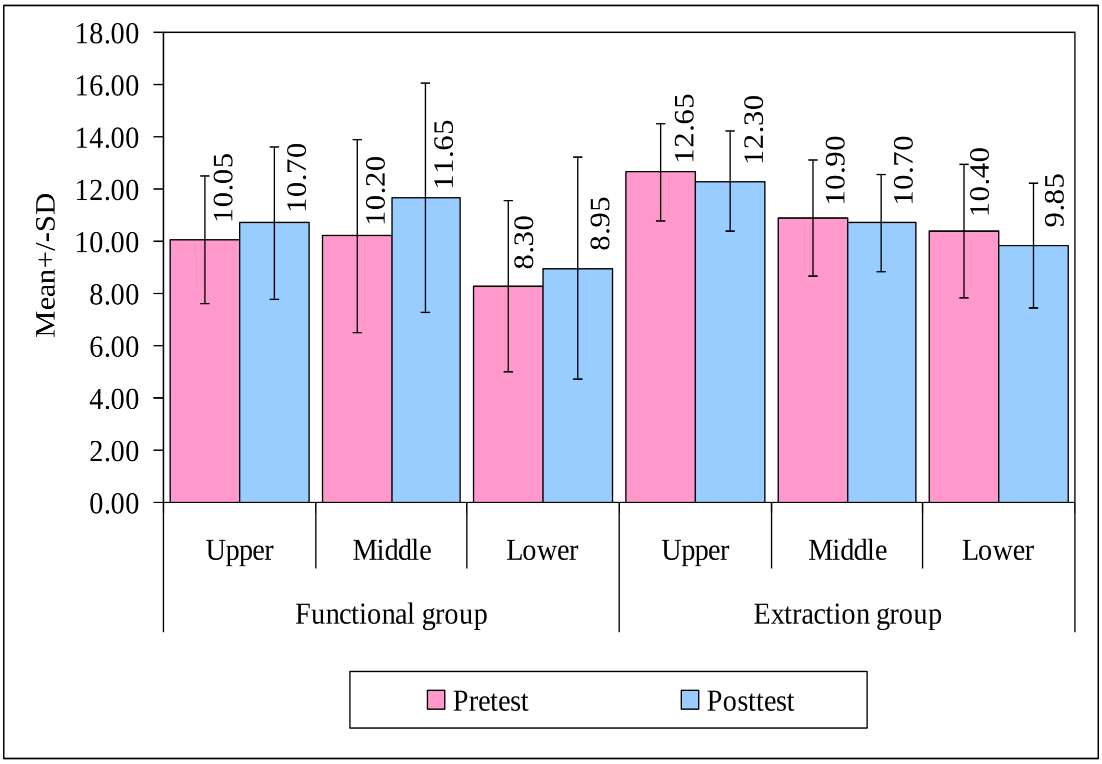
AIRWAY ANALYSIS

Table 3: Comparison of pre-treatment and post-treatment values (in mm) of upper, middle and lower airway in functional and camouflage treatment groups by dependent t test

Group	Section	Pretest		Posttest		Mean Diff.	% of change	t-value	p-value
		Mean	SD	Mean	SD				
Functional group	Upper	10.05	2.44	10.70	2.92	-0.65	-6.47	-1.8185	0.0848
	Middle	10.20	3.71	11.65	4.39	-1.45	-14.22	-2.0455	0.0549
	Lower	8.30	3.28	8.95	4.25	-0.65	-7.83	-0.8005	0.4333
Extraction group	Upper	12.65	1.87	12.30	1.92	0.35	2.77	2.3333	0.0308*
	Middle	10.90	2.22	10.70	1.84	0.20	1.83	0.9401	0.3590
	Lower	10.40	2.54	9.85	2.39	0.55	5.29	2.1464	0.0450*

*p<0.05

Graph 3: Comparison of pre-treatment and post-treatment values of upper, middle and lower airway in functional and camouflage treatment groups



<u>INTERPRETATION (Table 3 and Graph 3)</u>

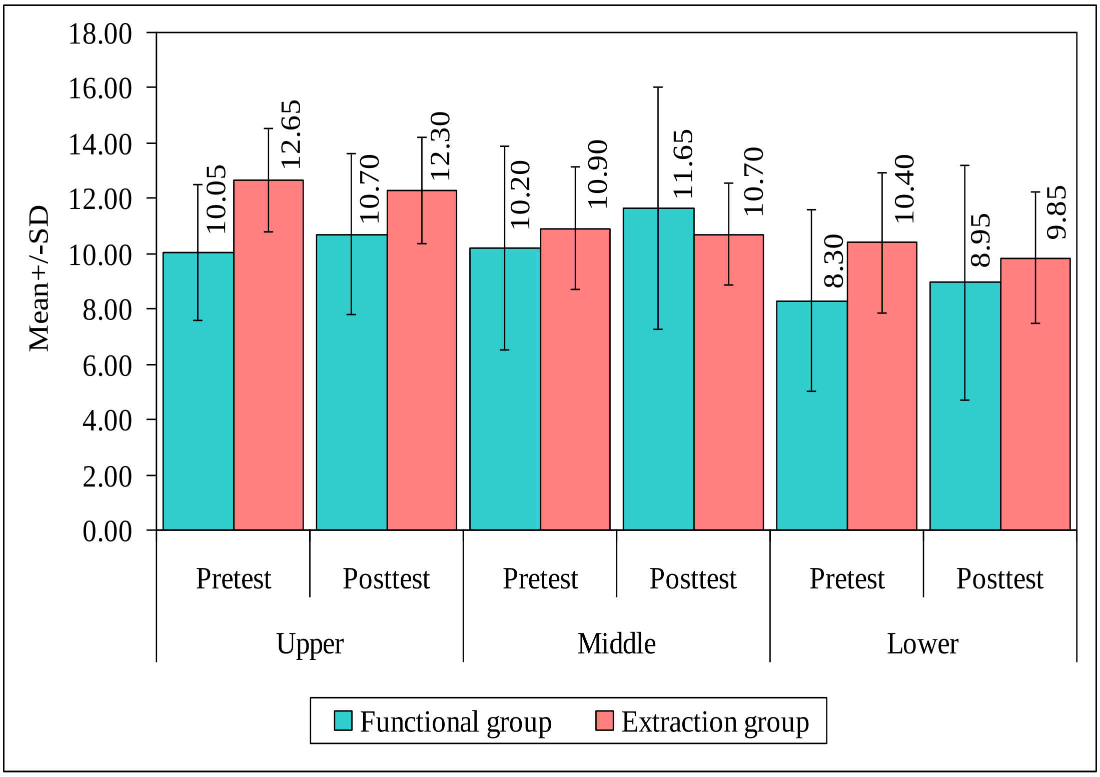
Table 3 depicts airway changes within each group. In the functional group, the middle airway showed borderline improvement ($p = 0.0549$), and the upper airway showed a non-significant change, suggesting benefits from functional treatment by mandibular advancement. In contrast, the extraction group demonstrated statistically significant difference by reductions in both upper (12.65 ± 1.87 (Pre), 12.30 ± 1.92 (Post)) and lower (10.40 ±2.54 (Pre), 9.85± 2.39 (Post)) airway widths post-treatment. The middle airway showed a reduction but not statistically significant. These results emphasize that extraction-based camouflage treatment leads to airway narrowing, especially in the upper and lower segments.

Table 4: Comparison between Functional appliance treatment group and Camouflage treatment group using pre-treatment and post-treatment values of upper, middle and lower airway by Independent t test

Sections	Time point	Functional group		Extraction group		Effect size	t-value	p-value
		Mean	SD	Mean	SD			
Upper	Pretest	10.05	2.44	12.65	1.87	-1.21	-3.7830	0.0005*
	Posttest	10.70	2.92	12.30	1.92	-0.66	-2.0459	0.0477*
	Difference	-0.65	1.60	0.35	0.67	-0.88	-2.5797	0.0139*
Middle	Pretest	10.20	3.71	10.90	2.22	-0.24	-0.7242	0.4734
	Posttest	11.65	4.39	10.70	1.84	0.30	0.8923	0.3779
	Difference	-1.45	3.17	0.20	0.95	-0.80	-2.2294	0.0318*
Lower	Pretest	8.30	3.28	10.40	2.54	-0.72	-2.2638	0.0294*
	Posttest	8.95	4.25	9.85	2.39	-0.27	-0.8257	0.4141
	Difference	-0.65	3.63	0.55	1.15	-0.50	-1.4093	0.1669

*p<0.05

Graph 4: Comparison between Functional appliance treatment group and Camouflage treatment group using pre-treatment and post-treatment values of upper, middle and lower airway



INTERPRETATION (Table 4 and Graph 4)

Table 4 highlights differences in pharyngeal airway widths between the two groups. For the **upper airway**, the functional group showed a mild improvement (0.65 mm) while the extraction group showed a reduction (0.35 mm), resulting in a significant difference (p = 0.0139). The **middle airway** also favored the functional group (1.45 mm vs. 0.20 mm in extraction), with statistical significance (p = 0.0318). The **lower airway** showed no significant difference between groups (p = 0.1669), though a trend toward functional group improvement was observed. These findings support the conclusion that functional appliances preserve or enhance airway dimensions, particularly in the upper and middle pharyngeal regions.

DISCUSSION

Obstructive Sleep Apnea (OSA) is a common yet significant sleep disorder, clinically defined by repetitive episodes of partial or complete obstruction of the upper airway during sleep, resulting in compromised respiratory airflow. Such episodes commonly manifest as snoring, frequent awakenings, fragmented sleep patterns, and intermittent hypoxia, adversely affecting the quality of life and systemic health of affected individuals(13,15). Patients typically present with daytime fatigue, impaired cognitive function, and various behavioral disturbances, including irritability, mood swings, and symptoms resembling Attention Deficit Hyperactivity Disorder (ADHD). The complex pathophysiology of OSA is multifactorial, involving anatomical, neurological, and physiological dimensions, often interlinked with underlying craniofacial structural discrepancies and neuromuscular dysfunction(13).

Historically, management approaches to OSA primarily involved general medical and surgical interventions facilitated by general practitioners or otorhinolaryngologists (ENT specialists). Conventional treatment modalities predominantly focused on enhancing airway patency through procedures such as adenotonsillectomy, nasal septoplasty, uvulopalatopharyngoplasty (UPPP), and turbinectomy, aiming to reduce anatomical obstructions of the upper respiratory tract(13). Despite their widespread application, these surgical approaches yielded varied outcomes, occasionally providing incomplete relief or short-lived improvements due to their limited influence on the fundamental craniofacial etiological factors.

Orthodontics emerged as a critical discipline in airway management by the latter half of the 20th century, recognizing that craniofacial abnormalities such as mandibular retrognathism, maxillary constriction, and altered tongue positioning substantially contribute to airway obstruction in OSA patients[20]. The introduction of orthodontic functional appliances was a transformative advancement in treating skeletal malocclusions, particularly Class II discrepancies, which are frequently associated with compromised airway space[35]. Functional appliances were initially created by Robin (monobloc), followed by influential modifications such as Andresen's activator, Balters' bionator, and notably Clark’s Twin Block appliance, each specifically designed to enhance mandibular growth and reposition mandibular posture anteriorly[20]. These appliances have shown substantial efficacy in improving airway patency, predominantly through favorable skeletal modifications, enhanced soft tissue positioning, and improved neuromuscular function[12,32]. In this present study, the Twin Block appliance was predominantly utilized due to its documented effectiveness, patient comfort, compliance benefits, and predictable clinical outcomes, followed closely by the activator and bionator appliances.

Despite their considerable clinical success, functional orthodontic appliances are not universally applicable across all patient populations. Alternative treatment modalities, notably extraction-based camouflage orthodontics and orthognathic surgery, remain clinically relevant due to varying patient demographics, growth potential, severity of malocclusion, and psychosocial or economic constraints[22,24]. Adolescents and younger patients often respond optimally to functional appliances due to their residual growth potential, which allows effective mandibular repositioning and skeletal remodeling. Conversely, post-adolescent patients with reduced or negligible growth potential commonly require alternative interventions. Orthodontic camouflage, which involves premolar extractions and significant anterior tooth retraction, is frequently preferred by patients reluctant to undergo invasive surgical procedures due to fear of complications, prolonged recovery periods, and financial limitations[22]. Nonetheless, camouflage treatment has its limitations, particularly regarding the potential adverse impact on airway dimensions, often leading to posterior displacement of oral structures and subsequent airway narrowing[37]. Orthognathic surgical interventions, notably mandibular advancement procedures, offer substantial and predictable improvements in skeletal and airway outcomes, representing the gold standard in treating severe skeletal discrepancies among adults[11,24]. Despite clear advantages, patient acceptance of surgery remains limited due to psychological apprehension, cost factors, and potential morbidity.

The present study was designed as a retrospective cephalometric analysis aimed at comparing the impact of functional appliance therapy and camouflage extraction treatment on the pharyngeal airway space and tongue posture in patients with skeletal Class II malocclusion. The sample was carefully chosen from the patient database, comprising 40 pre-treatment and post-treatment lateral cephalograms. Inclusion criteria were strictly defined to ensure sample consistency, focusing on skeletal Class II malocclusion characterized by mandibular retrognathism, an ANB angle of ≥ 4°, and AO-BO difference of >2 mm. Age stratification was applied, with the functional appliance group consisting of growing individuals aged 10–15 years, while the camouflage extraction group included older individuals aged 16–40 years, representing non-growing cases managed by dental compensation.

The sample size was determined using validated statistical formulae, with parameters set at an alpha level of 0.05 and a power of 85%, resulting in 20 subjects per group. This ensured sufficient statistical power to detect meaningful differences between the two treatment modalities. The study design incorporated both intra-group (pre- and post-treatment) and inter-group comparisons, enhancing the depth of analysis and reliability of the outcomes.

For measurement methodology, airway assessment adhered to established protocols described by Ozbek et al. , with specific focus on upper, middle, and lower pharyngeal airway widths. Tongue posture was assessed through a series of linear and dimensional parameters, as given by Rakosi and Lowe et.al, evaluating aspects such as tongue length, position, and height in relation to surrounding anatomical structures. This comprehensive evaluation framework allowed for a detailed understanding of how each treatment modality influences airway space and tongue posture, contributing valuable insights to clinical orthodontic practice.

The tongue, functioning as a muscular hydrostat, is critically involved in various essential functions, including mastication, speech articulation, swallowing, and the maintenance of airway patency(4). Proper tongue positioning against the palate plays a vital role in ensuring adequate transverse maxillary arch development and stability of dental arches(2,3).

The current study demonstrated significant improvements in tongue space (tgL), a statistically significant increase in total tongue length ($p = 0.0091$) and a noticeable anterior repositioning of the tongue (tg1) following functional appliance therapy, aligning with findings reported by Afzal and Fida(12) and Dedhiya et al.(33). These outcomes underscore the biomechanical effectiveness of functional appliances in enhancing tongue posture and oral cavity volume, thereby contributing to improved airway space and functional stability.

In contrast, extraction therapy led to statistically significant reduction in tongue space (tgL) (p = 0.0278), indicative of posterior displacement of the tongue due to incisor retraction. This finding is consistent with the observations of Bhatia et al., who noted that significant incisor retraction markedly reduced the available tongue space, potentially compromising airway patency(37). Although Sharma et al.(22) reported relatively limited effects of extraction therapy on tongue positioning, such variability in outcomes underscores methodological differences, individual anatomical variability, and variations in treatment protocols across studies.

Comparative analyses within this research clearly favored functional appliances by exhibiting a statistically significant difference in tongue length tgL (p = 0.0009), emphasizing their advantage in maintaining or enhancing optimal tongue posture relative to extraction therapies(7,35).

Similarly, airway analysis demonstrated significant improvements in airway dimensions following functional appliance therapy. Statistically significant enhancements, particularly in middle airway dimensions (p = 0.0549), were observed alongside positive trends toward increased upper airway dimensions. These findings are corroborated by studies such as Ali et al.(14) and Bidjan et al.(32), which collectively confirm that mandibular advancement appliances substantially enlarge airway spaces by anteriorly repositioning anatomical structures and decreasing airway collapsibility.

Conversely, the extraction group experienced statistically significant reductions in both upper (p = 0.0308) and lower airway (p = 0.0450) dimensions. This observation aligns with concerns articulated by Hu et al.(22), who emphasized that extraction treatment with significant anterior tooth retraction could compromise pharyngeal airway dimensions. Although Germec-Cakan et al.[38] reported minimal airway impacts in extraction patients with limited tooth retraction, they acknowledged that substantial incisor retraction negatively impacts airway size, confirming the observations of the present study.

Intergroup comparisons in this research strongly supported the use of functional appliances as superior to extraction-based camouflage treatments regarding airway preservation and enhancement, as it exhibited better outcomes in upper ($p = 0.0139$) and middle airway dimensions ($p = 0.0318$) reinforcing conclusions drawn by Kaur et al.[35] and Gu et al.[36].

Diagnostic methodologies employed in evaluating craniofacial structures, tongue posture, and airway dimensions primarily rely on lateral cephalometry, a well-established, cost-effective, reproducible diagnostic modality widely utilized in orthodontic clinical practice[31]. Despite its widespread acceptance, lateral cephalometry inherently provides only two-dimensional representations, lacking the volumetric accuracy afforded by advanced imaging technologies such as Cone Beam Computed Tomography (CBCT) and Magnetic Resonance Imaging (MRI)[29,31]. Nevertheless, lateral cephalometry remains a valuable, routinely utilized diagnostic modality due to its accessibility, cost-effectiveness, and minimal radiation exposure, providing reliable data on sagittal airway space and related anatomical structures critical for treatment planning and monitoring[31].

Early orthodontic diagnosis and timely therapeutic intervention during adolescence represent pivotal factors for optimizing treatment outcomes, capitalizing on residual growth potentials, and achieving maximal skeletal and airway benefits[24]. It is crucial to foster interdisciplinary collaboration and raise awareness among pediatricians, ENT specialists, and general healthcare providers regarding the significance of early orthodontic evaluations in managing airway-related malocclusions[13]. Orthodontists play an essential role not merely in addressing esthetic and dental alignment concerns but significantly contribute to enhancing airway patency, improving systemic health, and overall patient quality of life. For patients who surpass their optimal growth period without orthodontic intervention, contemporary treatment modalities such as Maxillary and Surgically Assisted Rapid Palatal Expansion (MARPE and SARPE) provide minimally invasive or non-surgical options, effectively addressing maxillary transverse deficiencies and indirectly improving airway dimensions and tongue posture[23].

In conclusion, orthodontics, particularly through functional appliance therapy, holds substantial promise in the integrated management of OSA and related airway disorders, significantly improving patient health and quality of life. Continued multidisciplinary collaboration and advancement in diagnostic and treatment methodologies will undoubtedly enhance clinical outcomes and optimize patient care for individuals experiencing airway-compromised malocclusions.

LIMITATIONS OF THE STUDY

- Variability in cephalometric magnification, which may affect linear accuracy; however, this was addressed through normalization techniques.
- Influence of head posture, body alignment, and mandibular position during imaging; despite using natural head position, minor variations could still affect measurement consistency.
- Relatively small sample size (n=40), which may limit generalizability of results to broader populations or different ethnic groups.

FUTURE SCOPE OF THE STUDY

- Prospective Longitudinal Design: Future research should follow a prospective design to assess dynamic changes across growth phases and post-retention effects.
- Role in Sleep Medicine: Integrating orthodontics into interdisciplinary sleep medicine teams can help manage pediatric OSA, using growth-modification appliances as non-invasive airway intervention.
- Multidisciplinary Collaboration: Coordination with ENT specialists, sleep physicians, speech pathologists, and radiologists can enable holistic patient evaluation and management.
- Exploring Other Orthodontic Approaches: Future research should evaluate how arch expansion, maxillary protraction, rapid palatal expansion, and skeletal anchorage systems influence airway dimensions and function.
- A newer approach to orthodontics, known as airway-focused orthodontics, emphasizes the importance of maintaining a healthy pharyngeal airway during treatment. This approach aims to optimize both the aesthetics and functionality of the mouth, while also promoting healthy breathing.

Hence, a potential research topic for future study can be as: ‘How do airway-focused orthodontic treatments impact pharyngeal airway development and breathing function in children, especially in managing pediatric sleep-disordered breathing?’

CONCLUSION

- **Functional appliance therapy promotes favorable anatomical changes**:

  In growing Class II patients, functional treatment significantly improved anterior tongue posture (tg1) and total tongue length (tgL), indicating better oral volume utilization and a forward tongue position conducive to healthier airway function.

- **Enhancement of pharyngeal airway dimensions**:

  Functional therapy led to measurable improvements in upper and middle pharyngeal airway spaces, with inter-group comparisons showing statistically significant differences reinforcing its role in optimizing airway patency during growth.

- **Camouflage extraction may compromise airway health**:

  In contrast, extraction therapy in non-growing individuals was associated with reductions in both tongue length and airway dimensions—especially in the upper and lower pharyngeal regions—raising concerns about potential long-term impacts on breathing.

- **Clinical implications for treatment planning**:

  These results emphasize the importance of integrating airway and tongue posture assessments into orthodontic decision-making. Functional appliances should be preferred in growing patients, while extraction-based camouflage should be approached cautiously with attention to possible airway compromise.

SUMMARY

This retrospective cephalometric study aimed to compare the effects of functional appliance therapy and camouflage extraction treatment on tongue posture and pharyngeal airway space in patients with skeletal Class II malocclusion. A total of 40 patients were included, divided equally into a functional group (10–15 years, growing individuals) and an extraction group (16–40 years, non-growing individuals). Measurements were taken from pre- and post-treatment lateral cephalograms using validated cephalometric parameters for tongue and airway assessment.

The results showed that functional therapy led to significant improvements in anterior tongue posture (tg1) and tongue length (tgL), along with favorable changes in upper and middle airway dimensions. In contrast, the extraction group exhibited a reduction in upper airway space, lower airway, and a decrease in tongue length, raising concerns about post-treatment airway compromise.

The study highlights the skeletal and functional benefits of using functional appliances in growing individuals, as opposed to extraction-based camouflage approaches that may risk airway constriction in non-growing patients.

It also emphasises the need for multidisciplinary approach in treatment for patients having skeletal Class II malocclusions.

Overall, the findings reinforce the need to integrate airway and tongue posture analysis into orthodontic treatment planning and suggest that functional appliances offer a more holistic approach to Class II correction.

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ANNEXURES

ANNEXURE-I : ETHICAL CLEARANCE CERTIFICATE

Research and Ethics Committee
KLE VK INSTITUTE OF DENTAL SCIENCES
A Constituent Unit of KLE Academy of Higher Education & Research
Accredited 'A' Grade by NAAC   Placed in Category 'A' by MHRD (GoI)
Nehru Nagar, Belagavi - 590 010, Karnataka State
☎: 0831-2470362   Web: http://www.kledental-bgm.edu.in
FAX: 0831-2470640   E-mail:principal@kledental-bgm.edu.in

Sl. No. : 1664

CERTIFICATE

This is to Certify that the synopsis titled A Comparative assessment of tongue posture and pharyngeal airway in Class II division 1 Patients treated with functional appliance and camouflage treatment - A Retrospective cephalometric study *Submitted by Dr.* - **REG. NO. II0222001** *P. G. Student / Staff, Guided by from Department of* Orthodontics and Dentofacial Orthopedics *has been critically evaluated by committee members and granted ethical clearance to conduct the above mentioned study*

Date : 16/4/25

Member Secretary
Research and Ethical Committee
KLEVK Institute of Dental Sciences
Belagavi

Chairman
Research and Ethical Committee
KLEVK Institute of Dental Sciences
Belagavi

MEMBER SECRETARY
Research & Ethical Committee
KLEVK Institute of Dental Sciences
BELAGAVI.

Chairman
Research and Ethical Committee
KLE VK Institute of Dental Sciences
Belgaum

ANNEXURE-II : DATA ENTRY SHEET

Group	PatientID	Upper_Pre	Upper_Post	Middle_Pre	Middle_Post	Lower_Pre	Lower_Post
Functional Group	F1	7	5	6	5	6	6
	F2	16	17	19	23	14	17
	F3	7	8	5	6	5	6
	F4	11	11	10	12	10	8
	F5	14	16	12	16	12	14
	F6	10	11	10	10	5	6
	F7	10	8	9	9	4	5
	F8	9	10	7	8	4	6
	F9	8	9	7	13	11	13
	F10	10	9	13	9	10	7
	F11	11	11	7	10	5	5
	F12	11	10	11	10	11	9
	F13	11	13	9	15	5	16
	F14	6	9	6	10	5	6
	F15	10	14	17	13	12	6
	F16	12	12	13	14	12	9
	F17	10	9	13	11	6	5
	F18	9	9	9	8	9	8
	F19	7	9	8	11	9	9
	F20	12	14	13	20	11	18
Extraction Group	E1	13	13	6	9	5	5
	E2	11	11	7	7	9	9
	E3	11	11	11	11	7	7
	E4	15	14	12	11	14	12
	E5	14	15	12	13	13	14
	E6	10	9	12	11	11	9
	E7	11	10	12	11	11	10
	E8	14	14	14	14	13	12
	E9	13	13	9	9	9	9
	E10	10	10	12	12	11	11
	E11	11	11	11	10	10	9
	E12	12	12	9	9	9	9
	E13	10	10	8	8	7	7
	E14	12	11	11	10	9	9
	E15	16	15	13	12	12	11
	E16	15	15	11	11	12	13
	E17	13	13	10	10	11	11
	E18	13	11	11	10	12	8
	E19	14	14	12	12	8	8
	E20	15	14	15	14	15	14

SL NO	PatientID	tg1_Pre	tg1_Post	tg2_Pre	tg2_Post	tg3_Pre	tg3_Post	tg4_Pre	tg4_Post	tg5_Pre	tg5_Post	tg6_Pre	tg6_Post	tg7_Pre	tg7_Post	tgH_Pre	tgH_Post	tgL_Pre	tgL_Post
1	F1	24	33	15	21	12	18	13	16	14	18	18	21	21	30	30	33	60	66
2	F2	30	26	18	19	14	15	11	12	11	12	12	15	22	24	29	30	66	65
3	F3	26	25	19	19	14	16	13	15	13	17	18	22	28	28	31	26	65	68
4	F4	29	30	22	22	19	17	18	18	19	19	23	20	28	26	24	25	61	61
5	F5	30	33	22	27	16	21	12	20	12	19	15	22	24	25	27	37	61	67
6	F6	26	29	19	21	14	15	14	13	14	14	18	13	28	23	26	29	60	64
7	F7	30	31	26	21	22	18	17	16	15	17	15	20	22	25	38	30	58	54
8	F8	28	31	19	22	15	18	14	17	16	19	18	20	24	32	27	35	64	74
9	F9	32	33	22	21	17	15	15	14	15	15	18	20	28	32	28	26	62	66
10	F10	31	31	20	24	16	19	13	16	14	16	18	20	22	31	26	31	66	66
11	F11	29	34	19	22	16	17	14	16	15	17	21	21	28	28	30	30	60	65
12	F12	30	33	23	27	21	23	18	21	19	19	21	22	31	26	31	31	69	63
13	F13	30	28	21	23	18	20	16	18	14	18	16	22	19	27	32	27	50	61
14	F14	29	29	21	22	18	19	17	18	17	17	19	18	26	22	30	31	57	54
15	F15	33	31	25	24	20	22	18	21	20	25	25	29	33	35	31	34	71	73
16	F16	29	22	20	13	16	10	14	10	14	12	17	17	23	22	27	25	65	69
17	F17	29	35	24	26	22	23	21	21	22	22	24	24	29	30	32	34	65	67
18	F18	31	31	27	21	22	14	19	7	18	8	21	18	28	28	29	22	58	61
19	F19	30	31	24	23	20	18	18	16	18	19	19	20	27	27	27	30	58	62
20	F20	35	43	29	30	24	22	21	19	23	19	26	22	29	33	29	28	63	77
21	E1	31	19	16	8	10	6	7	5	9	7	12	13	31	31	32	28	69	69
22	E2	34	33	22	20	18	14	16	12	16	13	17	18	21	32	27	24	66	70
23	E3	29	33	19	20	14	14	13	12	13	13	18	15	29	28	27	29	65	65
24	E4	20	24	12	16	9	12	9	11	12	14	16	18	33	31	27	26	70	65
25	E5	30	31	25	21	21	16	18	14	18	14	20	17	30	28	32	32	60	62
26	E6	26	30	19	22	12	15	11	13	11	14	15	18	28	29	30	22	65	64
27	E7	31	31	18	24	14	18	13	17	15	19	22	23	29	27	26	28	69	65
28	E8	25	28	22	18	20	17	18	17	18	19	21	23	30	29	31	28	67	67
29	E9	28	28	20	20	15	18	13	16	14	16	19	17	29	24	27	28	62	59
30	E10	23	22	13	15	11	13	11	13	14	16	21	21	27	27	25	26	64	63
31	E11	28	28	19	21	13	19	10	19	11	20	17	23	28	28	29	33	66	64
32	E12	39	32	30	22	23	17	21	16	22	17	25	21	35	31	36	29	80	78
33	E13	31	28	20	23	17	22	16	21	17	23	21	25	30	28	31	37	63	61
34	E14	34	30	27	16	16	11	12	10	11	13	13	20	21	25	29	19	64	62
35	E15	31	25	20	15	15	15	12	8	12	9	14	14	21	26	31	33	65	67
36	E16	33	33	22	25	17	21	16	21	17	24	21	28	33	32	26	36	81	78
37	E17	25	29	18	22	16	19	16	18	15	16	17	16	23	21	28	31	55	54
38	E18	30	23	24	16	18	15	17	14	19	14	27	18	25	29	32	28	69	67
39	E19	32	31	21	23	17	20	15	20	16	21	22	24	33	32	32	29	73	73
40	E20	30	26	24	20	19	14	16	12	15	12	14	15	30	25	28	30	60	57