Original Article

Evaluation of tongue pressure on the loop of transpalatal arch with acrylic button during deglutition in hyperdivergent patients

ABSTRACT

Introduction: To evaluate and compare the tongue pressure exerted on the acrylic button of variable size (10 mm and 14 mm) attached to the loop of trans palatal arch (TPA), placed at two different vertical heights (4 mm and 6 mm) from palatal mucosa during deglutition in hyperdivergent patients.

Materials and Methods: Tongue pressure was measured in 20 hyperdivergent patients (9 males and 11 females; age range 16–19 years with mean age 18.2 years) using FSR (Force sensing resistor) pressure sensors attached to acrylic button of TPA. Readings were obtained on amplifier attached to another end of sensor. In each patient, the tongue pressure was measured at two different vertical heights of TPA (4 mm and 6 mm) from palatal mucosa. At each vertical height diameter of acrylic button was also varied (10 mm and 14 mm). Hence, a total of 4 variables for each patient were evaluated. Measurements were divided into two groups – Group I (acrylic button of 10 mm size) and Group II (acrylic button of 14 mm size). Groups were further divided into subgroups (A and B) – Group IA (acrylic button of 10 mm size at 4 mm height), Group IB (acrylic button of 10 mm size at 6 mm height), Group IIA (acrylic button of 14 mm size at 4 mm height), and Group IIB (acrylic button of 14 mm size at 6 mm height). Unpaired Student's *t*-test was used for adequate intra- and inter-group comparisons.

Results: The mean tongue pressures for Group IIB was maximum (2.11 ± 0.228 N/cm^2) > Group IB (1.81 ± 0.169 N/cm^2) > Group IIA (1.57 ± 0.167 N/cm^2) > Group IA (1.30 ± 0.109 N/cm^2) and the difference was statistically significant ($P < 0.001$) for all the intergroup comparisions.

Conclusion: The tongue pressure measured on acrylic button of TPA in our study was in the range of 247–400 g (1.30–2.11 N/cm^2), which can be used to intrude molars in hyperdivergent individuals, thereby achieving counter-clockwise rotation of mandible.

Keywords: Acrylic button, hyperdivergent patients, pressure sensor, tongue pressure, trans palatal arch

INTRODUCTION

The orthodontic treatment essentially entails movement and adaptations of dental and dentoalveolar structures along with the adaptation of neuromuscular and soft-tissue structures around them.

The force exerted by perioral muscles on the dentoalveolar structures is counteracted by the forces exerted by tongue intraorally, thus maintaining the equilibrium.[1] The force exerted by tongue depends not only on its morphology but also on its position.[2] The tongue at rest lies in the floor of the mouth with dorsum touching the hard palate and tip lying against the lingual aspect of mandibular incisors.[3] The abnormal tongue posture at rest or altered function of tongue results in a disturbance of equilibrium in the buccinator mechanism.[4]

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Winders[5] stated that in all malocclusions, the lingual musculature is far more active than the perioral musculature during speech and swallowing. Christiansen *et al*.[6] evaluated the average force of the resting tongue as 0.8 g (pressure = 0.039 g/mm^2). Graber[3] reported the average frequency of deglutition once a minute between meals and nine times a minute during eating. Even during sleep, the swallowing act is performed at infrequent intervals. The average frequency of deglutition was reported 1600 times per day-2400 somatic and visceral swallow per day.[7,8]

Kydd and Toda[9] reported 112 g/cm^2 (1.10 N/cm^2) average tongue pressure during deglutition, much greater than tongue pressure at rest.[3] This suggests that tongue deliver forces of considerable magnitude at a variable frequency and the technical skills and protocol that the orthodontist uses to assess these forces may determine the ultimate success of orthodontic treatment.

Control of vertical dimension is of prime importance in orthodontic treatment planning specially in hyperdivergent patients. Overeruption of opposing teeth into the edentulous space is a common problem in patients with hypodontia and must be considered appropriately during treatment planning.[10] As trans palatal arch (TPA) prevents vertical descent of molars, hence could also be used for molar intrusion if tongue pressure exerted on loop of TPA could somehow be used.[11] Intrusion effect of TPA was enhanced if the loop was directed mesially,[11,12] its distance to the palatal mucosa was increased or if its interactional area with the tongue was augmented by adding an acrylic button to the loop.[9] Various authors[13-18] modified the TPA by adding acrylic pad or altering its distance from palate and evaluated the pressure exerted by the tongue during swallowing. The modifications of TPA such as nance appliance was also used to augment anchorage in the anteroposterior direction.[19]

We expect that by increasing the size of the acrylic button, tongue pressure during function can be transferred more effectively to the teeth for intrusion. The variation that occurs in the amount of tongue pressure on the TPA placed at a different vertical height from palatal mucosa with a variable surface area of acrylic button should be accessed.

Tongue pressure on the hard palate has been measured by sensing probes, sensors attached to palatal plate or sensor sheet system. Ready-to-use miniature pressure sensors enable researchers to install them with minimum discomfort in an experimental palatal plate or a maxillary dentition. Xu *et al*.[14] used resistance pressure transmitter sensors placed at the acrylic pads which was placed in the center and retained by the retentive arms of the Adam's clasp to measure the tongue pressure. As these sensors were easy to place in the patient's mouth and were very thin, so the patient compliance was more; hence, it was decided to use the same sensors in our study.

Aim and objective

The aim of the present study was to measure and compare the tongue pressure exerted on the acrylic button of the variable surface area attached to the loop of TPA placed at two different vertical heights during deglutition in hyperdivergent patients using pressure sensors.

MATERIALS AND METHODS

To select the hyperdivergent sample, screening of the subjects was done in two stages. Initial clinical examination to select the sample was done by estimating the FMPA angle (angle between mandibular plane [MP] and Frankfort horizontal plane [FHP]) using a metallic scale placed along FHP and keeping another scale along the lower border of mandible) which was confirmed by cephalometric analysis based on the values of Schudy's facial divergence angle[20] (SN-MP) and Jarabak's ratio[21] (S-Go/N-Me) × 100. Finally, in the duration of 1 year, 20 hyperdivergent patients (9 males and 11 females; age range 16–19 years with a mean age 18.2 years) were selected for the study. The sample size of the present study showed approximately 80% power ($\alpha = 0.05$). 95% confidence interval (limits) was provided for the study.

A signed informed consent as per the guidelines of university from the participants who agreed to participate in the study voluntarily and approval from Ethical committee of Babu Banarasi Das College of Dental Sciences affiliated to Babu Banarasi Das University was obtained.

In each patient, the tongue pressure was measured at two different vertical heights of TPA (4 mm and 6 mm) from palatal mucosa. At each vertical height diameter of acrylic button was also varied (10 mm and 14 mm). Hence, a total of 4 variables in each patient were evaluated and grouped as shown in Table 1 for the purpose of further tabulation and analysis.

Maxillary first molar preformed bands with attached lingual sheath were selected for each subject. The bands were placed on the first maxillary molars and working model was prepared for the fabrication of removable TPA.

Two acrylic buttons (self-cure acrylic material) of 1 mm thickness (10 mm and 14 mm diameter) were made with the help of a wax template. In the center of both the buttons, a hole (1 mm diameter) is made with a straight fissure bur for the insertion of measuring gauge. On the palatal side of

acrylic buttons, a nickel-titanium (NiTi) coil spring was fixed with self-cure acrylic in such a way so that this acrylic button can be engaged in the loop of TPA [Figure 1].

Removable TPA was fabricated on the plaster models from a 0.036-inch (0.9 mm) stainless steel wire. The loop of the TPA was positioned in the center of the imaginary line joining the two maxillary first molars and was distally oriented. For easy placement of the metal sleeve with the sensor, the length of the loop of TPA was kept 6 mm and the width of the loop was kept 5 mm. To have uniformity in the size of the loop, the template was made on the graph paper and was used for fabrication of loop and TPA in all the subjects. Two TPAs were constructed for each subject, keeping the distance of the loop with acrylic button from the palatal mucosa 4 mm and 6 mm, respectively. The distance of the loop with acrylic button in each patient was determined with the help of a custom made measuring gauge with markings at 4 mm and 6 mm. The gauge passes through that acrylic button till it touches the palate then TPA was adjusted to the required 4 mm and 6 mm height [Figure 2].

Pressure sensors were attached to the acrylic button with the help of double-sided adhesive tape. Button was then inserted into the loop of the TPA. The whole assembly was then transferred to the patient's mouth for measurement of tongue pressure on the acrylic button of TPA by being inserted into the lingual sheath. In order to minimize disturbance of the oral muscles and any hindrance in the occlusion, the connecting wires of the pressure sensors were passed distal to the last molar through the vestibule and out of the oral cavity at the angle of the mouth. The wire was connected to the battery-operated amplifier for pressure calibration [Figure 3].

The recordings were done with the subjects sitting in the upright position and head unsupported. The amplifier was calibrated to zero before each measurement when the tongue was not touching the sensors. The subjects were asked to swallow 15 ml of water at room temperature to minimize the influence of temperature change. The maximum pressure for five swallowing at each position of the TPA was recorded. Out of these five readings at each position, the mean was calculated and was used as the final value [Figure 4].

The same procedure was applied for all the subjects, and the data thus obtained were recorded into excel sheet which were then subjected to statistical analysis. The data were entered into MS Excel spreadsheet and analysis was done using SPSS (Statistical Package for Social Sciences) software, version 21.0. Categorical variables were presented in number and continuous variables were presented as mean ± standard deviation. Quantitative variables were compared using ANOVA and Unpaired *t*-test for intragroup and intergroup comparisons.

Table 1: Grouping of the variables used in the study

Diameter of acrylic button (mm)	Distance of loop with acrylic button from palatal mucosa (mm)	
Group I (10)	IA (4)	IB (6)
Group II (14)	IIA (4)	IIB (6)

RESULTS

The mean tongue pressure exerted on the loop of TPA with acrylic button in Group with 10 mm of acrylic button size

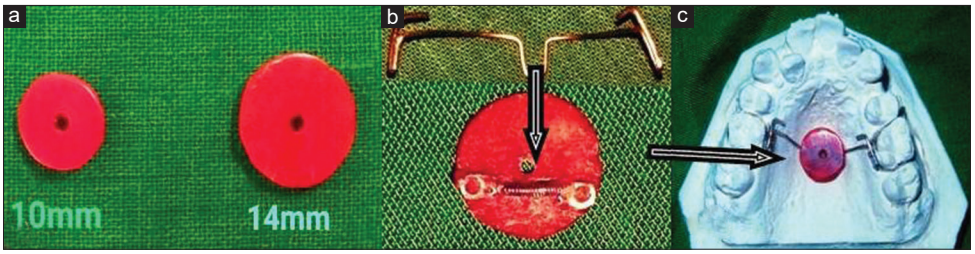

Figure 1: (a) Acrylic button of 10 mm and 14 mm diameter with central hole for measuring gauge. (b) Palatal side of acrylic button with nickel-titanium coil spring attached for the insertion of U-loop of trans palatal arch. (c) Acrylic button inserted to U-loop of trans palatal arch

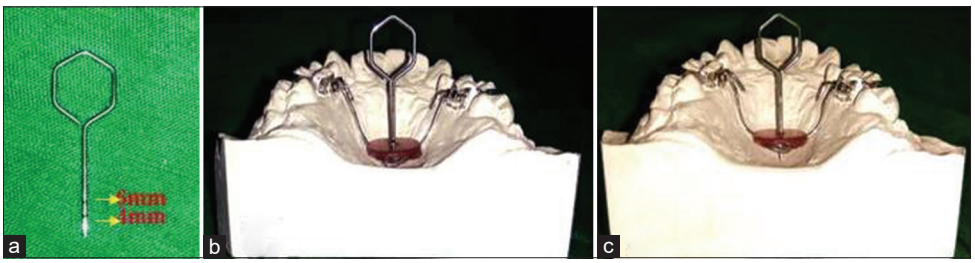

Figure 2: (a) Measuring gauge with markings at 4 mm and 6 mm. (b) Transpalatal arch with acrylic button at 4 mm height from palatal mucosa. (c) Transpalatal arch with acrylic button at 6 mm height from palatal mucosa

placed at 4 mm of vertical height from palatal mucosa (IA) was found to be lowest which was 1.30 N/cm^2, followed by Group with 14 mm of acrylic button size placed at 4 mm of vertical height from palatal mucosa (IIA) which was 1.56 N/cm^2 and Group with 10 mm of acrylic button size at 6 mm of vertical height from palatal mucosa (IB) which was 1.80 N/cm^2 and the highest values were obtained for Group with 14 mm of acrylic button size at 6 mm of vertical height from palatal mucosa (IIB) which was 2.10 N/cm^2 [Table 2]. The difference was statistically significant ($P < 0.00$ by ANOVA and $P < 0.001$ by paired *t*-test) for all the intergroup comparisons [Tables 3 and 4].

DISCUSSION

The mean tongue pressure was found to increase when the distance of the loop of TPA was increased from palatal mucosa. There was statistically significant difference between all the subgroups [Table 3]. Chiba *et al*.[13] also observed more tongue pressure, when TPA's was placed at 6 mm vertical height from palatal mucosa (2.23 N/cm^2) as compared to 4 mm (1.96 N/cm^2) and 2 mm (1.78 N/cm^2), respectively, at second molar region, while at first molar region contrary to our study the tongue pressure was found more at 4 mm vertical height (1.71 N/cm^2) than at 6 mm (1.57 N/cm^2) and 2 mm (1.25 N/cm^2). This conflicting result could be attributed to the smaller size of samples of their study. The mean tongue pressure for each group in the present study was found to be more as compared to studies done by Xu *et al*.[14] The skeletal and dental effects of a modified vertical holding appliance in a group of Egyptian children was evaluated by Aly.[22] and found that the appliance was able to induce forward and

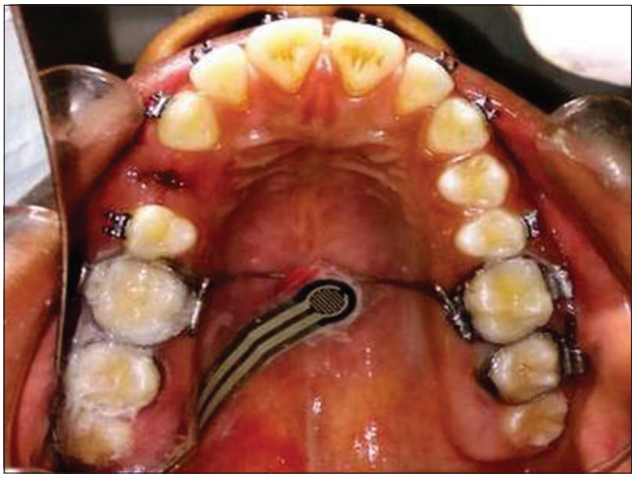

Figure 3: Placement of pressure sensor on acrylic button in the patient's mouth

Table 2: Tongue pressure exerted on the loop of trans palatal arch in Group I (A and B) and Group II (A and B)

Samples	Group I (with 10 mm acrylic button) (N/cm^2)		Group II (with 14 mm acrylic button) (N/cm^2)	
	IA (at 4 mm height)	IB (at 6 mm height)	IIA (at 4 mm height)	IIB (at 6 mm height)
n=20	1.26	1.94	1.69	2.56
	1.23	1.96	1.47	2.38
	1.31	1.82	1.45	1.99
	1.52	1.93	1.88	2.27
	1.29	1.78	1.60	1.94
	1.40	1.70	1.51	1.93
	1.18	1.58	1.37	1.85
	1.21	1.60	1.40	1.94
	1.20	1.61	1.37	1.83
	1.15	1.59	1.35	1.77
	1.20	1.56	1.38	1.89
	1.30	1.94	1.59	2.21

Table 3: Comparison of tongue pressure exerted on the loop of trans palatal arch for different variables (one-way ANOVA test)

Groups	Sum of squares	Df	Mean square	*F*	Significant
Between groups	3.986	3	1.329	42.681	0.000
Within groups	1.370	44	0.031		
Total	5.355	47			

P>0.05: Not significant, *P*<0.05: Just significant, *P*<0.01: Significant, *P*≤0.001: Highly significant

Figure 4: Recording of tongue pressure: (a) Projection of wire from sensor placed in patient's mouth. (b) Calibrated amplifier held by the side of patient at 0 with tongue not touching the sensor on acrylic button. (c) Reading on amplifier during swallowing

Table 4: Comparison of tongue pressure exerted on the loop of trans palatal arch for different variables (unpaired *t*-test)

Group	Mean tongue pressure (N/cm²)	Mean tongue pressure difference (N/cm²)	SD	95% confidence interval for mean (N/cm²)		*P*
				Lower bound	Upper bound	
Group IA versus Group IB	1.30	0.50	0.109	1.25	1.35	<0.001
	1.80		0.169	1.73	1.89	
Group IIA versus Group IIB	1.56	0.54	0.167	1.49	1.64	<0.001
	2.10		0.228	1.99	2.21	
Group IA versus Group IIA	1.30	0.26	0.109	1.25	1.35	<0.001
	1.56		0.167	1.49	1.64	
Group IB versus Group IIB	1.80	0.30	0.169	1.73	1.89	<0.001
	2.10		0.228	1.99	2.21	
Group IA versus Group IIB	1.30	0.80	0.109	1.25	1.35	<0.001
	2.10		0.228	1.99	2.21	
Group IB versus Group IIA	1.80	0.24	0.169	1.73	1.89	<0.001
	1.56		0.167	1.49	1.64	

P>0.05: Not significant, *P*<0.05: Just significant, *P*<0.01: Significant, *P*≤0.001: Highly significant. SD: Standard deviation

upward mandibular rotation as evident from the statistically significant increase in the facial axis angle (PtGn/NBa) as well as the significant increase in the overbite. Xu *et al*.[14] modified the TPA by incorporating acrylic pad placed at height of swallowing tongue record (referred to as 0 mm) with 2 additional modified TPA at height 3 mm more and 3 mm less than this height and found that the tongue pressure was higher when measured at +3 mm (7.91 kPa/0.79 N/cm²) and least when measured at −3 mm (5.23 kPa/0.52 N/cm²). Our findings may be attributable to the increased contact area of the dorsum of the tongue to TPA due to the presence of an acrylic button that resulted in increased measurements of tongue pressure as compared to those previous studies. Variation in the amount of pressure exerted by the tongue on the TPA between the present study and other studies are expected due to methodological difference regarding type, position, fixing of the sensors as well as due to difference in characteristics of the sample used in the study.

On comparing the mean tongue pressures exerted on acrylic button of 10 mm at distance of 4 mm and 6 mm from palatal mucosa, i.e., Group IA (1.30 ± 0.109 N/cm²) and Group IB (1.80 ± 0.169 N/cm²), respectively, the value for Group IB was significantly higher than Group IA. Similarly, when the mean tongue pressure for acrylic button of 14 mm at distance of 4 mm (Group IIA) and 6 mm (Group IIB) from palatal mucosa was compared the values for Group IIB was again significantly higher than group IIA. The results of the above comparisons demonstrated that when the distance of the loop of TPA from the palatal mucosa was increased, the resulting tongue pressure during deglutition over the TPA also increased in a consistent manner. The above results were in accordance with the findings of Chiba *et al*.[13] and Xu *et al*.[14]

The mean tongue pressures exerted on acrylic button of size 10 mm and 14 mm at distance of 4 mm from palatal mucosa was 1.30 ± 0.109 N/cm² and 1.56 ± 0.167 N/cm² for Group IA and IIA, respectively. The mean tongue pressure for Group IIA was found to be higher than Group IA and the mean difference of 0.26 N/cm² in tongue pressure was statistically significant. Similarly, the mean tongue pressures on acrylic button of size 10 mm and 14 mm at distance of 6 mm from palatal mucosa were 1.80 ± 0.169 N/cm² and 2.10 ± 0.228 N/cm² for Group IB and IIB respectively. The mean tongue pressure for Group IIB was found to be higher than Group IB [Table 3 and Figure 5] and the mean difference of 0.30 N/cm² in tongue pressure was statistically highly significant ($P < 0.001$). The resultant increased tongue pressure value with larger (14 mm) acrylic button may be due to increase in effective contact area of tongue to the TPA that leads to increased pressure exerted by the tongue on TPA for similar distance from the palatal mucosa. No studies had been done to evaluate the change in tongue pressure on varying the surface area of the acrylic button over the loop of TPA, hence direct comparison with the findings of our study was not possible.

When the mean tongue pressures for acrylic button of 10 mm placed at 4 mm distance from palatal mucosa and 14 mm placed at 6 mm distance from palatal mucosa i.e., Group IA and Group IIB were compared, the maximum tongue pressure was obtained in Group IIB where acrylic button size and distance from palatal mucosa both were more than Group IA, and the mean difference between tongue pressure was found 0.80 N/cm² which was statistically significant ($P < 0.001$). Mean tongue pressure obtained was highest for Groups IIB which suggests that tongue pressure over TPA can be increased by increasing the distance of the loop of TPA from palatal mucosa or by increasing the anteroposterior surface area and either of the variables can be used to achieve the vertical control as well as intrusion of maxillary molars to get desirable results.

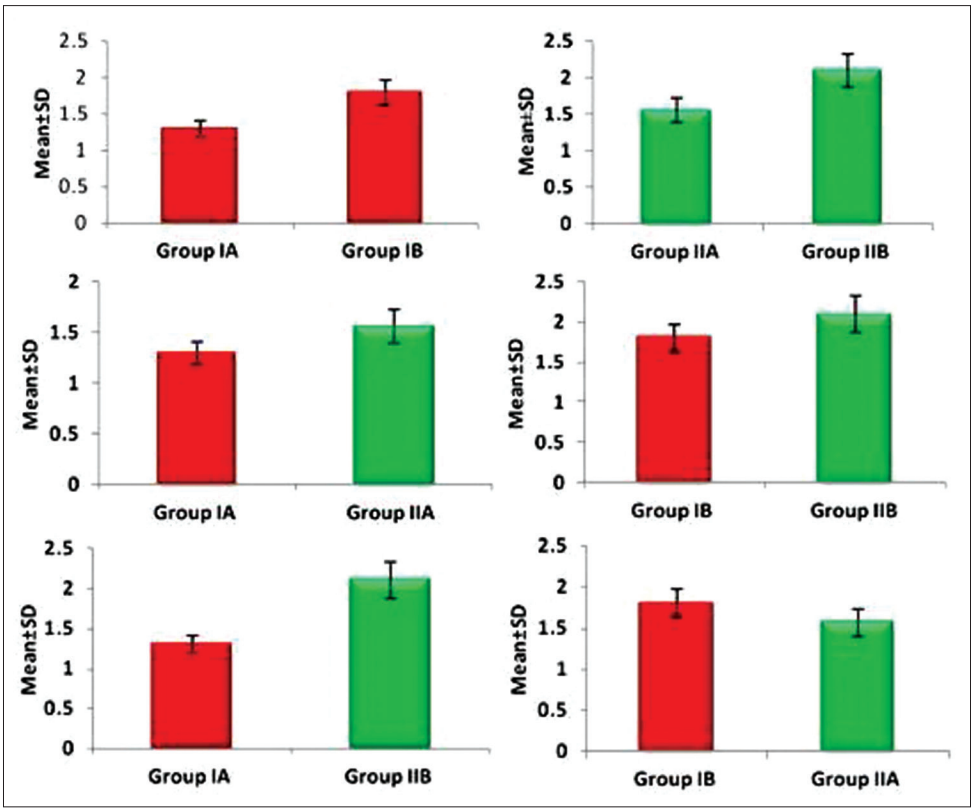

Figure 5: Bar diagrams showing comparison of tongue pressure exerted on the loop of transpalatal arch for different variables

On comparison of Group IB (group with 10 mm of acrylic button size with 6 mm of distance from palatal mucosa) and Group IIA (group with 14 mm of acrylic button size with 4 mm of distance from palatal mucosa), the mean tongue pressure was higher for Group IB as compared to Group IIA. The mean difference in tongue pressure was found to be 0.24 N/cm^2 which was statistically significant.

The above results suggest that increasing the distance of TPA from palatal mucosa increases the tongue pressure more effectively as compared to increasing the surface area of acrylic button. Results were consistent with the findings achieved by Deberardinis *et al*.,[23] Xu *et al*.[14] and Aly *et al*.[22] who also modified the design of TPA by adding the acrylic button over it to get the desired treatment outcome by maxillary molar intrusion resulting in mandibular counterclockwise autorotation. Xu *et al*.[14] in another study also opined that increasing the distance of the pads away from the mucosa leads to an augmentation of tongue force.

Previous studies[24,25] have shown that the forces required for molar intrusion had been in the range of 50–90 g. The forces measured on acrylic button of TPA in our study were in the range of 247–400 g (1.30–2.11 N/cm^2) and can be used effectively in hyperdivergent individuals to intrude molars, thereby achieving counter-clockwise rotation of mandible.

The clinical application of the present study would be that the morphology of the palatal vault and tolerance of the patient should be considered in deciding the type of modification of TPA (either increasing the distance of TPA or increasing the surface area of acrylic button or both) to be used in a particular case.

Further studies need to be conducted to evaluate the net effective intrusive force delivered to the molars using TPA with acrylic button. Limitation of the study includes difference in size, shape and muscular action of the tongue in different individuals which accounts for variability in amount of force exerted, hence further studies can also be conducted to evaluate the same. Furthermore, the role of tongue pressure in subjects with various defects such as Cleft of lip and palate can be evaluated.

CONCLUSION

1. Tongue pressure exerted over acrylic button increases when the surface area of acrylic button is increased
2. Tongue pressure over acrylic button of TPA also increases when the distance of acrylic button from palatal mucosa is increased
3. Increasing the distance of TPA from palatal mucosa is more effective in increasing the tongue pressure as compared to increasing the size of acrylic button.

The morphology of the palatal vault and tolerance of the patient should be considered in deciding the type of modification of TPA (either increasing the distance of TPA or increasing the surface area of acrylic button or both) to be used in a particular case.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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