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Articulatory Evaluation Of Lingua Palatal Sounds In Denture Wearers – Pre And Post Comparison

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ABSTRACT

Speech is an autonomous and unconscious activity. Its production involves a combination of phonation and articulation. Thus the aim of the study is to evaluate and compare linguo palatal sounds /ʈ/, /d/, /tʃ^/and /ʃ^/ in three different groups like Group A individual with conventional complete dentures without palatine rugae, group B individual with conventional complete dentures with palatine rugae and Group C normal dentition individuals. A total of 20 individuals completely edentulous were selected in the age range of 50 to 65 years for the study. Control group consisted of 10 individuals, with complete natural dentition in the same age group. 4 Linguo-palatal phonemes in Kannada like /ʈ/, /d/, /tʃ^/and /ʃ^/ were considered for the study and the target phonemes were identified in the initial and medial position of words of Kannada Articulation Test. The speech samples with target phonemes were analysed perceptually and acoustically by SLP software. Spectral parameters and temporal parameters were better in with palatal rugae denture than compared to without palatal rugae. Perceptual analysis reports showed many substitution errors with a conventional denture. To summarize, with customized rugae denture speech was clearer. To conclude, speech characteristic will be better after denture insertion compared to the edentulous stage.

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INTRODUCTION

Speech is an autonomous and unconscious activity. Its production involves neural, muscular, mechanical, aerodynamic, acoustic and auditory factors. It is a combination of phonation and articulation. Oral motor functions, such as mastication and speech production, share many common features. They are intimately related because the mouth, lower jaw, lips, teeth, and tongue are used for both mastication and speech production. Because a major portion of speech articulation takes place within the oral cavity, complete dentures may alter those structures and will inevitably mediate a disturbance in speech production (Runte *et al.*, 2001). The disturbance may be minor or more substantial in importance, depending on individual responses (Mahross and Baroudi, 2015). Fortunately, the phonetic problems that arise when speaking with new dentures rarely pose serious difficulties; because most patients' ability to adapt is good, initially experienced speech disturbances will be transient. Nevertheless, the treatment objective is to make complete dentures conform to the individual patient's existing neuromuscular patterns, rather than rely too much on the

patient's ability to adapt.

A major portion of speech articulation takes place within the oral cavity, and any alteration of those articulatory structures is adversely affecting the speech production. The dentist, orthodontist and prosthodontist should replace the structures proportional to the loss suffered by the individuals with cleft lip and palate. However, when they are replacing structural losses usually add to the regions that have no structural losses like hard palate that time, even articulation problem may be arising.

Speech is an important function of the stomatognathic system, which uses the oral cavity as an instrument. Teeth, alveolus, palate are static components of speech articulation whereas tongue, lip and velum are dynamic components. Among articulators' teeth are the important components of speech articulation. Loss of teeth affects the speech articulation and clarity of speech. The change in the pattern of speech production is identified as an error in speech articulation, so now a day's denture is recommended commonly to overcome the speech articulation problems.

In patients wearing complete dentures, articulatory errors may be due to denture factors like altered vertical dimension, size and position of the teeth, thickness and contour of the denture base.

Review of literature shown that the phonetic aspect of the denture has not been given the importance given to esthetics and fit of the denture. This may be attributed to the fact that most edentulous patients tend to return to normal speech after a post-insertion of the denture. But this period is usually embarrassing to the patient and adds to the burden of physiologic adaptation of the denture in their oral cavity. In addition, in inadequately constructed dentures, the faulty pronunciation of certain sounds persists even after a specified period of adaptation of denture (De Bruyn and Raes, 2014).

(Schlosser and Gehl, 1953) stated that correction of speech defects due to partial or complete loss of teeth in compliance with a phonetic requirement of denture prosthesis.

Few studies were proposed that to improve the phonetic quality in the denture wearers which includes duplication of palatal rugae, paleographic re-countering of the posterior part of the palate, incorporation of roughness in the anterior part of the palate. Rugae and incisive papillae are identified as a definitive landmark by the tongue. Failure to duplicate them in dentures causes loss of definitive landmarks, leading to farther movement of the tongue resulting in the altered speech (Pound, 1951).

Many contradictory statements were reported in the literature regarding the impact of various anatomic and denture factors on the quality of speech articulation. (Landa, 1954) stated that the addition of rugae was useless or even detrimental to most of the patients. The additional thickness of the rugae in denture causes phonetic difficulty as tongue prematurely comes in contact with the palate.

Dentures should be made to enable the patient to produce voice and speech without deficiencies. About 25% of patients in clinical dentistry are considered to suffer from temporary or permanent changes in articulation or speech production (Adaki et al., 2013). The most important instruments for the investigation of speech sound production are the trained hearing of a speech and language professional, spectral analysis, and palatographics (Stelzle et al., 2010).

Studies on speech sound production may have a clinical impact because many patients attach great importance to undisturbed speech sound production after dental treatment and Heyink et al. found that 28 (21%) of 131 denture wearing individuals from an elderly population had speech problems. Speech production has a significant effect on patients' general satisfaction with dentures (Lohmander and Olsson, 2004).

Therefore, this study has been designed to evaluate the various changes occurring in linguo-palatal sounds during the altered state of the oral cavity, which is during the edentulousness stage to the denture insertion stage.

Aim of the study

The aim of the present study is to evaluate and compare the linguo palatal sounds /ʈ/, /d/, /tʃˆ/ and /ʃˆ/ in three different groups like Group A individual with conventional complete dentures without palatine rugae, group B individual with conventional complete dentures with palatine rugae and Group C normal dentition individuals.

METHOD

Study Design- Cohort Study design.

Selection and Description of Participants

A total of 20 individuals completely edentulous were selected randomly from the outpatients in the Department of Prosthodontics, including both male and female individuals for the study group. Control group consisted of 10 individuals, with complete natural dentition in the same age group as the study group.

Table 1: Descriptive data of the sound /t/ in the initial and medial position

/t/	Group	Initial Edentulousness M± SD	Initial Denture Insertion M±SD	Medial Edentulousness M± SD	Medial Denture Insertion M±SD
VOT	A	18.20±5.84	20.30±3.77	65.70±14.64	74.40±17.38
	B	13.40±2.83	20.00±1.19	68.00±17.09	90.60±13.49
	C	21.20±1.81	21.20±1.81	87.20±14.97	87.20±14.97
VD	A	170.5±49.5	180.10±63.12	83.30±17.70	85.90±20.43
	B	184.90±33.47	224.40±25.57	80.10±12.76	112.8±14.75
	C	216.10±50.65	216.10±50.65	101.20±35.0	101.20±35.09
F1	A	483±51.86	477.30±42.42	538.90±80.0	528.60±45.09
	B	493.50±57.10	552.50±56.04	524.90±97.1	605.90±91.13
	C	498.30±43.59	498.30±43.59	628.50±109.4	628.50±109.4
F2	A	1040.00±98	1144.50±228.9	2007.00±320.3	2109.60±168.4
	B	1027.00±93.3	1115.60±76.6	1986.00±234.8	2149.60±203.4
	C	983.50±80.4	983.50±80.4	1944.60±139.7	1944.60±139.7

Table 2: Mixed ANOVA results

| /t/	Initial Group	Initial Condition	Initial Interaction b/w group and condition	Medial Group	Medial Condition	Medial Interaction b/w group and condition
VOT	$F_{(1,16)}=1.512$	$F_{(4,64)}=17.679^{***}$	$F_{(4,64)}=8.282^{***}$	$F_{(1,16)}=2.644$	$F_{(4,64)}=13.59^{***}$	$F_{(4,64)}=3.093^{*}$
VD	$F_{(1,16)}=2.880$	$F_{(4,64)}=3.245^{*}$	$F_{(4,64)}=1.251$	$F_{(1,16)}=2.604$	$F_{(4,64)}=9.470^{***}$	$F_{(4,64)}=9.777^{***}$
F1	$F_{(1,16)}=6.203^{*}$	$F_{(4,64)}=2.349$	$F_{(4,64)}=3.379^{*}$	$F_{(1,16)}=1.918$	$F_{(4,64)}=4.295^{**}$	$F_{(4,64)}=8.050^{***}$
F2	$F_{(1,16)}=0.131$	$F_{(4,64)}=3.482^{*}$	$F_{(4,64)}=0.68$	$F_{(1,16)}=0.095$	$F_{(4,64)}=6.915^{***}$	$F_{(4,64)}=1.642$

Sig. *$p<0.05$, **$p<0.01$, ***$p<0.001$

Group A consisted of 10 individuals with conventional complete dentures without palatine rugae replicated on maxillary dentures, and Group B consisted of 10 individuals given complete dentures with palatine rugae replicated on a maxillary denture.

Inclusion criteria for the study group as follows in the age range of 50-65 years, who were edentulous from past 3 months and were first-time denture wearers, who were native speakers of Kannada language, with no hearing deficits and neurological deficits as reported by the participants.

Inclusion criteria for control group like participants in the age range of 50-65 years, including male and female, who were native speakers of Kannada language, with a complete set of natural dentitions, with no hearing deficits and no neurological deficits as reported and with good general health.
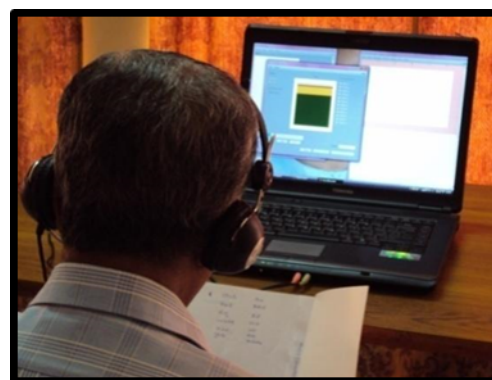
Figure 1: Digital Recording of Speech signal

Procedure

10 individuals with natural dentition and 20 individ-

Table 3: Descriptive data of the sound /d/ inthe initial and medial position

/d/	Group	Initial		Medial	
		Edentulousness	Denture Insertion	Edentulousness	Denture Insertion
		M± SD	M±SD	M± SD	M±SD
VOT	A	71.00±8.31	77.40±10.99	35.40±11.05	40.30±13.78
	B	95.00±16.63	110.3±15.46	43.00±10.44	46.70±13.17
	C	111.00±17.61	111.00±17.6	46.80±10.13	46.80±10.13
VD	A	170.50±49.57	180.10±63.1	180.70±28.07	183.90±36.78
	B	184.90±33.47	224.40±25.5	167.70±36.45	193.90±52.27
	C	216.10±50.65	216.10±50.65	193.90±52.27	193.90±52.27
F1	A	483.9±51.86	477.30±42.4	455.40±82.34	483.10±52.35
	B	493.50±57.10	552.50±56.04	458.80±35.37	503.90±68.05
	C	498.30±43.59	498.30±43.59	459.00±33.05	459.00±33.05
F2	A	1040.00±98.6	1144.50±228.	1171.00±118	1335.90±216.
	B	1027.00±93.3	1115.60±76	1242.00±156	1229.00±105
	C	2983.50±80.41	983.50±80.41	1075.00±163	1075.00±163

Table 4: Mixed ANOVA results

/d/	Initial			Medial		
	Group	Condition	Interaction b/w group and condition	Group	Condition	Interaction b/w group and condition
VOT	$F_{(1,16)}=17.009^{**}$	$F_{(4,64)}=4.643^{**}$	$F_{(4,64)}=3.718^{**}$	$F_{(1,16)}=5.507^{*}$	$F_{(4,64)}=1.245$	$F_{(4,64)}=.554$
VD	$F_{(1,16)}=12.982^{**}$	$F_{(4,64)}=12.681^{***}$	$F_{(4,64)}=6.883^{***}$	$F_{(1,16)}=.138$	$F_{(4,64)}=4.403^{**}$	$F_{(4,64)}=2.406$
F1	$F_{(1,16)}=.285$	$F_{(4,64)}=2.333$	$F_{(4,64)}=2.538^{*}$	$F_{(1,16)}=.651$	$F_{(4,64)}=3.139^{*}$	$F_{(4,64)}=.257$
F2	$F_{(1,16)}=.025$	$F_{(4,64)}=1.155$	$F_{(4,64)}=1.374$	$F_{(1,16)}=.736$	$F_{(4,64)}=1.971$	$F_{(4,64)}=2.253$

Sig. *$p<0.05$, **$p<0.01$, ***$p<0.001$
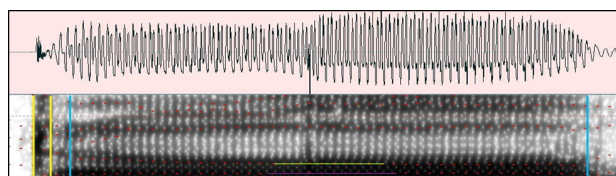
Figure 2: Spectrogram of consonant /t/ and vowel duration /o/ with formants f1 and f2 VOT=Voice Onset Time, VD=Vowel duration, F1=First formant,F2= Second formant
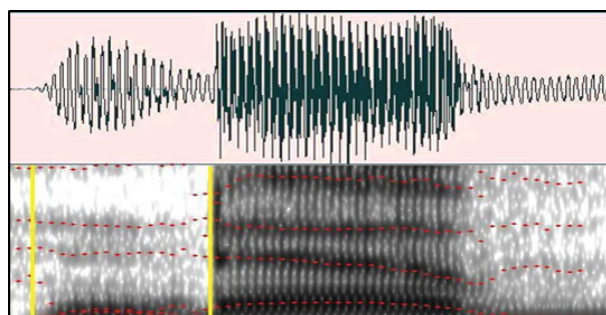
Figure 3: Spectrogram of VOT for sound/d/ VOT=Voice Onset Time, VD=Vowel duration, F1=First formant,F2= Second formant

uals for the study group were selected based on the above inclusion criteria, which included both male and female participants in equal ratio.

Kannada Articulation Test was administered to each individual and recorded after the preliminary examination and diagnosis. 4 Linguo-palatal phonemes in Kannada like /ʈ/, /d/, /tʃˆ/ and /ʃˆ/ were considered for the study and the target phonemes were identified in the initial and medial position of words

Table 5: Descriptive data of the sound /ʃˆ/ in the initial and medial position

/ʃˆ/	Group	Initial Edentulousness M± SD	Initial Denture Insertion M±SD	Medial Edentulousness M± SD	Medial Denture Insertion M±SD
FD	A	108.30±28	121.40±25.2	94.00±18.98	102.70±18.61
	B	108.70±24	127.30±18.6	102.10±19.14	130.70±12.35
	C	141.10±19	141.10±19.5	130.00±20.51	130.00±20.51
SP Energy	A	3602.0±309.9	4516.5±301.5	3728.8±397.2	4363.0±275.2
	B	3521.0±174.0	4853.4±193.7	3666.1±424.5	4864.4±256.9
	C	4630.0±410.9	4630.0±410.9	4828.3±343.2	4828.3±343.2
VD	A	76.60±17.1	80.60±24.2	186.80±51.92	189.60±36.50
	B	71.00±19.5	100.1±26.4	145.00±47.63	242.00±26.82
	C	89.00±15.31	89.00±15.31	221.10±49.73	221.10±49.73
F1	A	597.90±101.4	602.80±93.8	744.0±85.1	723.7±86.5
	B	586.40±108.7	711.60±105.	679.6±131.0	819.2±119.9
	C	654.90±77.7	654.90±77.72	795.9±102.5	795.9±102.5
F2	A	1927.0±189.0	1921.1±143.8	1693.9±231.2	1681.8±255.1
	B	1896.0±339.2	2093.8±348.6	1474.0±109.4	1673.6±138.2
	C	1855.0±206.8	1855.0±206.8	1599.0±118.9	1599.0±118.9

FD=Fricationduration, SP Pk=Peak Energy VD=Vowel duration, F1=First formant, F2= Secondformant

Table 6: Mixed ANOVA Results

/ʃˆ/	Initial Group	Initial Condition	Initial Interaction b/w group and condition	Medial Group	Medial Condition	Medial Interaction b/w group and condition
FD	$F_{(1,16)}=1.820$	$F_{(4,64)}=6.971^{***}$	$F_{(4,64)}=1.766$	$F_{(1,16)}=14.005^{**}$	$F_{(4,64)}=7.765^{***}$	$F_{(4,64)}=2.074$
SP Energy	$F_{(1,16)}=3.996$	$F_{(4,64)}=46.413^{***}$	$F_{(4,64)}=2.392$	$F_{(1,16)}=7.748$	$F_{(4,64)}=32.878^{***}$	$F_{(4,64)}=2.870^{**}$
VD	$F_{(1,16)}=1.543$	$F_{(4,64)}=10.023^{***}$	$F_{(4,64)}=6.856^{***}$	$F_{(1,16)}=2.933$	$F_{(4,64)}=16.215^{***}$	$F_{(4,64)}=13.329^{***}$
F1	$F_{(1,16)}=3.558$	$F_{(4,64)}=9.029^{***}$	$F_{(4,64)}=4.518^{**}$	$F_{(1,16)}=.736$	$F_{(4,64)}=9.237^{***}$	$F_{(4,64)}=11.476^{***}$
F2	$F_{(1,16)}=1.518$	$F_{(4,64)}=1.214$	$F_{(4,64)}=1.590$	$F_{(1,16)}=1.295$	$F_{(4,64)}=5.216^{***}$	$F_{(4,64)}=7.032^{***}$
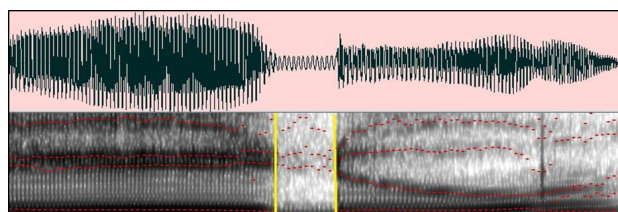
Figure 4: Spectrogram of closure duration of sound /d/ CD=Closure Duration, VD=Vowel duration, F1=First formant,F2= Second formant

/ʈo:pI/, /kIʈakI/,/dabˆI/ , /blξ:du/, / tʃˆm ātʃˆ/, /ba: tʃˆnlge/, /ʃˆnkʰa/, /gane:ʃˆ/, which are part of Kannada Articulation Test. The speech samples with target phonemes were analysed perceptually and acoustically by Speech-Language Pathologists.

Recording Procedure

The recordings were carried out in a sound-treated room. The Kannada articulation test sample and the Digital sound recordings were taken for both the groups under two different conditions like edentulous stage and post denture insertion.

Table 7: Descriptive data of the sound /tʃʌ/ in the initial and medial position

/tʃʌ/	Group	Initial Edenatulousness M± SD	Denture Insertion M±SD	Medial Edentulousness M± SD	Denture Insertion M±SD
AD	A	44.50±9.15	47.50±7.54	47.90±14.77	52.10±11.30
	B	38.50±6.39	59.50±4.92	41.80±9.61	80.90±25.12
	C	58.20±13.23	58.20±13.23	63.10±12.19	63.10±12.19
SP Energy	A	3602.5±294.6	4670.4±403.1	3695.1±334.8	4809.6±406.2
	B	3760.6±409.4	5052.2±227.1	3841.0±482.34	5141.6±366.5
	C	5011.9±310.1	5011.9±310.1	4982.0±300.0	4982.0±300.0
VD	A	63.80±14.50	68.80±13.90	72.30±16.91	79.20±6.46
	B	62.20±14.76	101.20±15.03	71.00±14.29	108.50±21.51
	C	101.10±24.66	101.10±24.66	106.90±30.22	106.90±30.22
F1	A	654.90±75	627.20±76.0	552.20±68.59	556.70±49.20
	B	622.0±79.1	754.60±72.6	526.40±74.86	676.60±69.20
	C	741.80±85	741.80±85.5	596.40±64.16	596.40±64.16
F2	A	1733.4±216.9	2404.3±281.7	2028.7±213.4	2030.6±234.0
	B	1772.1±217.6	2488.2±391.5	2003.4±221.3	2023.1±240.1
	C	1646.0±113.0	1646.0±113.0	2930.2±169.8	2998.2±169.8

AD=Affrication duration, SP Pk=PeakEnergy
VD=Vowel duration, F1=Firstformant, F2= Second formant

Table 8: Mixed ANOVA results

/tʃʌ/	Group	Initial Condition	Interaction b/w group and condition	Medial Group	Condition	Interaction b/w group and condition
AD	$F_{(1,16)}=.631$	$F_{(4,64)}=12.999^{***}$	$F_{(4,64)}=11.711^{***}$	$F_{(1,16)}=.489$	$F_{(4,64)}=8.069^{***}$	$F_{(4,64)}=6.301^{***}$
SP Energy	$F_{(1,16)}=4.390$	$F_{(4,64)}=88.692^{***}$	$F_{(4,64)}=.700$	$F_{(1,16)}=4.463$	$F_{(4,64)}=103.643^{***}$	$F_{(4,64)}=1.262$
VD	$F_{(1,16)}=4.739^{*}$	$F_{(4,64)}=40.480^{***}$	$F_{(4,64)}=29.249^{***}$	$F_{(1,16)}=9.688^{**}$	$F_{(4,64)}=12.048^{***}$	$F_{(4,64)}=16.459^{***}$
F1	$F_{(1,16)}=4.357$	$F_{(4,64)}=20.839^{***}$	$F_{(4,64)}=27.170^{***}$	$F_{(1,16)}=3.844$	$F_{(4,64)}=18.931^{***}$	$F_{(4,64)}=12.538^{***}$
F2	$F_{(1,16)}=.145$	$F_{(4,64)}=1.202$	$F_{(4,64)}=.873$	$F_{(1,16)}=0.213$	$F_{(4,64)}=3.351^{*}$	$F_{(4,64)}=.560$

Table 9: Correlation between stages with in Group A

	Stage Edentulousness	Stage Denture Insertion
Edentulousness	-	0.701*
Denture Insertion	-	0.908**

*p <0.05, **p<0.01
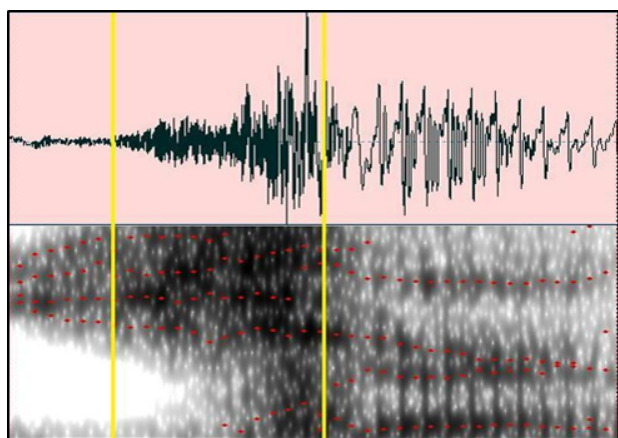
Table 10: Correlation between stages with in Group B

	Stage Edentulousness	Stage Denture Insertion
Edentulousness	-	0.83*
Denture Insertion	-	0.66**

*p <0.05, **p<0.01

Table 11: Friedman's test for group A and group B

	Chi-square
Group A	3.489
Group B	21.739***

df=4,***p=<0.001 A = with out rugae, B= with rugae

Figure 5: Spectrogram of frication duration of /sh/
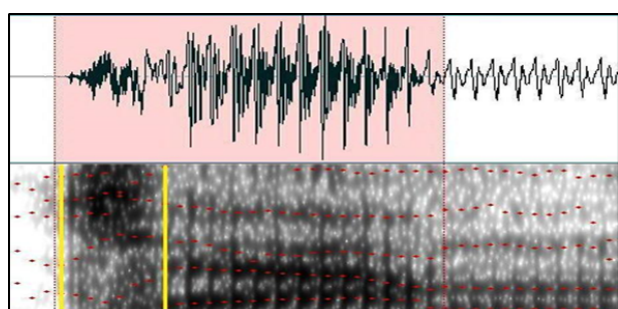
Figure 6: Spectrogram of affrication duration of /ch/

At each stage from edentulous to denture insertion digital sound recordings of 8 words were done, and this was subjected to acoustic analysis. The recordings were carried out with a mouth to microphone distance of 10 cm. The speech samples were directly recorded into the computer by the multimedia microphone with a sampling frequency of 44.1 KHz and 16- bit digitization and saved on hard disc for further analysis Figure 1.

Similarly, the control group of 10 subjects with complete natural dentition and no speech abnormalities were considered. Kannada articulation test was administered containing the target phonemes and was subjected to spectrographic analysis to obtain the values for the target phonemes and the target phonemes were subjected to acoustic analysis.

Spectral parameters like Spectral peak energy and F1, F2 were included, and temporal parameters like Voice onset time, closure duration, vowel duration, affrication duration and frication duration parameters were considered. The spectral parameters were measured in Hertz (Hz), and the temporal parameters were measured in milli-seconds(m sec).

Perceptual Analysis

The speech samples containing the target phonemes were randomized and presented to 3 speech-language pathologists for the perceptual analysis. 3 SLPs were instructed to listen to the samples for speech intelligibility by rating with a five-point scale

1. Very Poor

2. Poor

3. Average

4. Good

5. Very Good

The results were tabulated and subjected to appropriate statistical tests. The objectives of this study were achieved by comparing the groups of different dentures among the participants in the above-mentioned experimental conditions and then comparing within the groups with the values obtained in the edentulous stage and fourth weeks of denture insertion and comparing the two groups with the control group.

Statistics

Descriptive statistics was carried out to obtain the mean and standard deviation for linguo palatal sounds /ʈ/, /d/, /tʃˆ/and /ʃˆ/. The effect of group A and group B, stages and interactions were studied with the help of MIXED ANOVA. To study the interaction effects obtained in Mixed ANOVA, following analysis were done: Within-group A and within-group B, within each stage, groups were compared using One Way ANOVA (group A, Group B and Control).

For Perceptual Analysis

Inter-judge reliability was studied using Cranach's alpha coefficient. Under perceptual analysis, since data was in ordinal scale following non-parametric tests were applied: Friedman's test was used for the comparison of stages within each group. This was followed by Wilcoxon's signed Rank Test for pair wise comparisons. Mann Whitney test was used for comparison of groups A & B within each stage.

RESULTS

The present clinical study compares and evaluates the effect of edentulousness, and denture wearing, including the conventional and customized palatal rugae, replicated maxillary denture on the linguo-palatal sounds. The study also compares the speech articulation of the above situation with the natural dentition subjects.

Spectrographic analysis

4 linguo-palatal sounds were considered both in the initial and medial position taken from Kannada Articulation Test. The various parameters of the phonemes /ʈ/, /d/, /tʃˆ/and /ʃˆ/ were analyzed spectrographically and subjected to various statistical tests, for both Group A, Group B and Control group.

The descriptive data of all the parameters are presented in the following tables for the 4 linguo-palatal sounds in both initial and medial positions.

Tables 1 and 2 depicts the descriptive data like mean and SD of the phoneme /t/in the initial position and parameters included like Closure duration, VOT, VD, F1 and F2. Figure 2 depicts the parameter measured. Temporal parameters like VOT and VD are higher after denture insertion compared to the edentulous stage. Among three different groups, control group temporal parameters are higher than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group and conventional complete dentures with palatine rugae replicated on maxil-

lary denture group. Spectral parameters like F1 and F2 values have minor variation in three different groups the obtained values differences were negligible. The obtained mean and SD values of temporal parameters were relatively higher indenture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group and conventional complete dentures with palatine rugae replicated on maxillary denture group. When come to spectral parameters like F1 and F2, there is not such variations among three different groups in terms of its mean and SD values.

Mixed ANOVA was performed to check whether the obtained mean values were significantly different across parameters. The target phoneme /t/ in initial and medial word position were not significantly different for temporal parameters like voice onset time, vowel duration, closure duration and even spectral parameters like F1 and F2.

Tables 3 and 4 and Figure 3 depicts the obtained mean and SD values of temporal parameters were relatively higher in denture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group, i.e., group A and conventional complete dentures with palatine rugae replicated on maxillary denture group, i.e., group B.When come to spectral parameters like F1 and F2 there is not such variations among three different groups in terms of its mean and SD values. When compared to Group A and Group B, the group B, i.e., conventional complete dentures with palatine rugae replicated on maxillary denture group obtained higher value than compared to group A. Figure 4 and Tables 5 and 6 represents the measured parameters.

The obtained mean and SD values of temporal parameters like closure duration and vowel duration values were relatively higher in denture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group, i.e., group A and conventional complete dentures with palatine rugae replicated on maxillary denture group, i.e., group B.When come to spectral parameters like F1 and F2 there is not such variations among three different groups in terms of its mean and SD values. When compared to Group A and

Group B, the group B, i.e., conventional complete dentures with palatine rugae replicated on maxillary denture group obtained higher value than compared to group A.

Mixed ANOVA was performed to check whether the obtained mean values were significantly different across parameters. The target phoneme /d/ in initial and medial word position were not significantly different for temporal parameters like voice onset time, vowel duration, closure duration and even spectral parameters like F1 and F2 were not significantly different.

The obtained mean and SD values of temporal parameters like friction duration and vowel duration values were relatively higher in denture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group, i.e., group A and conventional complete dentures with palatine rugae replicated on maxillary denture group, i.e., group B.When come to spectral parameters like F1, F2 and Spectral Peak energy values were there is no such variations among three different groups in edentulous compared to denture insertion stage. When compared to Group A and Group B, the group A, i.e., conventional complete dentures without palatine rugae replicated on maxillary denture group obtained higher value than compared to group B.

The obtained mean and SD values of temporal parameters like friction duration and vowel duration values in /sh/ phoneme in medial position values were relatively higher in denture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group, i.e., group A and conventional complete dentures with palatine rugae replicated on maxillary denture group, i.e., group B.When come to spectral parameters like F1, F2 and Spectral Peak energy values were there is no such variations among three different groups in edentulous compared to denture insertion stage When compared to Group A and Group B the group A, i.e., conventional complete dentures without palatine rugae replicated on maxillary denture group obtained higher value than compared to group B.

Mixed ANOVA was performed to check whether the obtained mean values were significantly different across parameters. The target phoneme /sh/in initial and medial word position were not significantly

different for temporal parameters like voice onset time, vowel duration, closure duration and even spectral parameters like F1 and F2 were not significantly different represented by Figure 5.

The obtained mean and SD values of temporal parameters like affrication duration and vowel duration values in /ch/ phoneme in initial position values were relatively higher in denture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group, i.e., group A and conventional complete dentures with palatine rugae replicated on maxillary denture group, i.e., group B.When come to spectral parameters like F1, F2 and Spectral Peak energy values were there is no such variations among three different groups in edentulous stage compared to denture insertion stage When compared to Group A and Group B the group A, i.e., conventional complete dentures without palatine rugae replicated on maxillary denture group obtained higher value than compared to group B.

The obtained mean and SD values of temporal parameters like affrication duration and vowel duration values in /ch/ phoneme in medial position values were relatively higher in denture insertion stage than compared to edentulous stage. Among three different groups Control group, i.e., Group C obtained higher values than compared to conventional complete dentures without palatine rugae replicated on maxillary denture group, i.e., group A and conventional complete dentures with palatine rugae replicated on maxillary denture group, i.e., group B.When come to spectral parameters like F1, F2 and Spectral Peak energy values were there is no such variations among three different groups in edentulous stage compared to denture insertion stage When compared to Group A and Group B the group A, i.e., conventional complete dentures without palatine rugae replicated on maxillary denture group obtained higher value than compared to group B.

Mixed ANOVA was performed to check whether the obtained mean values were significantly different across parameters. The target phoneme /ch/ in initial and medial word position were not significantly different for temporal parameters like voice onset time, vowel duration, closure duration and even spectral parameters like F1 and F2 were not significantly different (Tables 7 and 8 and Figure 6).

Perceptual analysis

The statistical tests for Inter-judge reliability were

studied using Cranach's alpha coefficient. Under perceptual analysis, since data was in ordinal scale following non-parametric tests were applied. Friedman's test was used for the comparison of stage within each group. This was followed by Wilcoxon's signed Rank Test for pair-wise comparisons. Mann Whitney test was used for comparison of groups A & B within each stage (Table 9).

The correlation results show that when compared to edentulousness stage and denture insertion stage, the performance is seen better in denture insertion stage for group A, i.e., conventional complete dentures without palatine rugae replicated on maxillary denture group. A correlation was observed statistically significant between edentulousness and denture insertion stage (Table 10).

The correlation results show that when compared to edentulousness stage and denture insertion stage, the performance is seen better in denture insertion stage for group B, i.e., conventional complete dentures with palatine rugae replicated on maxillary denture group. A correlation was observed statistically significant between two stages (Table 11).

Friedman's test was used for the comparison of stages within each group. The above table shows a statistically significant value for Group B when compared to Group A.

DISCUSSION

Edentulous stage

All the temporal parameters of group A and B had a lower value compare to control group. The Formant frequencies F1 decreased significantly only for unvoiced sound /t /, but not invoiced sound /d/. This can be attributed to the fact that for unvoiced sounds, the vocal cord will be in an open position, resulting in increased size of the tract. In addition to this, the oral cavity is also larger due to complete loss of teeth. Since cavity size is inversely proportional to the formant frequency, increase in volume results in decreased formant frequency for unvoiced sounds. For voiced sounds, there will be vocal cord constriction and hence the overall vocal tract area also decreases, hence no significant changes informants are observed. The decrease in formant frequency in the edentulous condition is in consonance with the study (Ichikawa et al., 1995). The study evaluated for the formant frequency measurements for the sound /s/ speaking with and without the prosthesis, made on spectrograms. The analysis of the formant frequency indicated that there was a decrease of formant frequency for most of the edentulous speech patterns.

The decrement in the other parameters can be due to the altered oral environment created, where in the complete loss of teeth has affected appropriate positioning of the tongue to the palatal region. The acoustic analysis also correlated with perceptual analysis where the SLP's have rated both group A and B with 'average' ranking.

After denture insertion

In both the groups, all the parameters were increasing towards the control group, but the group with modified maxillary denture base was closer to the control group. Fricative Duration and Spectral peak energy for fricatives and affricates, group A, had a statistically significant value when compared to group B and Control group. This indicates clearly that fricative, and the affricates have improved with group B compared to group A.MeanwhilePerceptual analysis showed a statistically significant difference between group A & B where in group B was rated "good" compared to group A.

Speech problems are frequently reported after complete denture placement mainly expressed as problems with consonants, especially lingo palatal sounds (Runte et al., 2001). So, the lingopalatal sounds were analyzed in the present study. Some patients had a remarkable adaptive capacity after repeating words. Analyzed spectrograms are different by frequency (low or high) of emitted sounds related to the denture changes and oral resonance cavity (Bulbule et al., 2013). Specific letters were selected because not all the letters can be verified. According to Sinescu et al., some sounds such as /z/s/t/ and /sh/ are more sensible and more often compromised due to the changes of oral structures and because of the demand for more precise articulation movements. Therefore, these sounds were studied in this work (Nakajima and Ando, 1991).

Evaluation of the speech was performed by acoustic analysis and intelligibility analysis. Reports of the acoustic analysis revealed that pronunciation of "s," "sh," "t," and "d" was clearer with rugae incorporated denture than a conventional denture. Customized rugae dentures were better than arbitrary rugae dentures. Intelligibility reports showed many substitutional errors with a conventional denture (Schuster et al., 2006).

(Foti et al., 1998) investigate the speech of two edentulous subjects fitted with complete denture prosthesis. These recordings were tested from the auditory point of view by a series of six listeners (four men and two women) in an anechoic room. The results show that the group fitted with a denture was more intelligible in speech production than compared to edentulous stage.

Evaluation of the speech was performed by acoustic analysis and intelligibility analysis. Reports of the acoustic analysis revealed that pronunciation of "s," "sh," "t," and "d" was clearer with rugae incorporated denture than a conventional denture. Customized rugae dentures were better than arbitrary rugae dentures. Intelligibility reports showed many substitutional errors with a conventional denture. With customized rugae, denture speech was clearer (Adaki *et al.*, 2013).

Phonetics, esthetics, function, and comfort are the main foundation determining the success of a prosthodontic treatment done. Complete dental rehabilitation of edentulous patients with complete dentures includes not only esthetics and mastication of food but also speech quality. Maxillary anterior teeth, in particular, play an important role for adequate speech intelligibility and articulation, their rehabilitation improves articulation ability significantly (Stelzle *et al.*, 2010). It is the responsibility of the dentist to fabricate a denture that is functionally acceptable by the patient and is perfectly esthetic. One prime oral function that has always been overlooked for years is speech intelligibility. It has always been presumed that speech will eventually follow by mere replacement of teeth and that it is patient's duty to fine-tune speech with practice over the period of time or it is perfectly alright to have some kind of discrepancy in speech intelligibility (Jain *et al.*, 2014).

Studies reported that the Influence of the complete denture treatment on patient's speech intelligibility, and the results revealed that Improvement in the speech intelligibility of the patients was noted after denture insertion to edentulous patients (Godbole *et al.*, 2016).

CONCLUSIONS

This study was conducted to evaluate the impact of rugae on phonetics. Evaluation of the speech was done by acoustic analysis and perceptual analysis. Reports of the acoustic analysis revealed that pronunciation of lingua palatal sounds was clearer with rugae incorporated denture than without conventional denture. Spectral parameters and temporal parameters were better in with palatal rugae denture than compared to without palatal rugae. Perceptual analysis reports showed many substitutional errors with a conventional denture.To summarize, though both groups have improved significantly from the edentulous stage when compared to control, group B has showed a steady improvement compared to group A and closer to the control group. With customized rugae, denture speech

was clearer. Special attention should be given to the anterior palatal region while fabricating the denture. Bit of modification in the anterior part of the palate, which requires a minimal amount of time, gives better results regarding the pronunciation of speech sounds. To conclude, speech characteristic will be better after denture insertion compared to patients not rehabilitated with complete dentures.

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