Journal of Medicinal and Chemical Sciences 7 (2024) 436-447

Journal of Medicinal and Chemical Sciences

Journal homepage: http://www.jmchemsci.com/

Original Article

Morphological Analysis of Soft Palate Using MRI in Healthy Individual

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ARTICLE INFO

Article history

Receive: 2023-09-06
Received in revised: 2023-10-28
Accepted: 2023-11-01
Manuscript ID: JMCS-2310-2328
Checked for Plagiarism: **Yes**
Language Editor:
Dr. Fatima Ramezani
Editor who approved publication:
Dr. Yasser Fakri Mustafa

DOI:10.26655/JMCHEMSCI.2024.2.14

KEYWORDS

MRI
Obstructive sleep apnea
Soft palate
Velopharyngeal port

ABSTRACT

Velopharyngeal port is a vital structure in human body for carrying out important functions such as speech, swallowing, etc. Velopharyngeal incompetence arises due to ineffective or incomplete seal between oral and nasal cavity. The study of soft palate patterns like shape, length, and width offers an evidence to evaluate any risk factors for velopharyngeal insufficiency. This study was conducted to assess various palatal shapes and lengths using Magnetic resonance (MR) images and to establish their association with age and gender. A retrospective pilot study with 60 Magnetic resonance imaging (MRI) images belonging to 30 males and 30 females were assessed for soft palate shape, soft palate length, and vertical length. The data was entered in Microsoft Office Excel Sheet and was subjected to statistical analysis using SPSS version 26.0. Descriptive statistics like frequencies and percentages for categorical data, mean, and standard deviation (SD) for numerical data, comparison of frequencies of categories was done using chi-square test. 'Butt' variant was the most commonly encountered type, followed by the 'Rat-tail' variant as the second common type in our sample. A statistically non-significant difference was seen for the frequencies between the groups ($p>0.05$). The range of soft palate length (SPL) varied from 1.2 cm to 4.3 cm (S.D-0.674). The soft palate vertical length (SPVL) range is from 1.2 cm to 4.3 cm (S.D.-0.687). No statistically significant association of SPVL with the type of soft palate was seen ($p>0.05$). However, soft palate length (SPL) increases significantly with age. The study showed soft palate length increases significantly with age. Hence older individuals can be screened for soft palate related abnormalities for evaluation of sleep related disorder. Further such studies with more sample size are required to establish a correlation between the shape and length of the soft palate. This can aid as a diagnostic clue in the early diagnosis of soft palatal abnormalities during the patient examination.

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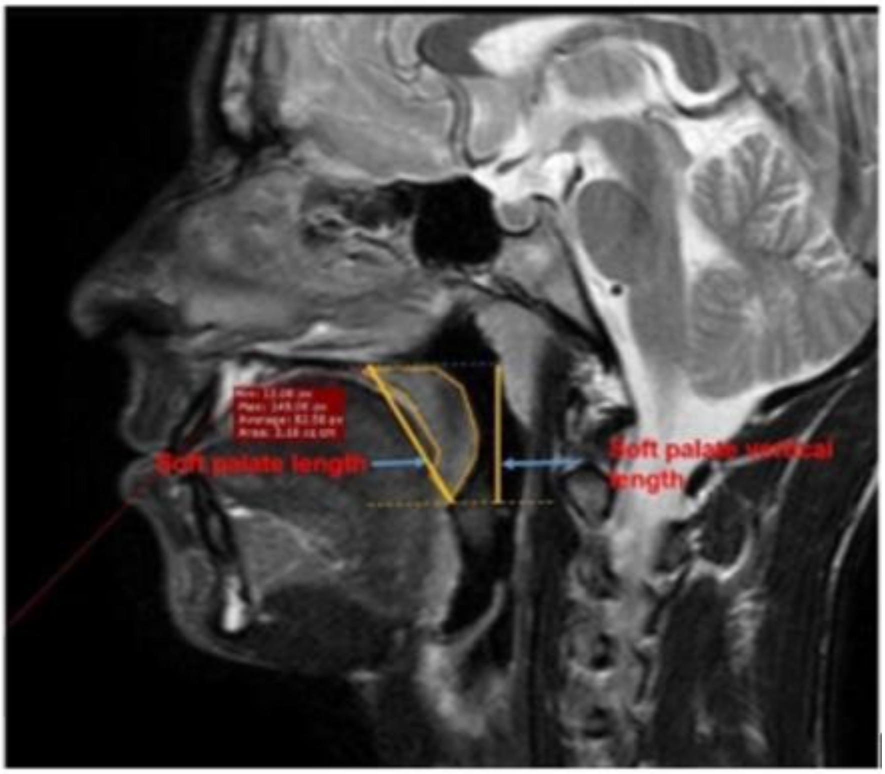
G R A P H I C A L A B S T R A C T



Introduction

The soft palate is a vital muscular structure that is located posterior to the hard palate. In conjunction with the posterior and lateral pharyngeal walls, it forms a muscular valve known as the velopharyngeal port. This velopharyngeal port is crucial for speech and swallowing, and is a requisite for the patient's overall well-being [1, 2]. Conditions such as obstructive sleep apnea (OSA), cleft palate, oral submucous fibrosis, enlarged adenoids, craniofacial malocclusion, and skeletal insufficiencies can directly/ or indirectly affect the soft palate and result in compromised function of the velopharyngeal valve. Defects in soft palate due to incomplete fusion of palatal shelves of maxillary processes results in a condition called cleft palate. Other common disorders encountered due to soft palate defect are obstructive sleep apnea which is characterized by repeated collapse of upper airway during sleep. Similarly, in Oral submucous fibrosis, the soft palate undergoes fibrosis resulting in reduced function [3-5]. Analyses of the various morphological patterns of the soft palate such as its shape, form, length, and width are therefore required to mark as indicators of potential risk factor of velopharyngeal insufficiency and function. Visualization of the soft palate is carried out using a flexible instrument called the nasopharyngoscope, which is uncomfortable and highly technique sensitive. Therefore, imaging is one of the opted modes of visualization of the soft palate, and can aid in the detection of associated conditions or deformities [6]. While lateral cephalograms are good adjuncts in imaging the soft palate [7], they are essentially two-dimensional images that provide minimal information about adjacent anatomical structures such as the nasopharynx and oropharynx. Agarwal *et al.* and More *et al.* used Computed Tomography (CT) as an imaging tool, which provides mid sagittal images with no overlap from the adjacent anatomical structures [8, 9].

MRI, however, is a non-ionizing soft tissue imaging modality which has superior muscular and soft tissue contrast, and is also commonly used for airway analysis in patients with obstructive sleep apnea.

Studies have shown velar shapes to vary across ethnicity and race [10]. Soft palate patterns have been classified qualitatively as "straight," "rat-tail," "crook," "S," "butt," and "leaf' shaped [4], with the "Rat tail "and "Butt' patterns being the ones most commonly encountered. Studies of different patterns of the soft palate such as its shape, length and width, offer clues to potential risk factors of velopharyngeal incompetence, for instance, the length of the soft palate is a significant causative factor in obstructive sleep apnea. An increase in the length of the soft palate over time in apnea patients when compared to those without apnea is a well-established concept, as is OSA in obese vs. non-obese patients [10].

This study was therefore conducted with the aim of assessing various palatal shapes and their occurrence in the two gender types using MR images. The objective was to measure the length of the soft palate and establish its association with age, gender and shape, and also to develop a correlation between the above factors for early diagnosis of soft palate abnormalities.

Material and Methods

This retrospective pilot study was conducted in the Department of Oral Medicine and Radiology in conjunction with the Department of Radiodiagnosis. Institutional Ethics Committee clearance was obtained (IEC No. 605/2020). 1100 brain MRI images were retrieved from the archives of the Radiodiagnosis wing attached to the Department of Trauma and Emergency. MRIs of the patient's head and neck region clearly depicting soft palate morphology were screened and chosen for the study. Patients with history of soft palate or oropharyngeal surgeries were excluded from the study. Images with artefacts which obscured the soft palate were excluded. Images of the subjects with medical conditions affecting the head and neck region like soft palate malignancy, syndromes affecting orofacial region, were also excluded from the study. After considering the inclusion and exclusion criteria only MRIs of 60 patients with ages ranging from 13 to 65 years were considered as the final sample size for analysis of the morphology of their soft palate. Participants from both genders who were only of Indian origin were recruited for the study. All the scans were performed using SIGNA™ 3.0Tesla MRI scanner machine of GE Healthcare (Chicago, USA) attached with 12 channel head coils incorporated with a high resolution T1- weighted turbo-spin-echo 3D scan. The subjects were scanned as per the general protocol in supine position without anaesthesia so that the velum was relaxed. Field of view was kept large with isotropic resolution maintained at 0.80 cycles in 4 minutes. The 3D MRI data was transferred to the Digital Imaging and Communications in Medicine (DICOM) viewer to visualize the velum slice along the midsagittal plane. The shape of the palate was analysed by an experienced diagnostician from the Department of Radiodiagnosis (with more than 10 years of experience in his field) and an oral radiologist (with more than 8 years of experience) to arrive at a consensus. The outline of palate was traced; its shape analysed and classified according to You *et al.*'s [3] classification of the morphology of the soft palate (Figure 1). The length of the soft palate was measured using the Digimizer Image Analysis Software. Under soft palate length, 2 parameters were measured -a) soft palate vertical length (SPVL) and b) soft palate length (SPL). The SPVL was measured from the apex or highest point of posterior nasal spine to the tip of the soft palate whereas SPL was defined as the distance between the posterior nasal spine and the tip of the traced soft palate (Figure 2). The data was entered and analysed in MS Office Excel Sheet.

Statistical analysis

Data obtained was compiled on a MS Office Excel Sheet (v 2019, Microsoft Redmond Campus, Redmond, Washington, United States) and subjected to statistical analysis using the Statistical Package for Social Sciences (SPSS v 26.0, IBM).

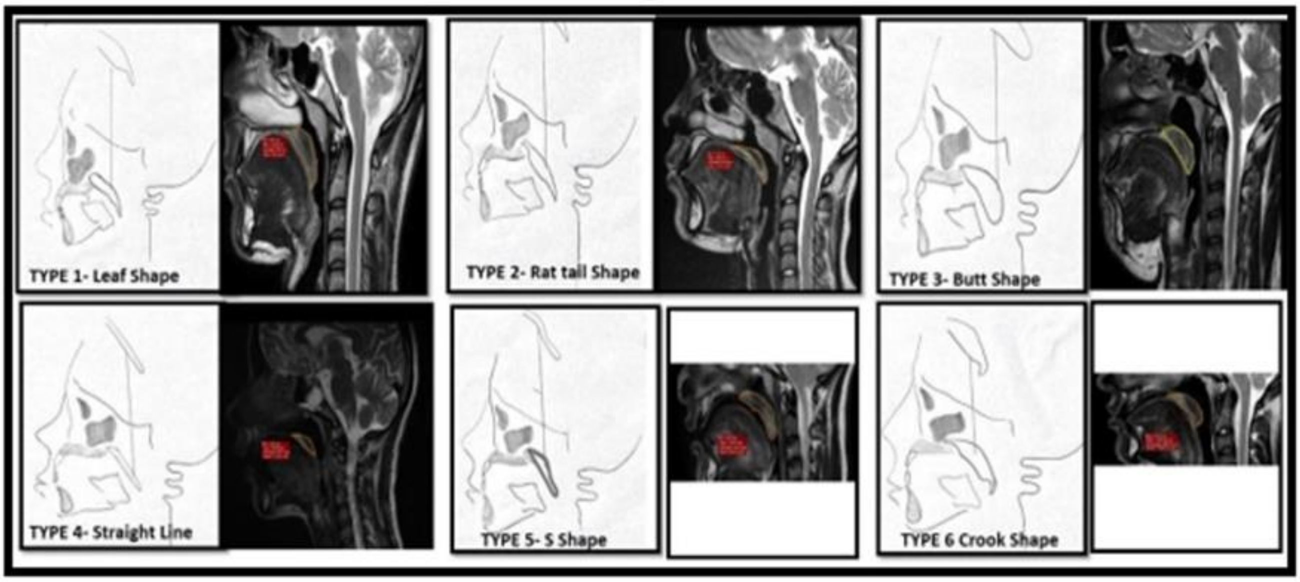


Figure 1: Morphological patterns of soft palate

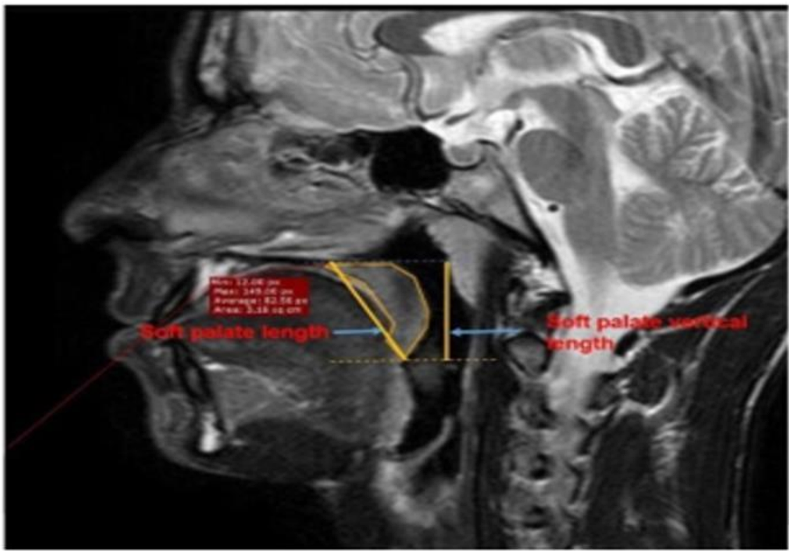


Figure 2: Soft palate measurement using digimizer image analysis software

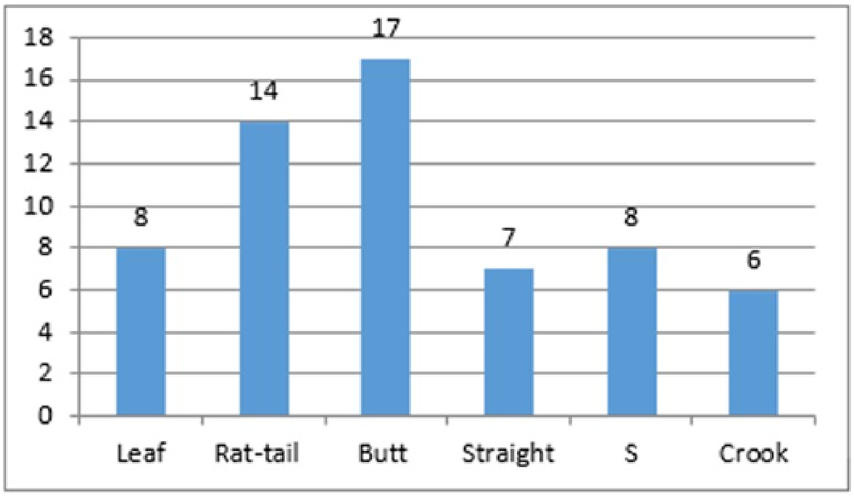


Figure 3: Distribution of the soft palate types in 60 MRIs

Table 1: Soft palate type distribution as per gender

		Gender				
		F	M	Total	Chi square value	p value of Chi square test
Soft palate type	Leaf	4	4	8		
	Rat-tail	6	8	14		
	Butt	9	8	17	1.654	0.895
	Straight	4	3	7		
	S	5	3	8		
	Crook	2	4	6		
	Total	30	30	60		

Descriptive statistics, namely frequencies and percentage for categorical data and Mean and SD for numerical data have been depicted. The comparison of frequencies in the different variable categories with groups was done using the chi square test. For all the statistical tests, $p<0.05$ was considered to be statistically significant, keeping α error at 5% and β error at 20%, thus giving a power of 80% to the study.

Results and Discussion

MR images of 60 gender matched (30- males, 30- females) subjects were studied, with age ranging from 13 to 65 years (mean- 30.5 years). In our sample of 60 MRIs, Butt variant (n=17) was the most commonly encountered type, followed by Rat-tail variant (n=14) (Figure 3).

Soft palate type distribution as per gender and age groups is depicted in Table 1. There was no statistically significant association observed between the type of soft palate and gender ($\chi(1) = 1.654$, $p = .895$). Likewise, no statistically significant association was found between the type of soft palate and age groups ($\chi (1) = .560$, $p = .990$).

Soft palate length (SPL) and soft palate vertical length (SPVL) were evaluated. The range of SPL varied from 1.2 cm to 4.3 cm (S.D-0.674). The range of SPVL is from 1.2 cm to 4.3 cm (S.D-0.687). ANOVA was done to determine whether there are any statistically significant differences in the mean values of SPVL and SPL among the soft palate types. No significant differences were found in the mean SPL ($p = 0.234$) and mean SPVL ($p = 0.152$) among the soft palate types (Tables 2 and 3).

Linear regression analysis is presented in Table 4, which shows that soft palate length (SPL) increases significantly with age. Each b-coefficient that indicates the average increase in length associated with a 1-unit increase in age, which was significant with SPL ($p = 0.049$). Beta coefficient (standardized regression coefficients) for SPL and SPVL were 0.245 and 0.009, respectively, suggesting that only SPL was a stronger predictor for age. No statistically significant association of SPL with type of soft palate were seen ($p>0.05$).

Variability in the palatal shapes were initially described on normal individuals using Lateral Cephalograms by You *et al.* [3] Conventional imaging like lateral projection of the skull are primarily for hard tissues like teeth and skeletal structures. However, due to their projection of soft tissues shadows and airway spaces they are often used for imaging of soft tissues mainly the soft palate, soft tissue profile of face etc. Therefore, further confirmation of their shapes using higher real time soft tissue imaging is required**.** MRIs are the best choice of imaging for soft tissues like soft palate and obtaining its measurement, diagnosing any abnormalities and assisting in treatment planning. We evaluated 60 gender matched MRI images for soft palate type, soft palate length and soft palate vertical length according to You *et al.*'s classification [3]. The present study showed that the Butt and Rat tail type are the most predominantly found shapes in both the age groups.

Table 2: Association of Soft palate vertical length with soft palate type using ANOVA

			Sum of Squares	df	Mean Square	F	Sig.
SPVL	Between Groups	(Combined)	2.941	5	0.588	1.413	0.234
	Within Groups		22.476	54	0.416		
	Total		25.417	59			

Table 3: Association of soft palate length with the soft palate type using ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SPL	Between Groups (Combined)	3.586	5	0.717	1.693	0.152
	Within Groups	22.873	54	0.424		
	Total	26.459	59			

Table 4: Regression analysis for age prediction using SPL and SPVL

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
SPL	(Constant)	2.546	0.223		11.438	0.000	2.100	2.991
	Age	0.013	0.007	0.245	1.926	0.049*	0.000	0.027
SPVL	(Constant)	2.520	0.234		10.767	0.000	2.216	2.552
	Age	0.001	0.007	0.009	0.071	0.944	0.000	0.019

Table 5: List of studies performed using different imaging modality to analyze the soft palatal shapes

Soft palate shape analysis on Oral Submucous Fibrosis Patients			
Sl. no	Study performed	Sample size of patient	Prevalent morphology in patients
1	Tekchandani V et al 2015 [15]	40-lateral ceph	Type 1 in Initial stage and type 6 in advanced stage
2	Domir SK 2019 [16]	217 lateral ceph	Type 1
		40 lateral ceph	Stage 1- Type 2 Stage 2- Type 1 Stage 3- Type 6
3	Nerkar A, 2017 [17]	35 lateral ceph	Type 1
4	Shankar VN 2014 [18]	35 lateral ceph	Type 1 in stage2
5	Rathore S 1019 [19]	50 lateral ceph	Type 1
6	Khare P 2019 [20]	45-cbct	Leaf type
7	Patil BM 2017 [21]	150 lateral ceph	Type 1 in stage 1, type 4 in stage 2
8	Deshmukh RA 2015 [4]	20 lateral ceph	Type 1
9	Lakshmi CR [1]	50 lateral ceph	Butt type and crook type
10	Tripathy et al., 2020 [22]	60 lateral ceph	Stage I and II OSMF- Type 1 most common (Leaf-shaped) Stage III OSMF- Type 3 most common (Butt shaped) As disease progressed, Type 1 converted to Type 3

Soft palate shape analysis on C left palate patients using MRI			
Sl.no.	Authors	Subjects	Findings
1	Perry JL [23]	11	Short hard palate and more flattened hard palate in those with repaired cleft palate; levator muscle length shorter in cleft palate; shorter velar insertion distance height and more acute angle of origin in repaired cleft palate; smaller velopharyngeal ratio in cleft palate group
2	Bae Y [24]	10	Male participants had significantly longer levator muscles than those of female participants.
3	Perry JL [25]	4	gravity had a minimal effect on velar thickness, velar length, velar height, levator muscle length, angles of origin, and pharyngeal dimensions. Differences between upright and supine were not significant with the exception of velar height during /i/ production
Soft palate shape analysis on normal individuals using CT, CBCT and Lateral Cephalograms			
Sl. No.	Authors	Investigation and no. of subjects	Findings
1	More CB [26]	300-CT	Butt type
2	Agrawal P. [27]	121-CBCT	Rat tail type
	You M. et al. (2008) [3]	200 lateral cephs (Age: 5-48 years)	6 types of soft palate morphology Type 1: Leaf-shaped/Lanceolate (most common- 53.0%) Type 2: Rat-tail shaped (18.5%) Type 3: Butt-like shape (13.5%) Type 4: Straight line (10.0%) Type 5: S-shape (3.5%) Type 6: Crook shape (1.5%)
2	Guttal et al. (2012) [28]	200 lateral cephs	Type 1 most common
3	Kumar et al. 2011 [29]	100 lateral cephs (46 men, 54 women; 15-35 years)	Type 1: 40% Type 2: 28% Type 3: 15% Type 4: 12% Type 5: 2% Type 6: 3%
4	Nagaraj et al. (2016) [30]	200 lateral cephs	Type 1 most common Followed by Type 2 and Type 3 Velar width more in males
5	Niu et al. (2006) [31]	106 lateral cephs	Six types observed Shuttle-shaped, crescent-shaped, strip-shaped, S-shaped,

			hamulus-shaped and anomalous shaped. The dynamic image was knee-shaped
6	Praveen et al. (2011) [32]	80 lateral cephs (Age: 9-31 years)	Type 2 most common (55%) Type 1 (10%) Type 3 (8.75%) Type 4 (18.75%) Type 5 (2.5%) Type 6 (5%)
7	Santosh et al. (2015) [33]	100 lateral cephs (41 males, 59 females; 15-25 years)	7 types Type 1 (47%) Type 2 (10%) Type 3 (16%) Type 4 (12%) Type 5 (2%) Type 6 (U-shaped - 8%) Type 7 (Bifid shape – 5%)
8	Verma et al. (2014) [34]	300 lateral cephs	Type 1 (48.7%) Type 2 (31%) Type 3 (4%) Type 4 (8.7%) Type 5 (4.7%) Type 6 (3%)
9	Khaitan *et al.* (2015) [14]	200 lateral cephs	8 types Type 1 (47.5%) Type 2 (33.5%) Type 3 (7.5%) Type 4 (4.5%) Type 5 (1.5%) Type 6 (1.5%) Type 7 (Triangular shaped – 2%) Type 8 (Bifid-shaped –2%) Type 1 most common inmales Type 2 most common infemales

There was no significant difference between age and gender based on the palatal shape. Similar results were seen by Kotlarek K. *et al.* who also observed Butt shaped palate to be the most common type in adults and children. However, in contrast to our study, Kotlarek *et al.* saw a significant difference in the shape of the palate and the age of the subject [11].

Dimensions of the soft palate influences velopharyngeal functions such as eating, deglutition, speaking, and breathing abnormalities of the soft palate can be observed in patients with cleft palates, abnormal velum, submucous cleft palates, excessively large tonsils or adenoids, webbing of the posterior tonsillar pillars, obstructive sleep apnea, skeletal craniofacial malocclusions, and oral mucosal conditions such as Oral submucous fibrosis [4, 5]. Increased length of soft palate is an airway factor significantly associated with obstructive sleep apnea. Previous studies have reported that the soft palate becomes longer and thicker over time. Excessive flaccidity and muscular atrophy is observed in the soft palate and uvula in patients with OSA and snoring. Malhotra *et al.* reported that the length of the soft palate increased progressively with age [12, 13]. An Italian study examined the value of MR imaging of the oropharynx during wakefulness [13]. They found an inverse correlation between the soft palate length and arterial oxygen partial pressure (an indicator of apnea). The length of the soft palate was found to increase significantly with age, as seen in a similar study by Tanya Khaitan *et al.*

[14]. This is a significant finding which was noted in our pilot study, further validation through large sample studies is being planned. With aging, increase in the length of the soft palate can pose an individual to higher risks of velopharyngeal abnormalities and obstructive sleep apnea. Hence, older individuals must be screened for soft palate related abnormalities and as a risk factor for sleep related disorder.

Although the correlation between dimensions of the soft palate and OSA has been proven, the relationship between its length and morphological shape has not been evaluated in previous studies. Table 5 provides the list of studies performed for soft palatal shape and size analysis in various scenarios using different imaging modalities. In the present study, we evaluated the relationship between SPVL and SPL with the shape of the soft palate and the age of the patient. There was no significant relationship between the morphological type of the soft palate and its length which could be due to smaller sample size of this study.

Speech abnormalities like improper pronunciation of words "k", "g" and nasal twangs is due to soft palate at lower level causing obstruction and directing the sound through nasal cavity than oral cavity. Hence, retaining the shape of the palate even after the surgical repair of palatal abnormalities like clefts is of utmost importance. Literature suggests that majority of patients have unclear speech after their soft palate surgical reconstruction. This is due to inability to retain their natural shape during the surgery. Study by Chungli *et al.* showed that speech difficulties and lack of reacquiring the regular articulation was very low in patients undergoing surgical repair of clefts. This was mainly due to the post-surgical annular or semi annular forms of the soft palate attained when compared to the usual circular shape. [35, 36] establishing a correlation between the shape and length of the soft palate can aid as a clue in early diagnosis of soft palatal abnormalities in dental clinical settings during oral examination.

However, the limitations of the present study were the small sample size. Hence, further studies with a larger sample size including different age groups of the population, can give a better prediction of the relationship between morphology of the soft palate and its influence on oropharyngeal abnormalities.

Conclusion

In the present study Butt (n=17) and Rat tail (n=14) type were the most predominantly found shapes in both the age groups. There was no significant difference between age and gender based on the palatal shape. However, the study showed that the soft palate length increases significantly with age. Hence, older individuals should be screened for soft palate related abnormalities and as a risk factor for sleep related disorder. Further such studies with a larger sample size are required to establish a correlation between the shape and length of the soft palate. This can aid as a diagnostic clue in the early diagnosis of soft palatal abnormalities during the patient examination. Soft palate shape and length analysis is an important factor is diagnosing and treatment planning of various conditions like cleft patients, obstructive sleep apnea patients.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

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HOW TO CITE THIS ARTICLE

Komal Smriti, Murali Venkata Rama Mohan Kodali, Prajna Nayak, Unati Sai Kodali, Srikanth Gadicherla, Vathsala Patil, Anupam Singh, Yogesh Chhaparwal, Tanya Kacker, Sanam Talwar. Morphological Analysis of Soft Palate Using MRI in Healthy Individual. *J. Med. Chem. Sci.*, 2024, 7(2) 436-447.

DOI: https://doi.org/10.26655/JMCHEMSCI.2024.2.14

URL: https://www.jmchemsci.com/article_183907.html