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Evaluation of changes in tongue pressure with twin-block appliance therapy in growing Class II Div 1 malocclusion. An *in vivo* study

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Abstract

INTRODUCTION: Twin-block appliance therapy in patients with Class II Div 1 malocclusion positions the mandible anteroinferior leading to possible alterations in tongue pressure, tongue length, and the oropharynx.

OBJECTIVES: To evaluate the changes in tongue pressure, tongue length and dimension of the pharyngeal airway in Class II Division 1 subjects before and after twin-block therapy.

MATERIALS AND METHODS: Twenty-four subjects were selected, in the range of 10–14 years (mean—12 years). The tongue pressure was recorded at three regions with sensors placed at the incisive papilla and bilaterally at the molar region of the palate for four minutes. The root mean square (RMS) values were recorded and used for further analysis. Evaluation of tongue length and pharyngeal airway dimension was done using a lateral cephalogram. All the measurements were done before and after twin-block appliance therapy. The paired *t*-test was performed to compare the changes.

RESULTS: Resting tongue pressures decreased from pre-treatment levels to post-treatment at all three regions. Change in ANB angle was found to have a significant negative correlation with tongue length, and pharyngeal airway dimension, a significant positive correlation with pressure at incisive papilla and left molar region and no correlation at right molar region.

CONCLUSION: There was a decrease in resting tongue pressure as the malocclusion was corrected from Class II to Class I. Hence, this decrease in pressure could be a contributory factor in the maintenance of the dental equilibrium as lighter forces exist in the oral cavity.

Keywords:

Class 2 Division I malocclusion, Tongue pressure, Twin block

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Introduction

The equilibrium of the tongue and perioral muscles at rest could affect the dental arch form as the tongue is a powerful muscle and is in direct contact with dental arches and jaws.[1,2] As a result, the question of how the teeth maintain their stability in the oral cavity, despite the ongoing interplay of muscles, arises. According to Proffit,[1] one of the most important components in maintaining dental equilibrium is the tongue's resting pressure. The tongue's light resting forces are more important than the intermittent dynamic forces, such as those exerted during speech, mastication, and swallowing.[1] Also, resting tongue pressure appears to be more essential than pressure during function.[3]

However, a consensus on what constitutes normal tongue pressure has yet to be reached, and clinical cases are often assessed

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without considering it. This is expected due to the difficulty in describing tongue actions. Winders *et al.*,[4] Kydd *et al*.[5] have used different devices and techniques for measuring the tongue pressure. Stetson[6] used small balloons as pressure sensors in the 1920s, and by the 1950s, high-quality electronic amplification systems capable of handling small signals from miniature intraoral pressure transducers were used. Recent advances like the force-sensing resistor device/sensor developed by Datalog (Flexiforce low type, Biometrics Ltd, Gwent, United Kingdom) now have the advantage of being flexible, accurate, and lightweight. Flexiforce sensor has previously been used in a study by Deshmukh, *et al*.,[7] who studied mean tongue pressure in individuals with different growth patterns. Mean tongue pressure in average growth pattern cases was found to be 49.48 Kpa. In comparison with average growth pattern cases, they reported that horizontal growth pattern cases showed a higher value and vertical growth pattern cases showed lower values. The forces exerted on the palate by the tongue were reported to range from 35.36 Kpa to 51.47 Kpa. Other studies like Lambrechts *et al*.[8] had previously reported an average tongue pressure 1.66 N.

Variations in tongue pressure may be linked to a malocclusion as reported by Kurabeishi *et al*.[9] However, Doto *et al*.[10] suggested that tongue pressure is not related to craniofacial morphology.

Correction of Class II malocclusion in a growing individual with deficient or retruded mandible by myofunctional appliances also alters the tongue position and the oropharynx.[11,12] Though there are numerous studies in the literature evaluating the skeletal and dental changes brought about by functional appliances, to our knowledge, no study has assessed the changes in tongue pressure in response to myofunctional appliances in Class II Div 1 malocclusion subjects.[2]

Keeping this in mind, a study was designed to evaluate the changes in resting tongue pressure, tongue length, and dimension of the pharyngeal airway in subjects before and after twin-block therapy in Class II Division 1 malocclusion patients with the secondary objective to assess if any correlation exists between changes in tongue pressure with treatment effects of twin block and with changes in tongue length and pharyngeal airway.

Materials and Methods

A prospective experimental study was conducted in the department, and patients within the age range of 10–14 years (mean age 12 years) seeking orthodontic treatment for Class II Division 1 malocclusion were screened (irrespective of socioeconomic status, religion, and sex) by undertaking a brief clinical examination.

Sample size estimation

For sample size estimation, software G Power ver. 3.1.9.7 (Dusseldorf University, Dusseldorf, Germany) was used. The appropriate sample size was calculated based on P values of < 0.05, a power of 95%, and an effect size of 0.4 from previous studies as 48. Thus twenty-four subjects were recruited (ten males, 14 females), as the readings would be analyzed both pre-treatment and post-treatment.

Only those subjects were selected whose craniofacial morphology favored growth modulation for correction of Class II Division 1 malocclusion by taking into account the lateral cephalometric measurement, clinical evaluation, and inclusion and exclusion criteria. Informed consent was obtained from each subject, and ethical clearance was obtained by the Institutional Ethics Committee [Protocol number (D.No. 254/FM Dated 11/05/2019)], before the start of the study.

Inclusion criteria

Normodivergent/hypodivergent patients with skeletal Class II malocclusion exhibiting a normal maxilla, backwardly positioned mandible in growing age period with Class II molar and canine relationship with overjet >/=4 mm, ANB angle >4.5 degrees, and a positive visual treatment objective (VTO) on clinical evaluation were included in the study.

Exclusion criteria

Patients with hyperdivergent growth pattern and skeletal class II pattern due to an underlying maxillary prognathism and normal mandible were not included in the study. Patients with craniofacial syndromes, systemic disease, conditions like macroglossia, microglossia, ankyloglossia, paralysis of the tongue or lip, a history of trauma, pathology, congenital anomaly, and drug intake influencing the tone of the muscle were excluded from the study.

After appropriate sample selection, the study proceeded with the collection of data, which was done to assess and record the following:

- Assessment of tongue pressure changes recorded using flexiforce sensor.
- Craniofacial measurements on lateral cephalometric radiographs.

Data were collected before starting the treatment (T0) and at the end of the active treatment phase (T1) with a mean treatment duration of 7–8 months.

Appliance design

Twin-block appliance was constructed with an average advancement of 6+/- 2.5 mm and a vertical bite opening of 2-3 mm in the molar region, 5–6 mm in the premolar region, and an edge-to-edge overbite in the incisor region. Each twin block was designed with similar components including bilaterally placed delta clasps on maxillary first molars as well as mandibular first premolars, an acrylic body, and ball end clasps mesial to mandibular canines. No breakages were reported throughout the study needing any change in appliance during the active phase.

Procedure for recording of pressure

DataLINK Software and Hardware of M/s Biometrics. Ltd (UK) were used to record resting tongue pressure using a flexiforce sensor with a standard force range of 0–25 lb (0-111N) and an operating temperature range of (-40°F) to 140°F. The hardware units comprised the DataLINK base unit and the data acquisition unit. This sensor was interfaced with the Datalogger of Biometrics for the acquisition of the pressure values of the tongue at rest. These facilities were availed at the Ergonomics Research Division of the Department of Mechanical Engineering. [Figures 1 and 2]

The tongue pressure was recorded in all subjects, while they were sitting in an upright position, with Frankfort horizontal plane parallel to the floor, to attain the natural head position and with the mandible in rest position.[13-15] [Figure 3].

Three sensors were placed one at a time for tongue pressure recording: one sensor at the incisive papilla region and the other two sensors bilaterally at the molar region of the palate as was done by Deshmukh *et al*.[7] The sensor was secured onto the removable plate which was individualized for each subject using a thin layer of adhesive tape. The ultra-flexible nature of the sensor allowed comfortable positioning of the sensor in the oral cavity [Figure 4].

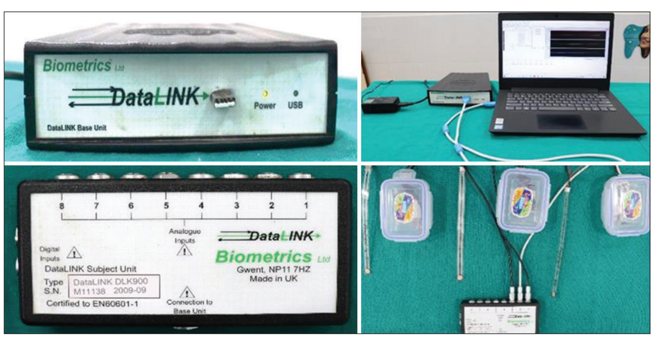

Figure 1: DataLINK Software and Hardware Biometrics Ltd data acquisition unit and its connections

Figure 3: Position of the patient while recording tongue pressure

The subjects were instructed to maintain their tongue in a habitual rest position. For the recording of the tongue pressure, a duration of four minutes was set, of which the initial two minutes were utilized to get the patient accustomed to the device and attain the rest position. The mean and maximum and minimum values of pressure were recorded using the DataLINK software by a single operator (G.S.). The RMS values of the pressures recorded for all three locations were obtained from the software and used for further analyses [Figure 5].

Assessment of tongue length and pharyngeal airway

Lateral cephalogram of each subject was taken using a digital cephalometric imaging machine, Rotograph Plus (Model # MR05, Italy) by orienting them in the natural head position to assess the dental, skeletal, and soft tissues.

The participants were told to relax their tongue to obtain records in resting tongue position.[16] To make the soft tissue outline of the tongue more visible in a radiograph, an X-ray contrast solution Iohexol (Omnipaque™) was coated on the dorsum of the tongue from the tip up to the most distal point. Subjects were asked to protrude the tongue, and the tongue was coated in the midline with the help of a brush.

Various landmarks, reference plane, and linear parameters were identified on the lateral cephalogram for

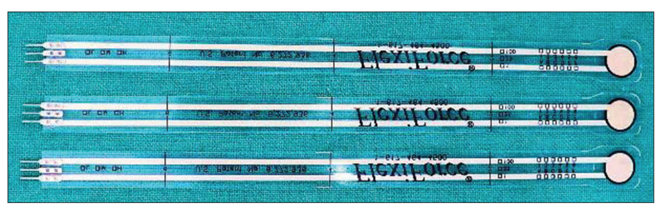

Figure 2: Flexiforce sensor

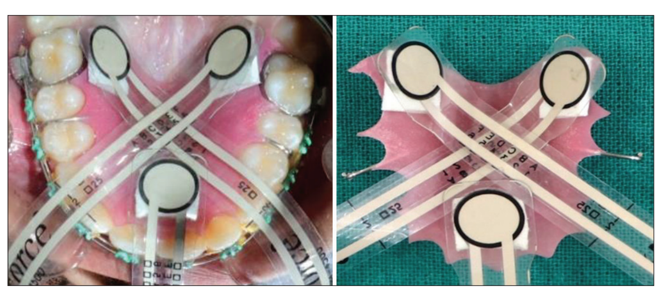

Figure 4: Positioning of the flexiforce sensor on the acrylic plate at three regions for recording of tongue pressure

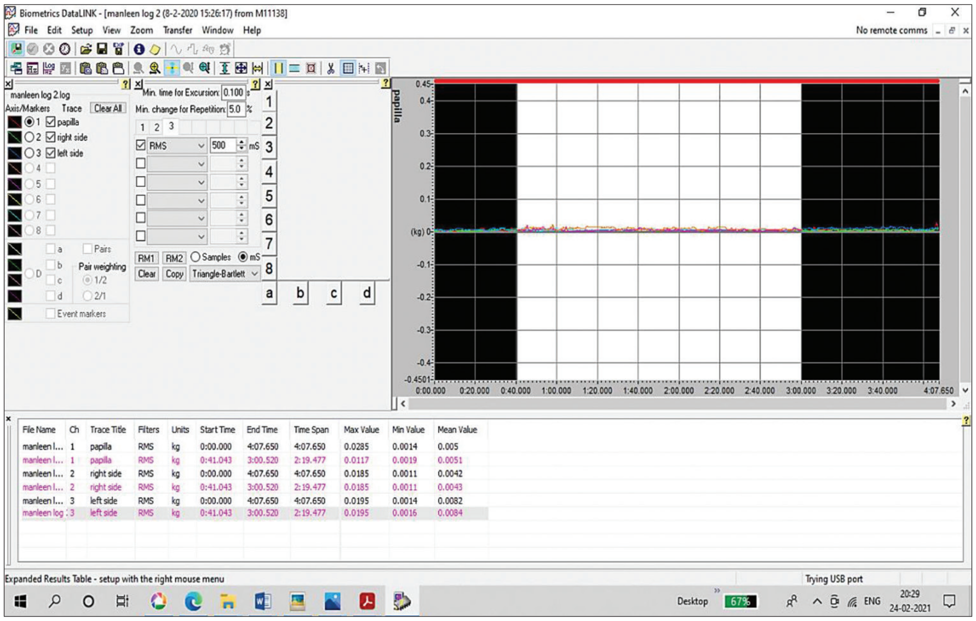

Figure 5: The DataLINK software displaying the mean and maximum and minimum value of a four-minute cycle as well as of a selected period of resting tongue pressure

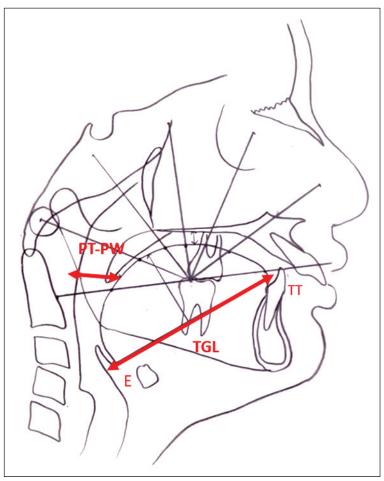

Figure 6: Cephalometric analysis for tongue posture, pharyngeal airway, and dentoskeletal features, *E The most inferior and anterior point of the epiglottis (Lowe et al., 1986); TT The tip of the tongue (Lowe et al., 1986); Pt The intersection point between the occlusal line (OL) and the contour of the tongue (Ingervall and Schmoker, 1990); Pw The intersection point between the occlusal line (OL) and the pharyngeal wall, (Ingervail and Schmoker, 1990); Pt-Pw The distance between the tongue and the pharyngeal wall (Ingervall and Schmoker, 1990) is described as the linear distance between a point on the tongue's contour (Pt) and a point on the pharyngeal wall (Pw) measured on the occlusal line (OL). TGL Tongue length as the Linear distance between E and TT (Lowe et al., 1986)*

the evaluation of tongue length and pharyngeal airway by a single operator (G.S.), as shown in Figure 6.[17,18]

Statistical analysis

Tongue pressure was measured twice by the same observer to determine intra-observer reliability by calculating the intraclass correlation coefficient (ICC). The cephalometric measurements were repeated by the same observer randomly selected patients, and intra-observer reliability was analyzed as well.

Data were statistically analyzed with Statistical Package for Social Sciences (version 21) (Chicago: SPSS Inc) and were subjected to descriptive analysis for mean and standard deviation. Paired *t*-test was used to analyze the significance of differences in mean value before (T0) and after (T1) treatment. A value of $P < 0.05$ was considered significant.

Results

The intra-observer reliability for tongue pressure and cephalometric measurements were excellent. Values for tongue pressure variables ranged from 0.987 to 0.995 for intra-observer reliability. Intra-observer reliability for cephalometric measurements ranged from 0.987 to 0.993.

The analysis was performed by interpreting the changes in tongue pressure at the incisive papilla, right molar, and left molar in the palatal region before and after treatment. The paired *t*-test was performed to compare the changes and to find any significant differences in measurements.

In our study, the resultant mean resting pressure values at the incisive papilla region showed a statistically significant difference with a *P* value of 0.047, where the pre-treatment values of resting tongue pressure were 12.50 ± 2.93 gm/cm^2 and the post-treatment values were 9.69 ± 2.36 gm/cm^2 with a mean difference of 2.81 gm/cm^2. This finding showed that tongue pressure at rest decreased after treatment.

The mean resting tongue pressure at the right molar region was found to decrease significantly from pre-treatment (8.1 ± 2.71 gm/cm2) to post-treatment (5.45 ± 1.86 gm/cm^2) with a mean difference of 2.70 gm/cm.^{2}

Similarly, the mean resting tongue pressure at the left molar region was also found to decrease significantly from pre-treatment (9.79 ± 2.26 gm/cm^2) to post-treatment (6.73 ± 1.31 gm/cm^2) with a mean difference of 3.06 gm/cm.^{2} [Table 1, Figure 7]

The mean tongue length increased significantly from pre-treatment (64.33 ± 4.71 mm) to post-treatment (68.42 ± 4.61 mm) with a mean difference of 4.09 mm (*P* value < 0.001) [Tables 2 and 3].

Pharyngeal airway showed a significant increase from pre-treatment (15.73 ± 3.78) to post-treatment (17.94 ± 3.92) with a mean difference of 2.22 (*P* value < 0.001).

For the changes in the craniofacial region, the mean SNA, SNB, ANB, FMA, IMPA (in degree) maxillary length, mandibular length, and overjet (in mm) were measured. A decrease in ANB (correction of 3.36 ° was observed) was seen along with a decreased SNA and maxillary length by 0.35° and 0.37 mm, respectively. There was an increase in FMA and mandibular length by 2.14° and 2.33 mm, respectively. Reduction of overjet by 6.29 mm and an increase of IMPA by 4° were observed [Table 4].

The correlation of ANB, mandibular length, incisive papilla, right molar region, left molar region, tongue length, and pharyngeal airway was done between pre- and post-treatment using the Pearson correlation test. There was a significant negative correlation of ANB changes with mandibular length, tongue length, and pharyngeal airway. There was a significant positive correlation of ANB changes with the pressure at the incisive papilla and left molar region and no statistical correlation at the right molar region [Table 5]

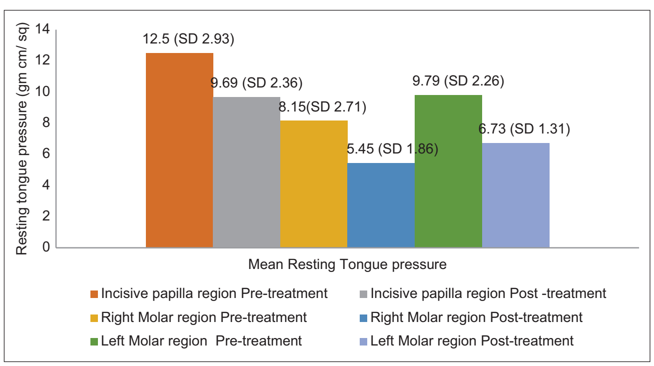

Figure 7: Comparison of difference of mean resting tongue pressure at incisive papilla. The region, right and left molar region pre- and post-treatment

Discussion

The muscles of the tongue, lips, and cheeks are thought to be the primary source of forces acting on the teeth.[10] If the balance between long-duration pressure from the tongue versus lip or cheek pressure changes, tooth movement would be expected. The skeletal and dentoalveolar changes brought about by the Twin-block appliance have been well documented in the literature.[19] The objective of our research was to analyze the changes in tongue pressure, tongue length, and pharyngeal airway dimension in subjects before and after twin-block therapy. In our study, the decrease in the tongue pressure values at all three regions (incisive papilla, right and left molar region of the palate) could be because the tongue has acquired a new position, as it moves anteriorly and flattens after treatment. Tongue pressure was seen to decrease as a factor of increased oral functioning space due to anterior displacement of the mandible. This was in agreement with the hypothesis proposed by Fish[20] that the mandible's rest position is linked to the tongue's posture.

According to Taslan,[21] the introduction of a tongue crib appliance could affect resting and swallowing tongue pressures due to tongue adaptation. This could also explain the decrease in pressure values in our study.

However, Fröhlich *et al.*[12] asserted that rather than actively molding dental arches, the tongue adapts to an existing morphology. Similarly, Proffit[3] found that Australian Aborigines have lower tongue pressures than Americans, although Aborigines have broader dental arches.

When comparing the resting tongue pressure values, it was seen that there was a significant decrease in mean

Table 1: Comparison of mean resting tongue pressure at incisive papilla region, right and left molar region pre- and post-treatment

Region	Mean	Std. Deviation	Mean difference	*t*-test	*P*
Incisive papilla region pre-treatment	12.50	2.93	-2.81	-2.049	0.047*
Incisive papilla region post-treatment	9.69	2.36			
Right molar region pre-treatment	8.15	2.71	-2.70	-2.329	0.045*
Right molar region post-treatment	5.45	1.86			
Left molar region pre-treatment	9.79	2.26	-3.06	-3.861	0.004*
Left molar region post-treatment	6.73	1.31			

Paired *t*-test. *Significant difference pressure at all three regions. Although observational studies[7,9,14,15] have recorded tongue pressure during rest and function, to our knowledge, no study had evaluated the effect of functional appliances on resting tongue pressure.

Our findings suggest that with twin-block appliance therapy, there was a decrease in resting tongue pressure as the malocclusion corrected from Class II to Class I, with the pressure at the anterior region (incisive papilla) being higher than in the posterior regions (right and left molar).

Hence, this decrease in pressures could contribute to the stability of the dental equilibrium as lighter force exists in the oral cavity. For evaluating the changes in the tongue length, the results in our study show that as the mandible moved forward from Class II to Class I normal occlusion, there was an increase in the tongue length. This result indicates that the tongue repositions and flattens as the mandible moves forward with a decrease in the ANB angle and reduction of overjet, as also stated by Zhou[22] and Yassaei *et al*.[23] Consequently, it is fair to assert that treatment with a functional appliance causes a considerable forward displacement of the tongue.

In our study, the mean pharyngeal airway value was found to have increased significantly post-treatment. This increase could be due to the orthopedic outcome of twin-block therapy to displace the mandible in a forward direction, leading to a beneficial effect on the posterior pharyngeal airway by the anterior movement of the tongue.[23] These results may be considered especially in Class II cases with reduced airway dimensions. One of the causes of malocclusion and post-treatment relapse is an abnormal tongue position.[24] Normalizing tongue position can help to break the cycle of unbalanced muscular activity, resulting in optimum jaw growth and stable occlusion.[24,25] In this study, it was seen that there were a decrease in SNA and maxillary length measurements which were not statistically significant, whereas a statistically significant decrease in ANB, FMA, and an increase in mandibular length was observed. Similar results have been reported in the literature.[26] Reduction of overjet was also observed which was statistically significant, and this shows that proclination of lower incisors, increment of mandibular length, and reduction of ANB could be the reason for the reduction of overjet, which is in accordance with previously reported studies.[27-29]

It was also observed that the treatment effects of the twin-block appliance consequently affect the tongue length.[30]

Correlation analysis was also performed to check whether any correlation exists between treatment effects with tongue pressure, tongue length, and pharyngeal airway. The result shows that with treatment as the ANB angle decreases, there was an increase in mandibular length, tongue length, and oropharyngeal airway. There was a significant negative correlation between them. When compared with pressure changes, it was found that there was a positive correlation of ANB angle with incisive papilla and left molar pressure and no correlation with right molar pressure.

The limitations of this study were the small sample size, which makes it difficult to establish any strong correlation. Further trials can be carried out on a larger sample size. Ideally, pressure should be directly measured at the tissue (hard palate) as the use of an acrylic

Table 2: Comparison of tongue length during treatment using paired *t*-test

Tongue length	Mean	Std. Deviation	Mean difference	*t*-test	*P*
Pre-treatment	64.33	4.71	-4.09	-11.566	<0.001*
Post-treatment	68.42	4.61			

Paired *t*-test. *Significant difference

Table 3: Comparison of pharyngeal airway during treatment using paired *t*-test

Pharyngeal Airway	Mean	Std. Deviation	Mean difference	*t*-test	*P*
Pre-treatment	15.73	3.78	-2.22	-6.974	<0.001*
Post-treatment	17.94	3.92			

Paired *t*-test. *Significant difference

Table 4: Comparison of SNA (in degree), SNB, ANB, FMA, maxillary length, mandibular length, overjet (in mm), and IMPA (in degree) between pre- and post-treatment using the paired *t*-test

	Pre-treatment		Post-treatment		*t*-test	*P*
	Mean	Std. Deviation	Mean	Std. Deviation		
SNA (in degree)	80.71	1.68	80.36	1.65	2.687	0.019
SNB	75.36	1.65	78.29	1.14	-11.951	<0.001*
ANB	5.36	1.55	2.00	0.96	12.459	<0.001*
FMA	19.86	2.11	22.00	1.84	-6.204	<0.001*
Maxillary length	47.76	1.32	47.39	1.24	2.334	0.036
Mandibular length	68.11	1.57	70.44	1.12	-11.357	<0.001*
Overjet (in mm)	8.50	1.95	2.21	0.80	12.837	<0.001*
IMPA (in degree)	94.93	4.30	98.93	5.05	-9.539	<0.001*

Paired *t*-test. *Significant difference

Table 5: Correlation of ANB, mandibular length (ML), incisive papilla (IP), right molar region (RMR), left molar region (LMR), tongue length (TL), and pharyngeal airway (PA) was done between pre- and post-treatment using the Pearson correlation test

		Correlations						
		ANB	ML	IP	RMR	LMR	TL	PA
ANB	Pearson Correlation	1	-0.615**	0.411*	0.257	0.405*	-0.392*	-0.635**
	Sig. (*P*)		0.000	0.030	0.187	0.032	0.039	0.000
	n	48	48	48	48	48	48	48
ML	Pearson Correlation	-0.615**	1	-0.083	-0.059	-0.112	0.489**	0.078*
	Sig. (*P*)	0.000		0.676	0.767	0.571	0.008	0.003
	n	48	48	48	48	48	48	48
IP	Pearson Correlation	0.411*	-0.083	1	0.825**	0.655**	-0.148	0.034
	Sig. (*P*)	0.030	0.676		0.000	0.000	0.452	0.864
	n	48	48	48	48	48	48	48
RMR	Pearson Correlation	0.257	-0.059	0.825**	1	0.773**	-0.352	-0.126
	Sig. (p)	0.187	0.767	0.000		0.000	0.066	0.524
	n	48	48	48	48	48	48	48
LMR	Pearson Correlation	0.405*	-0.112	0.655**	0.773**	1	-0.467*	-0.366
	Sig. (*P*)	0.032	0.571	0.000	0.000		0.012	0.055
	n	48	48	48	48	48	48	48
TL	Pearson Correlation	-0.392*	0.489**	-0.148	-0.352	-0.467*	1	0.677**
	Sig. (*P*)	0.039	0.008	0.452	0.066	0.012		0.000
	n	48	48	48	48	48	48	48
PA	Pearson Correlation	-0.635**	0.078*	0.034	-0.126	-0.366	0.677**	1
	Sig. (*P*)	0.000	0.003	0.864	0.524	0.055	0.000	
	n	48	48	48	48	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed)

plate and adhesive for the placement of the sensor might hinder the real measurement of pressure values. Another limitation is the use of two-dimensional cephalograms as an assessment tool in the present study, which might not be as accurate as currently available three-dimensional modalities such as cone beam-computed tomography. Future studies can be done for determining the dental equilibrium and stability, taking into account other factors like the perioral musculature, the force of occlusion, dental eruption, morphology, and the inclination of teeth. Also, the mean age of patients included in this study coincides with a period of soft tissue growth which could have a possible influence on the findings. Likewise, since tongue adaptation is a gradual process that occurs over 1–2 years, adaptation refers not only to the mandibular position but also to perioral musculature, size of the palate, and the lips. Thus, long-term follow-up studies are required to assess the tongue adaptation concerning these adjacent skeletal structures.

Conclusion

1. Resting tongue pressures at all three regions (incisive papilla, right molar, and left molar) decreased after twin-block therapy, which was statistically significant.
2. With an increase in tongue length and reduced pressure at the three regions, the changes were appreciable but were not statistically significant.
3. With a change in ANB angle, there is a significant negative correlation with tongue length, pharyngeal airway, and a significant positive correlation with pressure at incisive papilla and left molar region and no correlation at right molar region.

Ethics committee approval

This study was approved by Institutional Ethics Committee, Faculty of Medicine, Aligarh Muslim University, Aligarh [protocol number (D. No. 254/ FMDated 11/05/2019)

Informed consent

Written informed consent was obtained from all the patients who agreed to take part in the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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