"EVALUATION OF SPEECH AND EFFECT OF CUSTOMIZATION OF PALATAL RUGAE IN COMPLETE DENTURE REHABILITATION"

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(BRANCH – I)

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CERTIFICATE

This is to certify that **Dr. VINAY BHARTI,** Post Graduate student (2014 - 2017) in the Department of Prosthodontics and Crown and Bridge, has done this dissertation titled ***"EVALUATION OF SPEECH AND EFFECT OF CUSTOMIZATION OF PALATAL RUGAE IN COMPLETE DENTURE REHABILITATION"*** under my direct guidance and supervision in partial fulfillment of the regulations laid down by **The Tamil Nadu Dr. M.G.R. Medical University, Guindy, Chennai – 32** for **M.D.S.** in **Prosthodontics and Crown & Bridge (Branch I)** Degree Examination.

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DECLARATION

I **Dr. VINAY BHARTI** do hereby declare that the dissertation titled **"EVALUATION OF SPEECH AND EFFECT OF CUSTOMIZATION OF PALATAL RUGAE IN COMPLETE DENTURE REHABILITATION"** was done in the Department of Prosthodontics, Tamil Nadu Government Dental College and Hospital, Chennai-600 003. I have utilized the facilities provided in the Government Dental College and Hospital for the study in partial fulfillment of the requirements for the degree of **Master of Dental Surgery** in the speciality of **Prosthodontics and Crown & Bridge (Branch I)** during the course period 2014-2017 under the conceptualization and guidance of my dissertation guide **Professor Dr. A. MEENAKSHI. M.D.S.**

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Dr.A.MEENAKSHI,M.D.S., aged 50 years working as Professor, Department of Prosthodontics and crown and bridge at Tamil Nadu Government Dental College and Hospital, Chennai-3 having residence address at No. 137, fifth street, secretariat colony, Kelleys,Chennai-10 (herein after referred to as the 'Researcher and Principal investigator')

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1.

2.

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LIST OF ABBREVIATIONS

1.	VOT	Voice Onset Time
2.	VD	Vowel duration
3.	F1	First formant
4.	F2	Second formant
5.	CD	Closure duration
6.	FD	Frication duration
7.	AD	Affrication duration
8.	SP PK	Peak Energy

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ABSTRACT

Introduction: Speech has always been the most significant medium for the transmission of ideas and throughout the centuries it has been one of the main forces for the human progress. Speech is a critical activity of the stomatognathic system, which utilizes the oral cavity as an instrument. A significant part of speech articulation happens inside the oral cavity and any modification of the structures in that will unfavorably influence speech proportionate to the area and magnitude of change. Inability to form the palatal contours to suit ordinary tongue contact as a rule brings about poor speech. Therefore, for the success or coming to nothing of dental rehabilitation, speech production quality is a vital criterion.

Keywords: Spectrographic analysis of speech, Conventional Complete denture, Customized Complete denture, Duplicated denture.

Aim: The aim of this study was to assess and correlate the speech pronunciation (linguo-palatal sounds) of subjects with customized palatine rugae duplicated on upper complete denture and subjects with conventional upper complete denture and subjects with the natural dentition upto a duration of 4 weeks after denture insertion.

Materials and Methodology: A total of 18 subjects (12 completely edentulous and 6 dentulous) 45-60 years of age were selected for this study. These subjects further divided into 3 groups, **Control group:** 6 subjects, with natural complete dentition. Study group: 12 subjects, who were completely edentulous. **Group A:** were rehabilitated with conventional complete dentures with the palatine rugae duplicated on maxillary dentures. **Group B:** were rehabilitated with duplicated complete dentures without the palatine rugae duplicated on maxillary dentures. Tamil Articulation Test [(USHA.D (1986)] was

regulated to each subject and recorded. A total of 3 Linguo-palatal phonemes in Tamil /d/,/th/,/ja/ were selected for the study. Each recording was taken at 4 stages.The samples with target phonemes were evaluated for Acoustic analysis.

Results: All recordings were evaluated and comparison was done using one-way Anova followed by Tukey's post hoc test. At stage 1, subjects without the dentures shows statistically significant decrease in almost all the spectral and temporal parameters as compared to control group. At stage 2, Immediately after denture insertion mostly all the parameters shows improvement from stage 1, specially with the group A as compared to group B but compared to group C both A & B shows statistically significant decrease. At stage 3, denture with replicated palatal rugae shows less adaptation duration to the new dentures as compared to the conventional dentures. At stage 4, few parameters of group B still shows significance with the group A and C, like spectral peak energy, frication and affrication duration.

Conclusion: It is suggested to duplicate the palatal rugae in complete denture in light of the fact that the articulation of linguo palatal sounds of complete denture with rugae replication was better than the conventional complete denture without rugae replication.

INTRODUCTION

Speech is an exceptionally refined, self-governing, and oblivious action. Its production includes muscular, neural, mechanical, acoustic, aerodynamic, and auditory components. As orodental morphological highlights impact on speech, the dentist need to subsequently perceive the part of prosthetic treatment on the activity of speech[1].

Speech has always been the most significant medium for the transmission of ideas and throughout the centuries it has been one of the main forces for the human progress[2]. Speech is a critical activity of the stomatognathic system, which utilizes the oral cavity as an instrument[3]. It is such an acquired part of man's make up that we scarcely pause to believe that this is a learned function. Various organs takes part in the creation of speech are the components of the oral cavity[4].

A significant part of speech articulation happens inside the oral cavity and any modification of the structures in that will unfavorably influence speech proportionate to the area and magnitude of change. The dentist need to supplant the structures corresponding to the misfortune endured by the patient. However, the dentists when supplanting structural losses ordinarily add to the districts that have no structural losses, for instance, the hard palate. In the verbalization of speech, this is a standout amongst the most critical areas[5].

The phonetic part of the denture has not been given the significance given to function, retention and esthetics of the denture[6]. This might be credited to the way that most edentulous patients tend to come back to typical discourse after a post insertion practice time of a few days to a few weeks. However, this period is typically humiliating to the patient and adds to the burden of physiologic adjustment of the

denture[7]. Moreover, in inadequately fabricated dentures, the flawed articulation of specific sounds continues even after a predetermined time of adaptation[8].

Exact estimation of palatal forms of a maxillary denture to a patient's tongue can enhance speech clarity, if different variables, for example, occlusal plane, tooth position, and occlusal vertical dimensions are up to standard[9].

The speaking sounds are delivered from the contact of tongue with some part of the teeth and palate. These contact regions are either supplanted or secured by complete denture. Inability to form the palatal contours to suit ordinary tongue contact as a rule brings about poor speech[4]. Therefore, for the success or coming to nothing of dental rehabilitation, speech production quality is a vital criteria[10].

The significance of duplicating the rugae on the denture base has dependably been a point discuss from decades. Some recommend that the rugae duplication would simply add on to the bulk of the denture palatal surface, which would be inconvenient for phonation[11], while different analysts suggested that nearness of rugae on denture base would give an about tissue-like surface, opposite to which the tongue would work in a more regular way amid speech[12].

At the point when supplanting structural losses the districts that have no auxiliary loss, for instance, the hard palate, are likewise supplanted. The speech sounds which are influenced by the palatal coverage are predominantly the linguo-palatal sounds. These sounds are generated with the valve shaped by contact of the tongue tip with the anterior most part of the palate (the alveolus) or the lingual surfaces of the foremost teeth. There is no standardized appraisal of speech issue in grown-ups at the national or global level[13].

In this manner this study has been intended to assess the different changes happening in linguo-palatal sounds amid the adjusted condition of the oral cavity,

which is amid the edentulousness, to the accommodative time of one month post insertion of denture .

There have been not very many studies in the literature that utilization spectrographic examination to measure the progressions that insertion of dentures would deliver on different parameters of phonemes. Since, speaking science is a behavioral study, evaluation of speech quality is vital alongside the quantitative investigation. Consequently, the present study conducted to assess and correlate the speech pronunciation (linguo-palatal sounds) of subjects with customized palatine rugae duplicated on upper complete denture and subjects with conventional upper complete denture and subjects with the natural dentition upto a duration of 4 weeks after denture insertion. The concentrate likewise actualizes the duplication of the natural shapes of the palate (palatine rugae) on the palatal surface of denture and contrasts it with the conventional dentures.

AIM:

To assess and correlate the speech pronunciation (linguo-palatal sounds) of subjects with customized palatine rugae duplicated on upper complete denture and subjects with conventional upper complete denture and subjects with the natural dentition upto a duration of 4 weeks after denture insertion.

OBJECTIVES:

1. To assess and correlate the linguo-palatal sounds with complete dentures rehabilitation from the edentulousness up to a duration of 4 weeks after denture insertion.

2. To assess and correlate the speech pronunciation of customized palatine rugae duplication on upper complete denture up to a duration of 4 weeks after denture insertion.

3. To correlate the articulation of linguo-palatal sounds of customized palatine rugae duplicated on upper complete denture with conventional upper complete denture up to a duration of 4 weeks after denture insertion.

4. To correlate the speech pronunciation of completely edentulous subjects with the natural dentition subjects.

Review of Literature

Speech articulation can be defined as the placement and movement of organs that change or interrupt the voice or unvoiced air stream into meaningful sound during speech[14]. Phonetics is the science that deals with sounds used in speech[15]. Speech is nothing but a learned habitual neuromuscular pattern in a matured man[5]. This review presents the articles and studies was done by various authors.

Earl Pound (1951)[16] discussed the Phonetic problems arising due to denture wearing and their treatment. He pointed out that if nature can be accurately reproduced in the denture bases, the phonetic qualities can be made better in the denture to a greater extent. He also proposes that the palatal rugae are very crucial from phonetic point of view and they must be maintained and copied in their true form onto the denture base. Rugae appear in the anterior portion of the palate and are of great importance in pronouncing consonants, henceforth maintaining natural anatomy of rugae is very important. He also termed rugae as the playground of the tongue since 90 percent of the tongue's rapid movements while talking is limited to this area lingual to the mandibular anterior teeth.

LG Jordan (1954)[11] has proposed that carving inter rugae grooves on the tongue surface of the denture could improve phonetics but also noticed that prominent artificial rugae on the tongue surface of upper dentures is often detrimental than beneficial, especially to phonetics.

A technique described by **L C Dirksen and S J Campagna (1954)[12]** for mat surface and the rugae reproduction for maxillary partial denture castings. The

technique provided an exact reproduction of the palatal surface of the maxillary master casts. They concluded that, during speech nearly tissue-like surface, opposite to which the tongue will operate in a more natural manner can be furnished by a mat surface on upper partial denture castings.

Kaires AK (1957)[17] had conducted a study on the palatal pressures of the tongue during the pronunciation of chosen palato lingual speech sounds. He concluded that, the significance of an accurate vertical dimension of occlusion cannot be overstressed. In swallowing and in speech, it was found that compensatory tongue alterations resulted not only in alterations of the magnitude of palatal pressures, besides also in the time duration in which those pressures were applied.

LR Allen et al (1958)[7] developed a procedure that would allow patient to speak clearly even at the time of denture insertion and they even quoted many authors who recommended rugae reproduction as an adjunct to proper phonetics.

Rothman R (1961)[18] reviewed mechanism of speech production in general and mechanics of the production of sound units of dental concern in particular. They also quoted a study done by **Boghosian and Spangenberg** have suggested that after insertion of a prosthesis, the maximum changes in the quality of vowel sounds happened in the anterior region of the mouth with half-high or high vowel sounds. According to their study, rugae should not be replicated on dentures, in order to make the anterior portion of the upper denture base as thin as possible.

Martone AL and Black JW (1962)[19] elaborated that the speech mechanism involves the upper respiratory and digestive tracts which are modified to form and control the valves. Valves are divided into-Physiologic valve I,II & III, among these

Physiologic valve III formed by the mouth and it is very crucial in speech mechanism as it is capable of making many changes both in capacity and size. The innervations of speech was briefly described by them.

Martone AL and Black JW (1962)[5] in their research on speech science concluded that the tip of the tongue has the fastest rate of movement among the various articulatory structures followed by the jaw, back of the tongue, lips and the velum. While placing dentures, natural contours of the mouth should not be altered to a significant extent so that speech adaptation stays easy.

Bond EK and Lawson WA (1968)[14] did an important study touching upon the various aspects of speech, they discussed the effects of placement of dentures or orthodontic appliances on speech sounds and also the effects on speech caused by changes in the vocal tract. The conclusion made by them that the patients are usually still capable of producing the sounds within the range called normal by making compensation for the changes in the oral cavity.

A technique was described by **FW Shaffer, RA Kutz (1972)[20]** for creating the palatal contour of the dentures to help in phonetics. They suggested that the palatal rugae could be reproduced physiologically and the so developed form of the palate by using the soft wax would aid in enhancing the speech of the patient.

A study was conducted by **JG Agnello and L Wictorin (1972)[8]** to analyse phonetic alterations in complete denture wearers at various stages. The stages were: Edentulous stage, Immediately after denture insertion, 2 weeks after denture insertion, 12 weeks after denture insertion. The phonemes /t/,/s/, /sh/ & /th/ were evaluated perceptually by speech pathologists and spectrographic analysis. Results from the study showed that the phonemes /t/,/s/,/sh/ displayed improvement through the stages

while the /th/ phoneme displayed no general improvement. They also suggested that the phoneme /th/ required special attention during denture fabrication and by the speech pathologist.

H Tanaka (1973)[21] analysed the relationship between palatal contour and speech production through study of changes in speech pattern before and after the denture insertion in various stages. The sounds of consonants /t/, /d/, /ch/, /j/, /zh/, /s/, /sh/, /n/, /l/, /z/ were evaluated at various time intervals which were: Before denture insertion, 1hr after denture insertion, 24hrs after denture insertion, 1 week after denture insertion. By Speech pathologists Perceptual analysis was conducted with a rating scale of 1-7 (1-poor to 7-best). The conclusions drawn were: Speech intelligibility improved with denture insertion, the improvement in intelligibility was directly associated to duration for which denture used . Acoustic distortions are more frequent with /zh/, /s/, /ch/, /j/, /sh/ than the /z/, /l/, /t/, /d/, /n/ sounds.

Palatal rugae seems to be a neglected force when it comes to speech considerations as observed by **George Chierici and Lucie Lawson (1973)**[22] in their review of clinical speech considerations in prosthodontics. They threw light on the fact that there were no experimental studies to support palatal rugae as a 'speech organ'. They also quoted Landa who had reported that rugae replication will unnecessarily increase the bulk of the denture base which has negative effects on speech.

JM Palmer (1974)[23] suggested some techniques and guidelines in the assessment of speech problems of complete dentures wearing patients to prosthodontist. He

suggested that static structures like palatal rugae and mucous membrane on the anterior palate helps in speech. According to him, the palatal rugae on the anterior denture base would help the tongue for recognizing an area to produce the finest sounds. If the tongue could not feel the rugae, the /t/ and /d/ sounds would be poorly pronounced.

Ana Petrovik (1974)[24] described the use of spectrographs for speech analysis in complete denture wearers. The author concluded that spectrograms have an additional advantage of containing significant information about the speech quality that will be useful for the objective diagnosis of status of speech system, however spectrographic analysis was backed up by auditory and articulatory information.

Hamlet, Geoffrey and Bartlett (1976)[25] have analyzed the changes of voice characteristics due to dental prostheses by fitting subjects with experimental dental appliances that artificially lower and retract the alveolar-palatal contour. They determined that the intelligibility of speech was significantly decreased by prosthesis wearing, especially before the subject had time to adapt to the new condition.

H Ghi and G P McGivney (1979)[26] studied the impact of tooth proprioception on speech articulation wherein the alterations in speech patterns were analyzed between overdenture patients and complete denture patients. They concluded by saying that for patients without the prosthesis, the time duration to pronounce /s/ sound was increased and the accuracy for speech movement for the /s/ sound production was being affected by the presence of tooth proprioception.

John. M.Palmer (1979)[27] has conducted a study and stated that it has been felt that loss of palatal rugae (covered by denture base) and papillae as being related to articular undesireness. Tongue to lose tactile sensation as it seeks true articulatory positioning for speech sound production with loss of these anatomical landmarks. He quoted a study of **Bloomer et al** who have proposed nearly exact duplication of the natural contours into the denture base, and have supported the replication of the rugae, but this was not verified. He concluded that tactile function of the tongue and speech can be enhanced by replicated rugae and an incisive papilla.

B K Goyal and P Greenstein (1982)[28] did a study to find ways to modify palatal configuration of the upper complete denture according to the individual's tongue-to palate contact for enounce of normal speech immediately post insertion of dentures which will eliminate or reduce the post insertion practice duration. The study result showed that modified maxillary denture helped in producing normal speech immediately post insertion. The modified upper denture evident to be better in providing additional physiologic and natural tactile guidepost to the tongue while speech compared to highly smooth, polished, arbitrarily formed palatal surface of conventional complete denture.

Kestenberg JM et al. (1983)[29] has described the speech assessment in dentistry, they categorised the speech samples as imitative samples, spontaneous samples, samples by reading and deep samples and used them for speech assessment. The author did propose a speech articulation test with a set of twelve questions. They highlighted the importance of the dentist working in association with a speech pathologist.

E A Tobey, and IM Finger(1983)[30] was conducted an acoustic study of vowels produced**,** with and without dentures to investigate active versus passive adaptation of prosthesis to the orofacial reconstruction. They suggested that adjusting the prostheses would alter only passive characteristics of the prosthesis and would not necessarily affect active articulatory accommodation by the patient.

A technique was described by **Erika Garfunkel (1985)**[31] for reproducing the patient's own palatal rugae in the upper complete denture for first time denture wearers who complained that their palatal rugae had been changed by a smooth surface. Palate of the stone cast was poured with dental stone to form a core, on to which softened baseplate wax was applied to the core and the customised waxed palate was adapted onto the festooned denture base.

The effects of speech sounds due to changes of the oral cavity dimensions with complete dentures of various positions of maxillary incisors and various thickness of the denture palatal plate were evaluated by **A.Petrovik (1985)**[32]. He concluded that patient's adaptation to the dentures was accomplished during first 30 days post denture insertion and adaptation relays strongly on the patient's hearing perception potentiality. Speech distortion changed with the palatal plate thickness of the denture and increased immediately after 1mm of thickness.

KC White, ME Connelly (1989)[33] have suggested replicating natural palatal forms in complete dentures for making individual palatal contours that are custom made for individual patient to control the thickness of maxillary dentures which may be helpful to enhance phonetics.

Laine (1992)[34] studied the relationship between occlusal anomalies and articulatory disorders in young adults. He concluded that various types of malocclusions, like lateral crossbite and mandibular overjet were related with incorrect articulation of some medio-alveolar consonants, particularly /s/. He also argued that the analyzed occlusal abnormalities affect speech especially by changing the position of the hyoid bone and tongue.

Ichikawa, Komoda J, Horiuchi M, Matsumoto N (1995)[35] have conducted an investigation with two experimental manipulations: Palatal augmentation – assigned by 1 mm thick acrylic artificial palatal surface with the posterior tooth location palatally greater by 4mm than original dentition ; and increased vertical dimension. They concluded by saying that the voice onset time for /ci/ and /ki/ and Consonant duration for /s/ was influenced more by the palatal enhancement than the aspiration time.

A study was conducted by **Foti et al (1998)**[36] to investigate the speech of two complete edentulous patients rehabilitated with a maxillary prosthesis fabricated with three different palatal materials: resin, aluminium, stellite. They concluded that, the hierarchy factors affecting SRT are most significant in the order: Listener→material→speaker; and the group rehabilitated with a metal prosthesis (stellite, aluminium) was more intelligible in regard the way they were perceived by others.

Scarsellone, Rochet, and Wolfaardt (1999)[37] have done the investigation on an elderly population for the alterations in nasalance because of maxillary dentures.They

compared pronunciations with and without total denture, and concluded that nasalance values were significantly lower with the maxillary dentures removed.

Christina A. Gitto et al (1999)[38] proposed a method of incorporating rugae in a newly constructed and existing complete denture. They used tin foil to adapt onto the cast with prominent palatal rugae and sealed to the waxed denture base and fabricated with autopolymerizing resin. They proposed that this technique could be a tool for the remedy of speech problems encountered by the patient's.

A study conducted by **C Runte (2001)**[39] on the effect of various maxillary central incisor positions on the phonetic patterns. The results showed by the study suggested that the amplitude of the maximum energy level and frequency, reduced with increasing age of the individuals. The longer the denture was used, the higher the first fricative formant median was observed. He concluded that the adaptability to dentures decreases with increasing age of the subject.

Petr Jindra, Miroslav Eber, and Josef Pesak (2002)[40] have conducted an investigation to study the alterations in speech and voice in patients suffering from loss of teeth and the degree of speech enhancement using dentures. They concluded that it is necessary to ensure perfect shaping of the dentures for eliminating speech defects.

A study by **Christoph Runte et al (2002)**[41] was conducted to measure the effect of the maxillary central incisors free from adaptation phenomena utilizing spectral analysis. They stated that misplacement of the maxillary incisors must be believed a

cause of immediate changes in /s/ sound distortion. They concluded by saying that, denture teeth should be arranged in the original tooth position as precisely as possible.

An investigation was done by **M Ozbek et al (2003)**[42] to study the alterations in articulation of Turkish phonemes and familiarization to removable partial dentures, before denture insertion, immediately post insertion and one week after insertion. The results disclosed a significant decrease in the articulatory problems of phonemes with time. In general, after 1 week of denture insertion the difficulties in articulation of investigated phonemes were resolved.

The effect of partial denture on the quality of speech and eventual variations in pronunciation of postalveolar sounds and dental sounds were analysed by **I Stojcevic, A Carek and D Bukovik (2004)**[43]. Results showed by them, that partial dentures did not notably interfere with resonance frequency and pronunciation of the investigated sounds notably improved however accuracy of articulation movements deteriorated.

Tushar Mowade and SP Dange (2004)[44] have suggested a simplified technique using lead foil to replicate palatal rugae in complete dentures. They concluded by saying that it could help in solving speech problems encountered by patients.

De Souza and Compagnoni (2004)[45], studied the pronunciation of the /s/ consonant in association to the denture, particularly with the free space confined by the artificial complete denture, in contrast with speakers with natural dentition, and found little correlation among the speaking space of /s/ and the freeway space for subjects with the natural dentition, and a total association for the subjects wearing denture. They believed that the fact can be described by "a functional adaptation

which resulted in more equivalent values for the freeway space and the speaking space of /s/.

Bortun Cristina et al (2004)[46] conducted a study to assess the phonetic changes in complete denture wearers caused by size, position and material (resin or ceramics) of the anterior artificial teeth.They concluded that, the most significant sound variations appeared when the upper anterior teeth were mounted in an oralized position (100% of the cases), accompanied by the buccalized position (80%), ceramic teeth (70%) and the presence of interdental spaces (20%).

Alexander J Hassel, and Thomas Hostle (2006)[47] have conducted a pilot study to investigate a universal and easy technique for enhancing the speech function of maxillary complete dentures. They concluded that efforts to reproduce the rugae still remains controversial for enhancing the speech.

T Ando (2006)[48] had investigated the intelligibility of the /f/ sound using a speech recognition system. Peculiar things about the /f/ sound is that it is based on palatal configuration of complete dentures.The results obtained clearly demonstrated that the curvature of the palatal contour affects the pronunciation of the /f/ sound, and 2-4mm is the appropriate curvature of the palatal contour in complete dentures for correct pronunciation of this sound.

Shusuke Inukai et al (2006)[49] have conducted a study to investigate the correlation between the incisal overjet of the anterior teeth in a maxillary denture and the intelligibility of the /S/ sound.They concluded that accurate pronunciation of [Si]

progressively become more difficult, with increasing distance between the incisal edges of the maxillary and mandibular incisors.

Hyung-Jun Kong and Carl A.Hansen (2008)[9] have described a technique for customizing palatal contours with autopolymerizing acrylic resin of a maxillary complete denture to improve speech intelligibility. In their opinion, the modified palatal form of a maxillary complete denture do not appear to cause any notable impact on swallowing, mastication, or retention. Technique can be used either on processed dentures or waxed trial dentures to attain optimum speech.

Tino Haderlein et al (2009)[50] have conducted a clinical pilot study to assess speech intelligibility of edentulous patients objectively and automatically and to determine, whether the impact of complete dentures on speech intelligibility can be assessed by automatic analysis as part of oro-dental rehabilitation assessment.They have concluded that, there is a significant relationship between automatic evaluation and subjective rating of intelligibility. They also reveals the influence of dentures on intelligibility just as the subjective ratings do. Therefore, the method can use as the basis for more investigations towards an automatic system that can help oro-dental rehabilitation by objective speech evaluation.

F. STELZLE et al (2010)[10] have conducted a study on completely edentulous patients, to institute and validate a computer-based speech recognition system (ASR) for automatic speech analysis. The speech outcome of completely edentulous patients with and without dentures was compared to examine the impact of dentures on speech production. Total twenty-eight patients pronouncing a standardized text were recorded

twice – with and without their dentures in situ. A control group with natural dentition of 40 healthy subjects was recorded under the same conditions. They concluded that word accuracy was remarkably reduced in completely edentulous speakers as compared to the control group's WA. On the other hand, WA of the edentulous patients significantly increased after wearing complete dentures. After complete loss of teeth, speech production quality was remarkably reduced. Speech production quality reconstitution is an significant part of dental rehabilitation and can be enhanced for completely edentulous patients by means of dentures.

Vamsi krishna et al (2012)[51] have described a simplified method of adding patient's palatal contours and customized rugae to the maxillary denture to attain standard speech patterns in completely edentulous patients. They concluded that, one of the principal factor in complete denture construction is Phonetics. Patients with complete denture tends to mispronounce certain sounds, which depends upon the palatal contour and rugae pattern for phonation. Thus, Prosthodontists need to fabricate the palatal contour and rugae pattern in complete denture with care for attaining speech which is much more accurate and also abolish the training and waiting period after denture insertion.

Abdul-Aziz Abdullah Al Kheraif and Ravikumar Ramakrishnaiah (2012)[52] have discussed the relationship between occlusion and speech, as these two factors are usually not considered related to each other. Besides during phonation, the mandibular teeth function on one's own and there should not be any contact with maxillary teeth. They also emphasized the use of phonation as a tool for placement of

maxillary anterior teeth in partial and complete denture rehabilitation.They have quoted that, prosthodontists must be aware of the consequences to phonetic deterioration, with the increased aptness to placement of anterior teeth in an irregular mode.

Raghavendra Adaki et al (2013)[3] have conducted a study to evaluate acoustic and speech intelligibility analysis in completely edentulous patients and also to assess the influence of arbitrary rugae conventional dentures and customized rugae dentures on speech. There results of acoustic analysis showed that pronunciation of 't','s', 'sh', 'd' was less clearer with conventional denture than the rugae incorporated denture. Between dentures with rugae incorporated, dentures with customized rugae were better than dentures with arbitrary rugae. Intelligibility results displayed, with customized rugae denture speech was clearer than the conventional denture which showed many substitutional errors.

A study was carried out by **HALA M. ABDEL HAMID and MOHAMED E. EL-SAYED (2014)**[53] to assess the effect of various techniques for palatal denture base contours on pronunciation of various speech sounds in complete denture wearer.

Total seven completely edentulous patients were selected, each patient received three upper dentures with various palatal denture base contours and one lower denture. The upper denture bases were grouped into three groups based on their palatal contours. Group I upper denture with functional palatal configuration. Group II upper denture with duplication of the patient's palatal rugae on the palatal surface with tin foil . Group III upper denture with the cast metal denture base. Based on the results they concluded that, with proper denture fabrication, the palatine rugae plays a

significant role in speech pronunciation, in the presence of few anatomical landmarks where tongue can identify and produce best particular sound.

Priya Vaswani et al (2015)[54] have conducted a study to analyze the improvement in linguo-palatal sounds using two different impression materials in deep, medium & shallow palatal vault configuration by replicating the existing rugae in maxillary complete denture prosthesis. Results showed statistical significance in speech enhancement when mucostatic impression obtained rugae pattern was integrated in upper arch prosthesis through Mann-Whitney U test and Wilcoxon matched pair test . They concluded that, in case when mucostatic impression material was used for replication of rugae the speech improvement was seen rapid.

Hamada Zaki Mahross and Kusai Baroudi (2015)[55] investigated the influence on complete dentures speech from reproduction of various thickness and palatal rugae materials using Computerized Speech Lab (CSL) (spectrogram). Total five groups divided based on the patient's' speech groups, Group I: patients without complete dentures; Group II: those patients treated with conventional acrylic dentures; Group III: patients with rugae reproduced on conventional acrylic dentures; Group IV: patients with complete dentures of minimal thickness with metallic framework and at rugae area directly ragged metallic palatal surface; Group V: patients with complete dentures with palatal rugae reproduced from resilient acrylic resin material with thickness which is less than the conventional denture. By using Computerized Speech Lab (CSL) (spectrogram) speech samples were recorded post insertion of each complete denture for various groups. Linguo palatal sounds /s/z/sh/t/d/ and /l/ were selected for evaluation of speech.They have concluded that it is advocated to reproduce the rugae area in dentures because the phonetic quality of conventional

denture was inferior to the complete denture with reproduced rugae. Metallic denture bases can enhance /t/d/s/sh/ and /z/ sounds. With the use of resilient acrylic to duplicate the rugae in complete denture can enhance /z/l/s/sh/t/ and /d/ sounds.

MATERIALS AND METHODOLOGY

ARMAMENTARIUM:

I. For Clinical Examination:

1. Mouth mirror
2. Probe
3. Explorer
4. Kidney tray
5. Gloves and Mask

II. For denture fabrication

S.No	MATERIAL	COMMERCIAL NAME
1.	Stock trays	Jabbar & Co.,India
2.	Impression Compound	Hiflex, Provest dent, India
3.	Self cure PMMA resin	DPI RR Cold cure, Dent. products of India
4.	Dental plaster	Asian chemicals, India
5.	Greenstick compound	DPI Pinnacle tracing sticks, Dent. products of India
6.	Zinc Oxide Eugenol impression paste	DPI Impression paste, Dent. products of India
7.	Hard Wax	Cavex Set Up Hard, Cavex Holland BV.
8.	Dental Stone	KALSTONE, kalabhai, India
9.	Cold mold seal	DPI Cold mold seal , Dent. products of India
10.	Articulator	Dentatus type ARH, Sweden
11.	Teeth set	Acry Rock, Ruthinium Dental Prod. Pvt Ltd
12.	Heat cure PMMA resin	DPI heat cure, Dent. products of India

II. For Replication of Palatal rugae:

- Dental floss - Thermoseal waxed dental floss, ICPA Health Products Ltd, India.
- Inlay wax - Kronenwachs, BEGO, Made in Germany.

III. For Denture Duplication:

S.No.	MATERIAL	COMMERCIAL NAME
1.	Teeth set	Acry Rock, Ruthinium Dental Prod. Pvt Ltd
2.	Lab Putty	Unisil Lab Putty, Delta products
3.	Hard wax	Cavex Set Up Hard, Cavex Holland BV
4.	Heat cure PMMA resin	DPI heat cure, Dent. products of India
5.	Denture Flasks and Clamps	Varsity flasks, Jabbar & Company

IV. For speech recording and analysis:

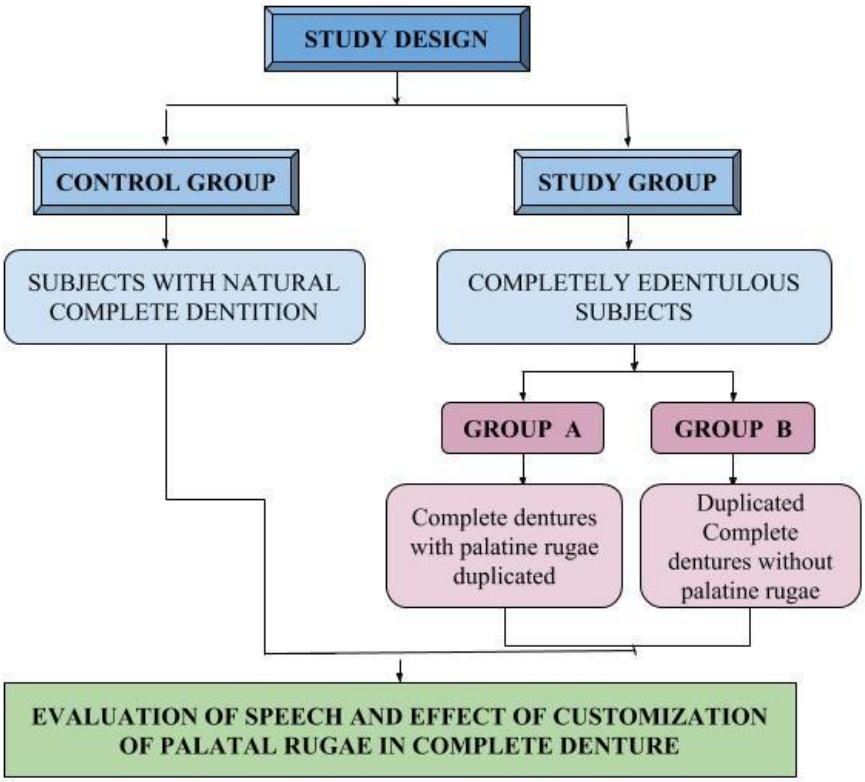
- Philips SBCMD110/01 Corded Microphone - frequency range of 20Hz - 44100Hz.
- Speech recording and evaluation software - PRAAT (Version 5.1.43) - generated by School of London.

METHODOLOGY:

The clinical study was done in the Dept. of Prosthodontics, TAMIL NADU GOVERNMENT DENTAL COLLEGE AND HOSPITAL, CHENNAI and INSTITUTE FOR SPEECH REHABILITATION AND HEARING HANDICAPPED MADRAS MEDICAL COLLEGE GOVERNMENT GENERAL HOSPITAL, CHENNAI.

Source of data18 subjects (12 completely edentulous and 6 dentulous) were selected from the outpatients in the Dept. of Prosthodontics, TAMIL NADU

GOVERNMENT DENTAL COLLEGE AND HOSPITAL, CHENNAI, including 6 male and 6 female patient for the study group and 3 male and 3 female for the control group.



Control group: 6 subjects (3 male and 3 female), with natural complete dentition with the age group of 45-60years as considered for study group.

Study group: 12 subjects (6 male and 6 female), who were completely edentulous, further divided into two Groups: A and B.

Group A: were rehabilitated with conventional complete dentures with the palatine rugae duplicated on maxillary dentures.

Group B: were rehabilitated with duplicated complete dentures without the palatine rugae duplicated on maxillary dentures.

Duplication was done to preserve the same occlusal plane, tooth position, vertical dimension and thickness of denture base for comparison.

Inclusion criteria:

Inclusion criteria for control group	Inclusion criteria for study group
In the age range of 45-60 years	In the age range of 45-60 years
Who were native speakers of Tamil language	Who were native speakers of Tamil language
Who were completely dentulous	Who were new/first complete denture wearers and were completely edentulous from past min. 1 to 3 months.
With no neurological and no hearing deficits	With no neurological and no hearing deficits
With good general health condition	With good general health condition

Exclusion criteria for both the groups :

- Subjects below 45years and above 60 years of age.
- Who were not the native speakers of Tamil language.
- Subjects with neurological and hearing deficits.
- Who were previous complete denture wearers.

Those who agreed to participate voluntarily, written consent was taken and ethical clearance for conducting this study was obtained from the ethical committee of Tamil Nadu Government Dental College and Hospital.

Methodology:

For Control Group:

A total of 6 subjects (3 male and 3 female), with natural complete dentition were selected based on the inclusion and exclusion criteria. Ling's test was done to assessed the hearing capabilities. The speech samples for each subject were recorded.

For Study Group:

Preparation of the subjects :

A total of 12 subjects (6 male and 6 female), who were completely edentulous were selected based on the inclusion and exclusion criteria. Ling's test was done to assessed the hearing capabilities for the selected subjects. The speech sample for each subject was recorded before the processing of complete denture.

Preliminary impressions were recorded with stock edentulous trays and impression compound, and poured with Type II dental plaster, primary casts were obtained. Special trays were fabricated with the autopolymerizing acrylic resin and 2 mm border reduction was done.

Border molding was done using tracing compound material and final impression were made using Zinc- oxide eugenol impression paste, then poured with Type III gypsum product and master casts were obtained.

Fabrication of record bases were made on the master cast with autopolymerizing acrylic resin. Occlusal rims were made with hard wax and bite fork was attached anteriorly 3 mm above the occlusal plane to the maxillary occlusal rim. Face bow recording was done, and mounted to the Dentatus articulator after the zeroing of articulator. Vertical jaw relation was established with physiologic method before recording horizontal relation.

Horizontal relation was established with gothic arch tracing method. Extraoral tracers were attached and patient was guided for the centric and eccentric movements.

Tracing was recorded and quick setting plaster was injected between the rims allowed to harden, thus the record obtained and transferred to the articulator.

Teeth arrangement was done with conventional norms and evaluated in patient mouth.

Replication of the palatal rugae :

After patient acceptance for the trial dentures, replication of palatal rugae was processed. Rugae was marked in the master cast with permanent marker. Rugae portion in the trial denture was cut-off and made with clear autopolymerizing acrylic resin using sprinkle on method.

Dental floss [ICPA waxed interdental floss] was cut as per the required length and luted over the rugae markings which were seen through the transparent acrylic resin in the cast using inlay casting wax. Two or more floss threads were luted together for variations in the thickness of palatal rugae [56].

The waxed up trial dentures were dewaxed and the maxillary denture base kept for the duplication of the denture. Processing was done conventionally with the heat cure acrylic resin, finished and polished.

Duplication of the Maxillary Denture [57]:

Duplication was done to preserve the same occlusal plane, tooth position, vertical dimension and thickness of denture base for comparison.

Lab putty was adapted to the entire tissue surface of the denture and bended wire loops were inserted before the material sets. Approximately 2mm border of the denture was exposed with scalpel knife blade.

Rectangular box bigger than the denture was made with baseplate wax and was poured with the mixture of dental plaster and stone and the same mix was poured on to the putty material. Denture was inverted onto it and four keys were made before the mix was set.

Roll of baseplate wax was waxed to form sprues on the either side of the posterior region of 2nd molar. Again lab putty was adapted on the entire denture teeth and the palatal surface, and bended wire loops were inserted before the material sets.

Whole assembly was boxed with baseplate wax and poured with the dental stone. After the stone sets, wax box was removed and both halves was trimmed so the sides are continuous and parallel.

Two halves of the mold were separated and denture with sprues were removed. Impression of the tissue surface of the denture was in one half and the teeth imprints were in the other half, and both were in lab putty.

Identical teeth were placed in the teeth imprints and denture base was placed on the impression surface, which was taken out after dewaxing of the original denture and both halves were closed.

Molten hard wax was poured into one of the sprue holes until it was exuded through the second sprue hole. Wax was allowed to harden and both halves of the mold were separated, and the waxed denture was recovered.

Duplicated waxed maxillary denture was placed on the master cast and, occlusion and vertical dimension were checked from the lab remounting procedure with the original mandibular denture.

Wax tryin of the duplicated maxillary denture was evaluated in patient mouth also, minor occlusion corrections were made and denture was processed conventionally with the heat cure acrylic resin, finished and polished.

Preparation for the speech recording :

Tamil Articulation Test [(USHA.D (1986)] was regulated to each subject (control and study group) and recorded. 3 Linguo-palatal phonemes in Tamil [d, th, ja] were selected for this study.

The target phonemes were recognized in the medial and initial position of words like for /d/: dappa, veedu; /th/: thatha, paththu; /ja/: jannal, manjal which are part of Tamil Articulation Test. A standard Tamil passage was executed to both the groups and for the study group at each stages of the study. The samples with target phonemes were evaluated using **Acoustic analysis** by Speech Pathologists. In acoustic analysis, both the Temporal and Spectral parameters were evaluated and analyzed.

The recordings were executed at the INSTITUTE FOR SPEECH REHABILITATION AND HEARING HANDICAPPED MADRAS MEDICAL COLLEGE GOVERNMENT GENERAL HOSPITAL, CHENNAI in a soundproof room for both the control and study groups.

For the control group recordings were done only once but for study groups (Group A and B) recordings were done under the accompanying stages-

- Edentulous stage – **STAGE 1**
- Immediately after post insertion - **STAGE 2**
- 10 days after denture insertion - **STAGE 3**
- 4 weeks after denture insertion - **STAGE 4**

At each stage from stage 1 to 4, recordings were done of 6 words with 2 trials and this was administered to acoustic analysis. The recordings were taken with the distance of 10-14 cms from mouth to microphone. The speech samples were recorded by Philips SBCMD110/01 Corded Microphone into the computer with a sampling

recurrence of 20 Hz - 44100 Hz and for further analysis, recordings were saved on hard disc.

To extricate the spectral and temporal parameters for both the study groups, the digital sound recordings were administered to spectrographic analysis.

Likewise the control group of 6 subjects with no speech malformation were considered. Tamil articulation test was imposed comprising the target phonemes and to get the readings for the target phonemes, it was administered to spectrographic analysis.

The target phonemes were administered to acoustic analysis under two parameters:

Temporal parameters (m sec) : Vowel Duration, Frication Duration, Affrication Duration, Formant frequency (F1, F2), Spectral peak energy.

Spectral parameters (Hz) : Voice Onset Time and Closure Duration.

The **VOT** was evaluated for the sound : /d/ in the initial position “dappa”. The **closure duration** was evaluated for the sound : /d/ in the medial position “veedu”. The duration of the **fricative** were evaluated for the sounds: /th/ in initial “thatha” and /th/ in medial position “pathu”. The **affrication duration** were evaluated for the sounds: /ja/ in initial “jannal” and /ja/ in medial “manjal”. **Spectral Peak energy** were evaluated for the sounds: /th/ in initial “thatha” and /th/ in medial position “pathu”, /ja/ in initial “jannal” and /ja/ in medial “manjal”. **Vowel duration** were evaluated for all the sounds and the groups.

Method of Statistical Analysis:

Statistical analysis was carried out using SPSS (Statistical Package for Social Science, Ver.10.0.5) package. . In this study data was normally distributed and parametric test was used to compare between the groups. Comparison between the different groups was carried out using one-way Anova followed by Tukey's Post-Hoc test. In all the above test "p" value of less than 0.05 was accepted as indicating statistical significance

ARMAMENTARIUM

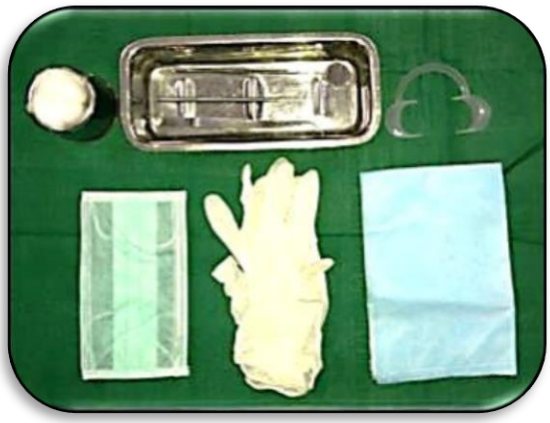


Fig 1. ARMAMENTARIUM FOR EXAMINATION

Fig 2. ARMAMENTARIUM FOR DENTURE AND RUGAE DUPLICATION

Fig 3. ARMAMENTARIUM FOR DENTURE FABRICATION

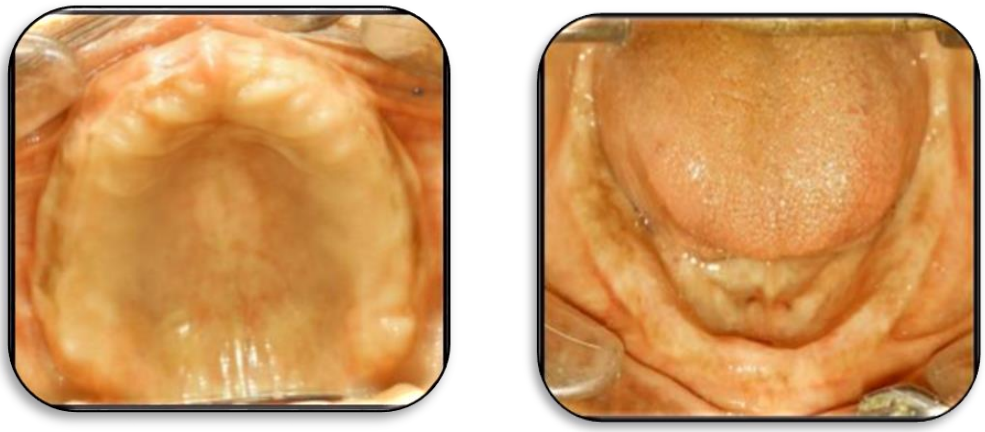


Fig 4a, 4b. INTRAORAL PICTURE OF MAXILLARY AND MANDIBULAR

Fig 5a, 5b. UPPER AND LOWER PRIMARY IMPRESSION

Fig 6a, 6b. UPPER AND LOWER FINAL IMPRESSION

Fig 7a, b. UPPER AND LOWER MASTER CAST

Fig 8. FACE BOW RECORDING

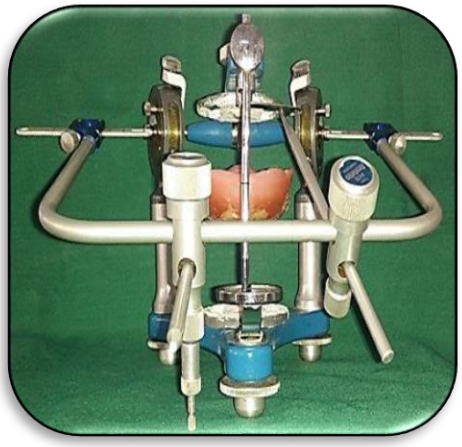


Fig 9. FACE BOW TRASFERRED TO ARTICULATOR

Fig 10. TRACER'S ATTACHED

Fig 11. TRACING RECORDED

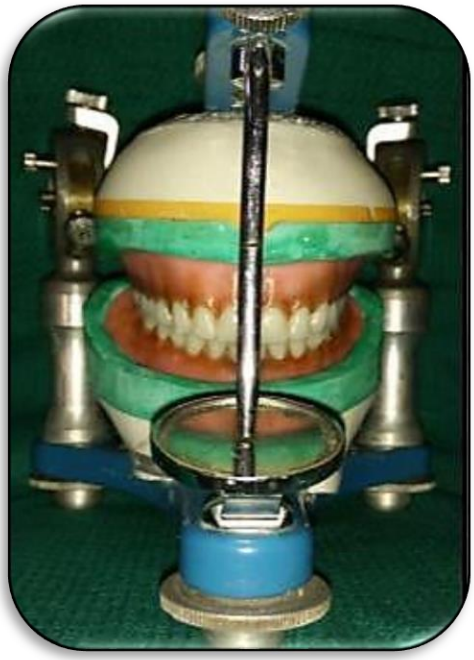


Fig 12. TEETH ARRANGEMENT

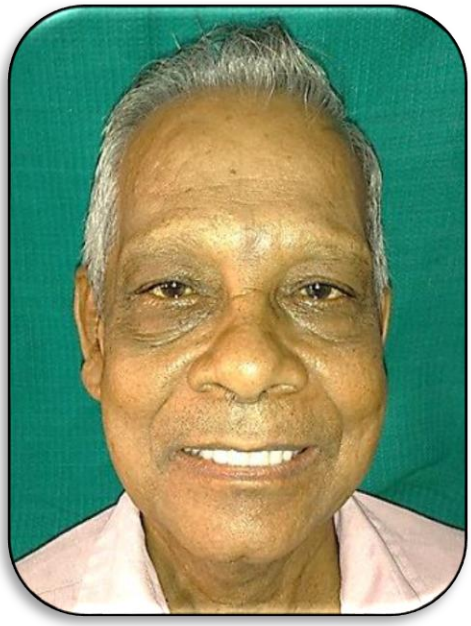


Fig 13. WAX TRIAL

RUGAE REPLICATION

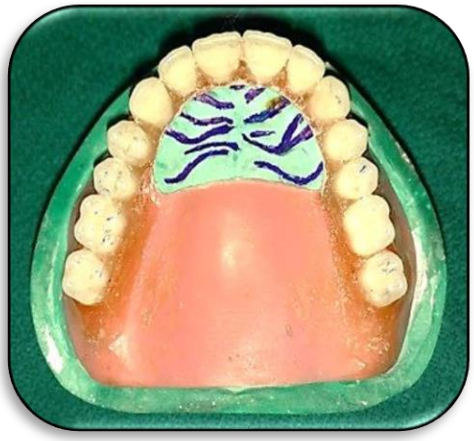


Fig. 14 REMOVAL OF RUGAE PORTION IN TRIAL DENTURE BASE

Fig. 15 DENTAL FLOSS WAS LUTED OVER RUGAE MARKING USING INLAY CASTING WAX

DENTURE DUPLICATION

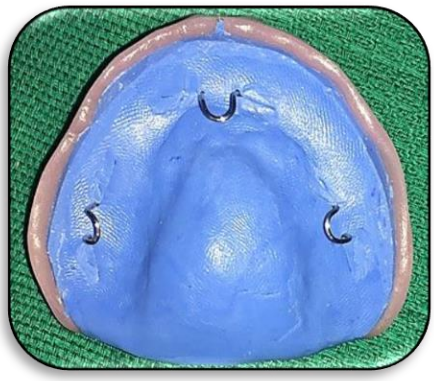


Fig 16 LAB PUTTY WAS ADAPTED ON TISSUE SURFACE WITH BENDED WIRE LOOPS

Fig 17.DENTURE WAS INVERTED INTO THE RECTANGULAR BOX & ROLL OF WAX WAS WAXED TO FORM SPRUE ON EITHER SIDE

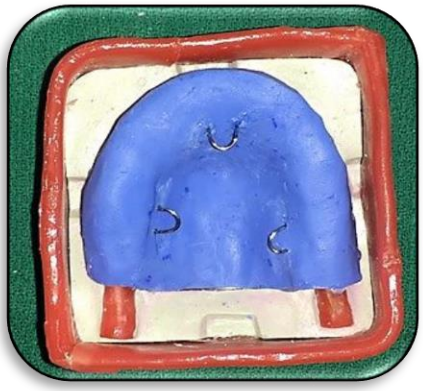


Fig 18. LAB PUTTY WAS ADAPTED ON ENTIRE POLISHED SURFACE.

Fig 19. WHOLE ASSEMBLY WAS BOXED WITH BASEPLATE WAX AND POURED WITH DENTAL STONE.

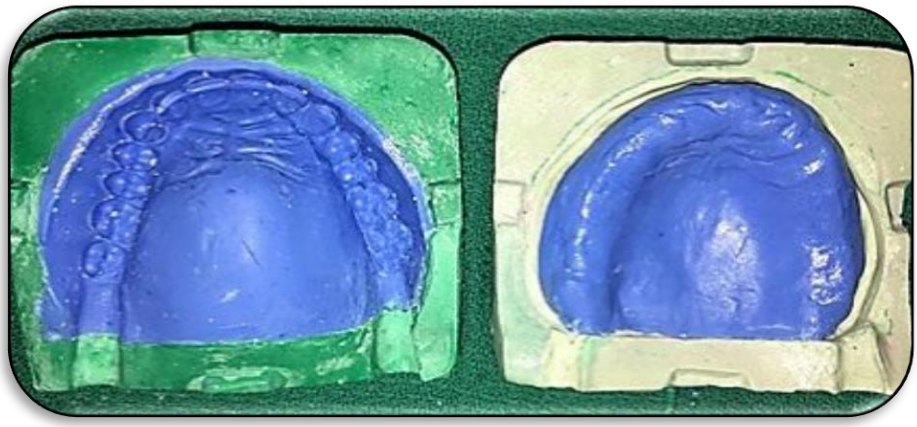


Fig 20. TWO HALVES OF MOLD WERE SEPARATED AND DENTURE WITH SPRUE WERE REMOVED

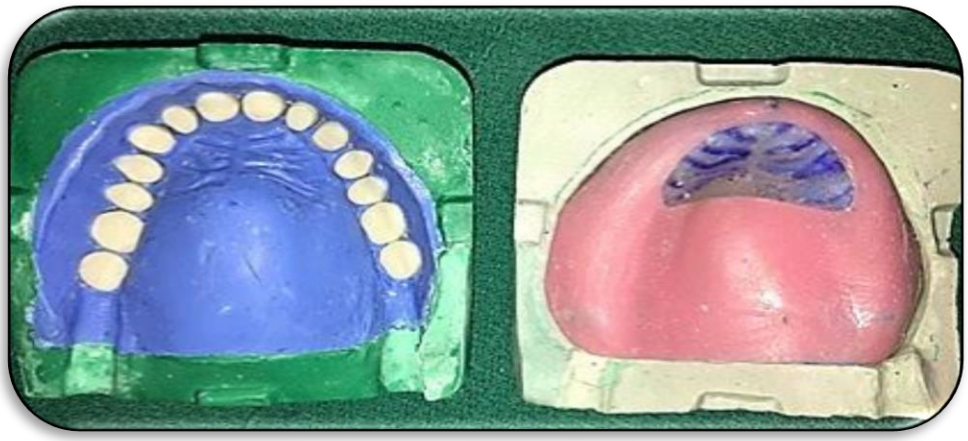


Fig 21. IDENTICAL TEETH WERE PLACED OVER TEETH IMPRINTS AND DENTURE BASE WAS PLACED ON IMPRESSION SURFACE

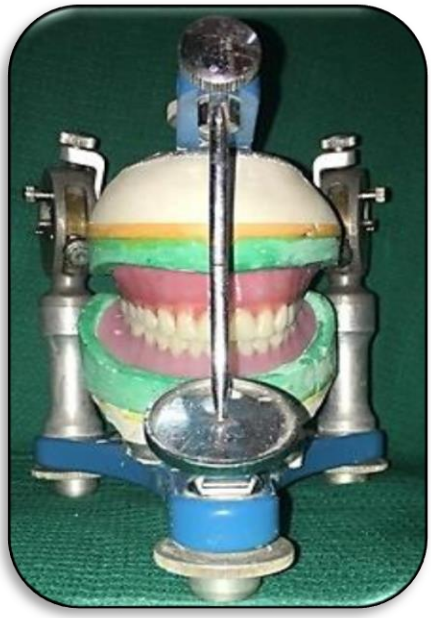


Fig 22. LAB REMOUNTING

Fig 23. DUPLICATED DENTURE

Fig 24. RECORDING OF SPEECH SOUNDS

SPECTROGRAM

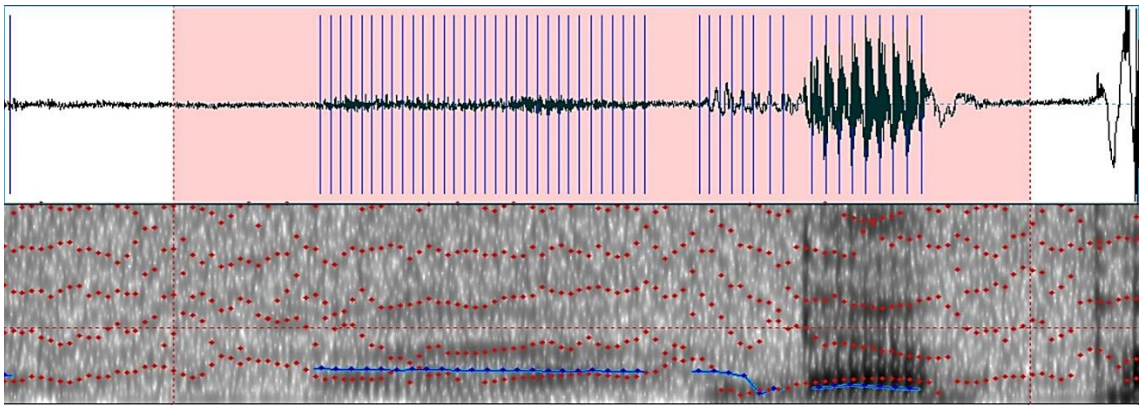


Fig 25. SPECTROGRAM FOR SOUND /d/ INITIAL

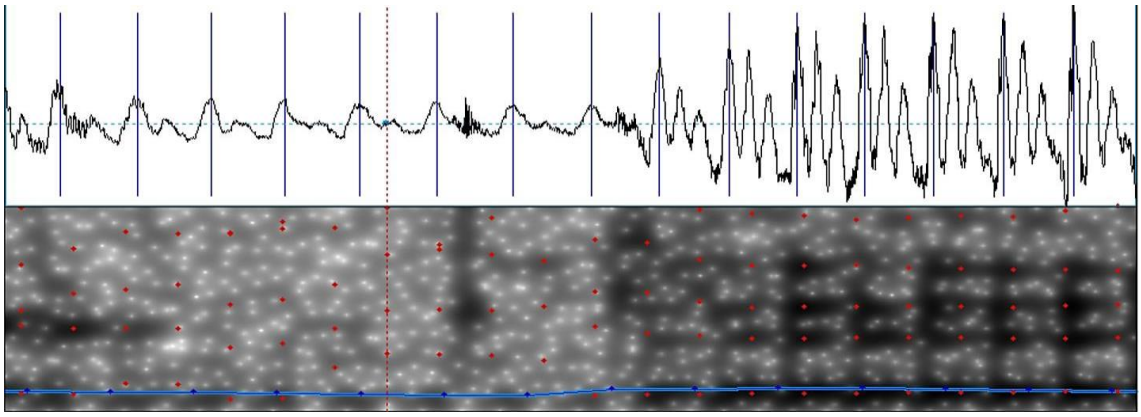


Fig 26. SPECTROGRAM FOR SOUND /d/ MEDIAL

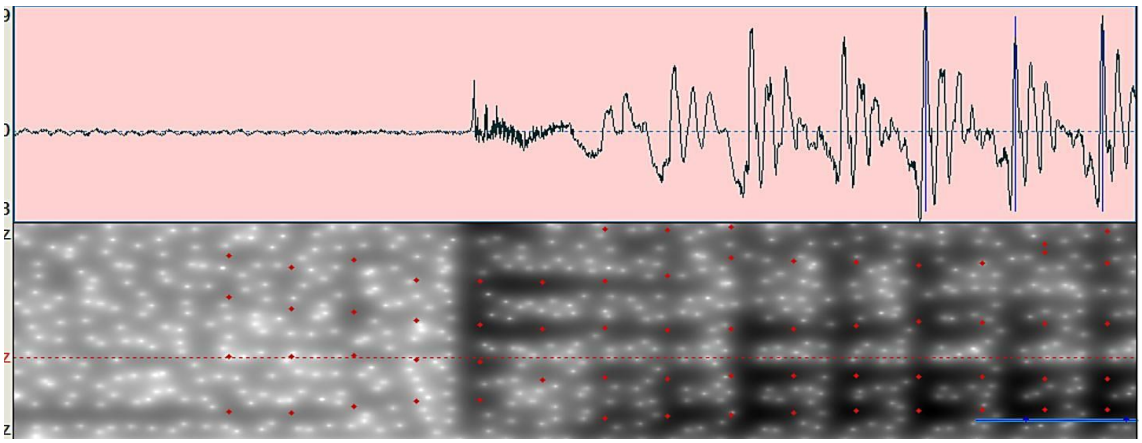


Fig 27. SPECTROGRAM FOR SOUND /th/ INITIAL

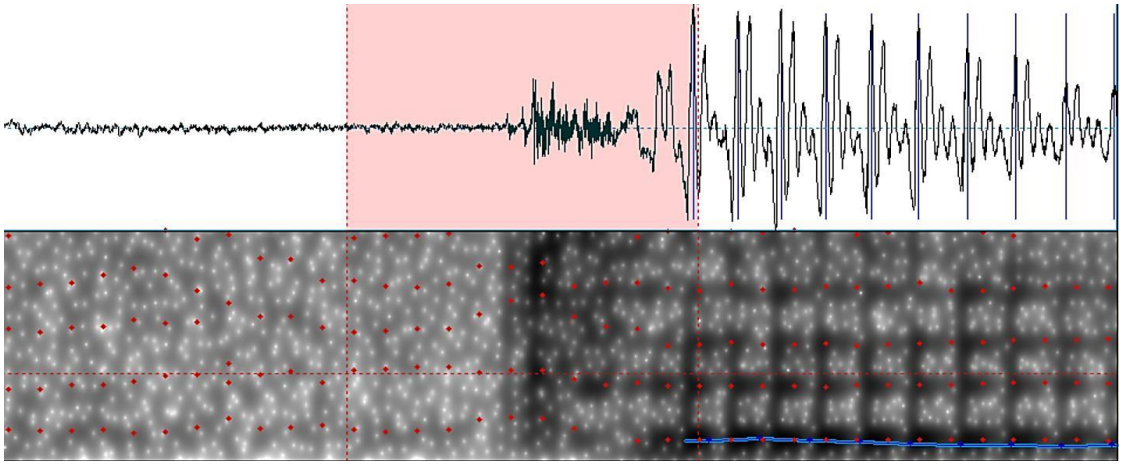


Fig 28. SPECTROGRAM FOR SOUND /th/ MEDIAL

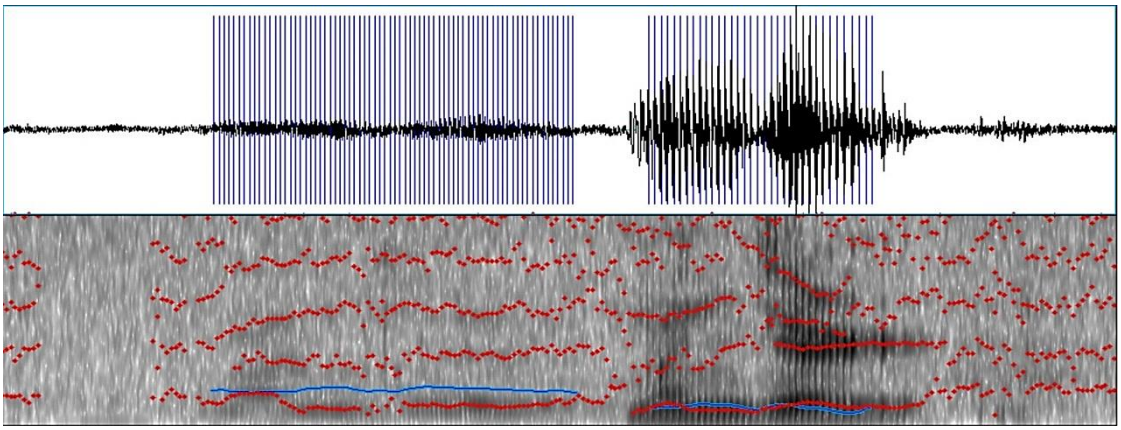


Fig 29. SPECTROGRAM FOR SOUND /jh/ INITIAL

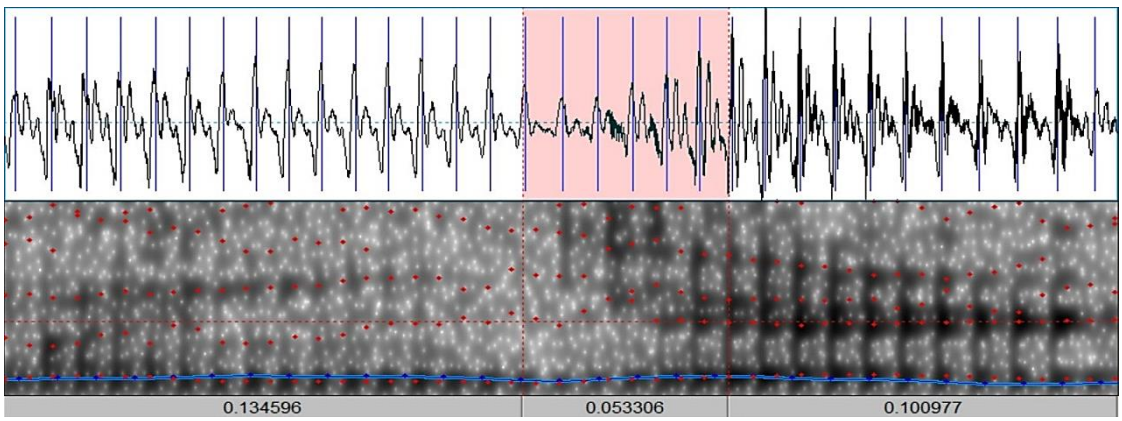


Fig 30. SPECTROGRAM FOR SOUND /jh/ MEDIAL

RESULTS

This clinical study was performed to assess and correlate the speech pronunciation (linguo-palatal sounds) of subjects with customized palatine rugae duplicated on upper complete denture and subjects with conventional upper complete denture and subjects with the natural dentition upto a duration of 4 weeks after denture insertion.

The following methods of statistical analysis have been used in this study. Data was entered in Microsoft excel and analysed using SPSS (Statistical Package for Social Science, Ver.10.0.5).

The results were averaged (mean + standard deviation) for continuous data and number and percentage for dichotomous data are presented in Table and Figure. Normality assumption of the data was tested using Shapiro-Wilks test. If the assumption is not significant then parametric test was carried out otherwise non parametric test was carried out. In this study data was normally distributed and parametric test was used to compare between the groups.

One way Analysis of Variance (Anova):

One way analyses of variance were used to test the difference between groups. Analysis of Variance is a technique by which the total variation is split into two parts one between groups and the other within the groups. If 'F' value is significant there is a significant, difference between group means. Then further pair wise comparison between the groups was tested using **Tukey's Post-Hoc test.** The formula used:

$$F = \frac{MS_{betweengroups}}{MS_{Withingroups}}$$ where MS=Mean Sum of Square

In all the above test "p" value of less than 0.05 was accepted as indicating statistical significance.

Table-1 : Comparison among the GROUP A, B & C for different parameters at various stages for the sound /d/ initial (dappa) by Descriptive analysis and One-way Anova test:

	GROUPS	N	Stage 1		Stage 2		Stage 3		Stage 4	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
VOT	Group A	12	59.78	6.211	68.52	10.438	65.18	9.443	70.63	10.757
	Group B		59.78	6.211	54.55	7.222	61.47	9.369	59.27	9.073
	Group C	6	73.20	27.248	73.20	27.248	73.20	27.248	73.20	27.248
	F value*		2.561		4.489		1.313		2.525	
	P value		0.096		***0.021***		0.286		0.099	
VD	Group A	12	82.08	11.898	113.07	33.327	116.21	34.899	123.10	34.578
	Group B		82.08	11.898	87.08	21.561	74.34	23.128	79.36	16.693
	Group C	6	116.03	53.586	116.03	53.586	116.03	53.586	116.03	53.586
	F value*		4.275		2.247		5.051		5.533	
	P value		***0.024***		0.125		***0.014***		***0.010***	
F1	Group A	12	595.38	59.299	607.25	65.414	618.45	54.847	651.05	51.295
	Group B		595.38	59.299	575.34	57.430	583.28	52.397	576.74	43.811
	Group C	6	606.58	69.866	606.58	69.866	606.58	69.866	606.58	69.866
	F value*		0.080		0.906		1.166		6.053	
	P value		0.923		0.416		0.327		***0.007***	
F2	Group A	12	1534.03	68.371	1556.39	71.308	1561.03	60.784	1558.25	60.472
	Group B		1534.03	68.371	1556.39	61.595	1558.59	54.377	1638.56	52.012
	Group C	6	1589.13	88.055	1589.13	88.055	1589.13	88.055	1589.13	88.055
	F value*		1.389		0.591		0.502		4.855	
	P value		0.267		0.561		0.611		***0.016***	

Table-2: Multiple comparison between the groups for the sound /d/ initial (dappa) at various Stages using Tukey HSD Post-Hoc Test :

	GROUPS	Stage 1		Stage 2		Stage 3		Stage 4	
		Mean diff	P value	Mean diff	P value	Mean diff	P value	Mean diff	P value
VOT	A vs B	0.00	1.000	13.97	0.059	3.71	0.806	11.37	0.162
	A vs C	-13.42	0.116	-4.68	0.790	-8.02	0.518	-2.57	0.936
	B vs C	-13.42	0.116	-18.65	***0.037***	-11.73	0.255	-13.93	0.162
VD	A vs B	0.00	1.000	25.98	0.170	41.87	***0.019***	43.74	***0.010***
	A vs C	-33.95	***0.033***	-2.97	0.984	0.18	1.000	7.07	0.908
	B vs C	-33.95	***0.033***	-28.95	0.227	-41.69	0.064	-36.67	0.093
F1	A vs B	0.00	1.000	31.91	0.442	35.17	0.302	74.31	***0.005***
	A vs C	-11.21	0.929	0.67	1.000	11.87	0.909	44.47	0.226
	B vs C	-11.21	0.929	-31.24	0.590	-23.30	0.695	-29.84	0.501
F2	A vs B	0.00	1.000	-4.37	0.988	2.43	0.995	-80.31	***0.012***
	A vs C	-55.10	0.297	-37.12	0.556	-28.11	0.662	-30.88	0.600
	B vs C	-55.10	0.297	-32.74	0.632	-30.54	0.615	49.43	0.281

Table-3 : Comparison among the GROUP A, B & C for different parameters at various stages for the sound /d/ medial (veedu) by Descriptive analysis and One-way Anova test:

	GROUPS	N	Stage 1		Stage 2		Stage 3		Stage 4	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
CD	Group A	12	31.56	8.302	40.22	8.534	35.04	10.048	39.62	11.743
	Group B		31.56	8.302	32.92	11.505	34.08	11.305	35.6	8.879
	Group C	6	39.38	11.312	39.38	11.312	39.38	11.312	39.38	11.312
	F value*		1.840		1.667		0.502		0.501	
	P value		0.178		0.208		0.611		0.611	
VD	Group A	12	311.6	29.973	301.69	40.521	318.14	33.926	331.13	26.097
	Group B		311.6	29.973	297.87	31.124	308.18	40.452	319.79	28.496
	Group C	6	332.48	26.643	332.48	26.643	332.48	26.643	332.48	26.643
	F value*		1.212		2.185		0.943		0.682	
	P value		0.313		0.132		0.402		0.514	
F1	Group A	12	436.03	68.606	456.61	75.893	473.72	84.814	485.02	64.367
	Group B		436.03	68.606	447.56	72.007	456.34	68.449	462.86	68.118
	Group C	6	382.03	35.553	382.03	35.553	382.03	35.553	382.03	35.553
	F value*		1.720		2.562		3.437		5.704	
	P value		0.198		0.096		***0.047***		***0.009***	
F2	Group A	12	2031.14	110.99	2085.43	130.743	1987.11	102.768	2009.03	93.261
	Group B		2031.14	110.99	2141.33	130.711	2163.68	87.419	2142.83	94.655
	Group C	6	1883.45	103.684	1883.45	103.684	1883.45	103.684	1883.45	103.684
	F value*		4.352		8.561		19.343		15.529	
	P value		***0.023***		***0.001***		***<0.001***		***<0.001***	

Table-4 : Multiple comparison between the groups for the sound /d/ medial (veedu) at various Stages using Tukey HSD Post-Hoc Test :

	GROUPS	Stage 1		Stage 2		Stage 3		Stage 4	
		Mean diff	P value	Mean diff	P value	Mean diff	P value	Mean diff	P value
CD	A vs B	0.00	1.000	7.30	0.214	0.97	0.974	4.02	0.625
	A vs C	-7.82	0.205	0.83	0.986	-4.34	0.704	0.24	0.999
	B vs C	-7.82	0.205	-6.47	0.436	-5.31	0.594	-3.78	0.757
VD	A vs B	0.00	1.000	3.83	0.960	9.97	0.774	11.34	0.570
	A vs C	-20.88	0.344	-30.79	0.195	-14.34	0.703	-1.35	0.995
	B vs C	-20.88	0.344	-34.62	0.131	-24.31	0.373	-12.69	0.624
F1	A vs B	0.00	1.000	9.05	0.944	17.38	0.823	22.16	0.658
	A vs C	54.00	0.226	74.57	0.093	91.68	***0.041***	102.98	***0.007***
	B vs C	54.00	0.226	65.52	0.154	74.31	0.112	80.82	***0.037***
F2	A vs B	0.00	1.000	-55.90	0.531	-176.58	***<0.001***	-133.80	***0.006***
	A vs C	147.69	***0.031***	201.98	***0.009***	103.66	0.101	125.58	***0.037***
	B vs C	147.69	***0.031***	257.88	***0.001***	280.23	***<0.001***	259.38	***<0.001***

Table-5 : Comparison among the GROUP A, B & C for different parameters at various stages for the sound /th/ initial (thatha) by Descriptive analysis and One way Anova test :

	GROUPS	***N***	***Stage 1***		***Stage 2***		***Stage 3***		***Stage 4***	
			Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
FD	Group A	12	16.05	4.393	18.22	6.414	21.23	7.862	22.36	6.827
	Group B		16.05	4.393	15.66	4.629	17.41	5.179	20.67	6.055
	Group C	6	28.85	9.999	28.85	9.999	28.85	9.999	28.85	9.999
	F value*		11.484		8.183		4.794		2.628	
	P value		***<0.001***		***0.002***		***0.017***		0.091	
SPPK	Group A	12	4097.15	337.541	4512.76	315.159	5038.58	350.598	5221.86	286.478
	Group B		4097.15	337.541	4476.91	370.768	4769.75	365.612	4908.91	359.41
	Group C	6	5116.03	309.601	5116.03	309.601	5116.03	309.601	5116.03	309.601
	F value*		22.530		8.142		2.654		2.890	
	P value		***<0.001***		***0.002***		0.089		0.073	
VD	Group A	12	73.13	21.509	88.13	27.474	95.51	25.545	103.2	23.955
	Group B		73.13	21.509	74.94	25.576	79.29	23.929	81.09	23.152
	Group C	6	92.05	23.961	92.05	23.961	92.05	23.961	92.05	23.961
	F value*		1.777		1.157		1.389		2.626	
	P value		0.188		0.329		0.267		0.091	
F1	Group A	12	491.43	53.733	531.57	61.033	564.28	59.617	602.28	56.132
	Group B		491.43	53.733	500.58	96.316	516.58	77.987	498.68	76.075
	Group C	6	543.33	96.514	543.33	96.514	543.33	96.514	543.33	96.514
	F value*		1.585		0.664		1.211		6.022	
	P value		0.223		0.523		0.314		***0.007***	
F2	Group A	12	1722.38	76.629	1794.88	71.176	1852.53	68.134	1943.53	94.523
	Group B		1722.38	76.629	1711.85	48.854	1683.91	37.303	1718.79	54.956
	Group C	6	1656.28	114.445	1656.28	114.445	1656.28	114.445	1656.28	114.445
	F value*		1.454		7.927		23.625		30.827	
	P value		0.251		***0.002***		***<0.001***		***<0.001***	

Table-6 : Multiple comparison between the groups for the sound /th/ initial (thatha) at various Stages using Tukey HSD Post-Hoc Test :

	GROUPS	Stage 1		Stage 2		Stage 3		Stage 4	
		Mean diff	P value	Mean diff	P value	Mean diff	P value	Mean diff	P value
FD	A vs B	0.00	1.000	2.57	0.615	3.82	0.425	1.69	0.836
	A vs C	-12.80	***<0.001***	-10.63	***0.009***	-7.62	0.117	-6.49	0.191
	B vs C	-12.80	***<0.001***	-13.19	***0.001***	-11.44	***0.012***	-8.18	0.079
SP PK	A vs B	0.00	1.000	35.85	0.964	268.83	0.163	312.95	0.062
	A vs C	-1,018.88	***<0.001***	-603.28	***0.004***	-77.45	0.898	105.82	0.790
	B vs C	-1,018.88	***<0.001***	-639.13	***0.002***	-346.28	0.136	-207.13	0.415
VD	A vs B	0.00	1.000	13.19	0.441	16.22	0.257	22.11	0.074
	A vs C	-18.92	0.216	-3.92	0.952	3.46	0.957	11.15	0.618
	B vs C	-18.92	0.216	-17.11	0.401	-12.76	0.561	-10.96	0.628
F1	A vs B	0.00	1.000	30.99	0.641	47.69	0.283	103.59	***0.005***
	A vs C	-51.90	0.252	-11.77	0.958	20.94	0.844	58.94	0.259
	B vs C	-51.90	0.252	-42.76	0.571	-26.75	0.759	-44.65	0.453
F2	A vs B	0.00	1.000	83.02	***0.027***	168.62	***<0.001***	224.73	***<0.001***
	A vs C	66.10	0.281	138.59	***0.002***	196.25	***<0.001***	287.24	***<0.001***
	B vs C	66.10	0.281	55.57	0.305	27.63	0.712	62.51	0.324

Table-7 : Comparison among the GROUP A, B & C for different parameters at various stages for the sound /th/ medial (pathu) by Descriptive analysis and One way Anova test :

	GROUPS	N	Stage 1		Stage 2		Stage 3		Stage 4	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
FD	Group A	12	45.02	11.475	61.03	14.415	68.32	12.535	72.18	16.013
	Group B		45.02	11.475	51.56	10.802	49.49	10.183	51.42	11.612
	Group C	6	72.58	24.302	72.58	24.302	72.58	24.302	72.58	24.302
	F value*		8.42		3.751		7.013		5.849	
	P value		***0.001***		***0.037***		***0.004***		***0.008***	
SPPK	Group A	12	4160.52	257.572	4731.36	315.553	5110.83	268.115	5328.76	231.232
	Group B		4160.52	257.572	4322.55	342.934	4536.07	425.529	4780.25	351.125
	Group C	6	5291.12	473.484	5291.12	473.484	5291.12	473.484	5291.12	473.484
	F value*		32.099		14.638		10.486		9.134	
	P value		***<0.001***		***<0.001***		***<0.001***		***0.001***	
VD	Group A	12	261.91	36.921	284.78	46.315	296.6	35.814	301.95	37.293
	Group B		261.91	36.921	274.66	31.753	267.83	25.238	268.93	24.862
	Group C	6	294.72	71.535	294.72	71.535	294.72	71.535	294.72	71.535
	F value*		1.255		0.380		1.653		1.970	
	P value		0.301		0.688		0.210		0.159	
F1	Group A	12	504.27	82.832	547.71	96.499	564.96	69.878	582.42	78.33
	Group B		504.27	82.832	498.47	50.411	506.92	45.6	491.6	31.31
	Group C	6	562.1	71.492	562.1	71.492	562.1	71.492	562.1	71.492
	F value*		1.228		1.892		3.106		6.827	
	P value		0.309		0.170		0.061		***0.004***	
F2	Group A	12	1882.39	124.885	1894.67	196.688	1899.10	164.088	1912.45	133.898
	Group B		1882.39	124.885	1854.43	150.074	1875.93	140.268	1917.83	160.907
	Group C	6	1858.33	149.958	1858.33	149.958	1858.33	149.958	1858.33	149.958
	F value*		0.082		0.189		0.158		0.356	
	P value		0.921		0.829		0.855		0.704	

Table-8 : Multiple comparison between the groups for the sound /th/ medial (pathu) at various Stages using Tukey HSD Post-Hoc Test :

	GROUPS	Stage 1		Stage 2		Stage 3		Stage 4	
		Mean diff	P value	Mean diff	P value	Mean diff	P value	Mean diff	P value
FD	A vs B	0.00	1.000	9.47	0.310	18.83	0.011	20.76	***0.012***
	A vs C	-27.57	***0.002***	-11.55	0.313	-4.27	0.831	-0.41	0.999
	B vs C	-27.57	***0.002***	-21.03	***0.030***	-23.09	***0.011***	-21.17	***0.040***
SP PK	A vs B	0.00	1.000	408.81	***0.026***	574.77	***0.003***	548.51	***0.001***
	A vs C	-1130.60	***<0.001***	-559.76	***0.012***	-180.28	0.615	37.64	0.973
	B vs C	-1130.60	***<0.001***	-968.57	***<0.001***	-755.05	***0.001***	-510.87	***0.014***
VD	A vs B	0.00	1.000	10.13	0.860	28.77	0.226	33.02	0.151
	A vs C	-32.81	0.332	-9.93	0.907	1.88	0.995	7.23	0.937
	B vs C	-32.81	0.332	-20.06	0.676	-26.89	0.411	-25.79	0.448
F1	A vs B	0.00	1.000	49.24	0.268	58.04	0.071	90.82	***0.004***
	A vs C	-57.83	0.340	-14.39	0.924	2.86	0.995	20.32	0.791
	B vs C	-57.83	0.340	-63.63	0.233	-55.18	0.191	-70.50	0.077
F2	A vs B	0.00	1.000	40.23	0.833	23.17	0.926	-5.38	0.996
	A vs C	24.06	0.927	36.33	0.905	40.77	0.854	54.12	0.748
	B vs C	24.06	0.927	-3.90	0.999	17.59	0.971	59.50	0.705

Table-9 : Comparison among the GROUP A, B & C for different parameters at various stages for the sound /ja/ in initial (jannal) by Descriptive analysis and One-way Anova test :

	GROUPS	***N***	***Stage 1***		***Stage 2***		***Stage 3***		***Stage 4***	
			Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
AD	Group A	12	108.24	25.607	111.74	25.657	114.62	28.148	119.87	28.39
	Group B		108.24	25.607	105.46	24.322	107.96	22.629	106.71	20.937
	Group C	6	120.95	23.25	120.95	23.25	120.95	23.25	120.95	23.25
	F value*		0.611		0.795		0.565		1.089	
	P value		0.550		0.462		0.575		0.351	
SPPK	Group A	12	3854.59	271.356	4352.51	256.515	4669.59	279.72	4872.14	364.326
	Group B		3854.59	271.356	4211.37	265.856	4396.23	248.422	4689.76	263.259
	Group C	6	4909.53	380.15	4909.53	380.15	4909.53	380.15	4909.53	380.15
	F value*		30.786		12.202		6.739		1.279	
	P value		***<0.001***		***<0.001***		***0.004***		0.295	
VD	Group A	12	53.76	15.597	65.15	19.572	72.98	17.206	81.91	19.3
	Group B		53.76	15.597	64.12	17.232	58.87	13.96	68.19	13.433
	Group C	6	84.38	15.302	84.38	15.302	84.38	15.302	84.38	15.302
	F value*		9.317		2.932		5.815		2.879	
	P value		***0.001***		0.070		***0.008***		0.074	
F1	Group A	12	501.98	97.046	538.16	101.023	559.64	90.993	578.98	89.091
	Group B		501.98	97.046	486.99	78.304	498.44	71.9	496.63	71.821
	Group C	6	552.28	121.363	552.28	121.363	552.28	121.363	552.28	121.363
	F value*		0.584		1.240		1.527		2.586	
	P value		0.565		0.305		0.235		0.094	
F2	Group A	12	2007.29	225.494	1971.47	216.99	1998.59	212.758	2045.39	209.47
	Group B		2007.29	225.494	1948.79	183.627	1994.74	168.273	2005.38	151.762
	Group C	6	1997.60	277.934	1997.60	277.934	1997.60	277.934	1997.60	277.934
	F value*		0.004		0.104		0.001		0.160	
	P value		0.996		0.902		0.999		0.853	

Table-10 : Multiple comparison between the groups for the sound /ja/ in initial (jannal) at various Stages using Tukey HSD Post-Hoc Test :

	GROUPS	Stage 1		Stage 2		Stage 3		Stage 4	
		Mean diff	P value	Mean diff	P value	Mean diff	P value	Mean diff	P value
AD	A vs B	0.00	1.000	6.28	0.809	6.66	0.795	13.17	0.403
	A vs C	-12.71	0.578	-9.21	0.739	-6.33	0.870	-1.08	0.996
	B vs C	-12.71	0.578	-15.49	0.432	-12.99	0.562	-14.24	0.489
SP PK	A vs B	0.00	1.000	141.13	0.461	273.36	0.071	182.38	0.379
	A vs C	-1054.94	***<0.001***	-557.03	***0.002***	-239.94	0.240	-37.39	0.972
	B vs C	-1054.94	***<0.001***	-698.16	***<0.001***	-513.30	***0.004***	-219.78	0.391
VD	A vs B	0.00	1.000	1.03	0.989	14.11	0.087	13.72	0.120
	A vs C	-30.62	***0.001***	-19.23	0.099	-11.41	0.324	-2.47	0.951
	B vs C	-30.62	***0.001***	-20.27	0.078	-25.52	***0.008***	-16.19	0.138
F1	A vs B	0.00	1.000	51.17	0.411	61.20	0.241	82.36	0.081
	A vs C	-50.31	0.591	-14.13	0.954	7.36	0.986	26.70	0.824
	B vs C	-50.31	0.591	-65.29	0.382	-53.84	0.470	-55.66	0.441
F2	A vs B	0.00	1.000	22.68	0.965	3.85	0.999	40.01	0.881
	A vs C	9.69	0.996	-26.13	0.969	.99	1.000	47.79	0.886
	B vs C	9.69	0.996	-48.81	0.895	-2.86	1.000	7.78	0.997

Table-11 : Comparison among the GROUP A, B & C for different parameters at various stages for the sound /ja/ in medial (manjal) by Descriptive analysis and One-way Anova test :

	GROUPS	N	Stage 1		Stage 2		Stage 3		Stage 4	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
AD	Group A	12	39.11	9.018	60.14	16.319	65.38	16.385	71.02	17.403
	Group B		39.11	9.018	44.63	11.054	45.71	10.256	45.93	9.802
	Group C	6	68.90	21.521	68.90	21.521	68.90	21.521	68.90	21.521
	F value*		14.010		5.643		6.678		8.658	
	P value		***<0.001***		***0.009***		***0.004***		***0.001***	
SP PK	Group A	12	3534.25	130.814	4415.17	154.478	4572.54	125.877	4800.34	152.744
	Group B		3534.25	130.814	4159.28	121.902	4633.49	175.762	4750.27	109.825
	Group C	6	5023.95	352.893	5023.95	352.893	5023.95	352.893	5023.95	352.893
	F value*		143.929		38.598		10.365		4.160	
	P value		***<0.001***		***<0.001***		***<0.001***		***0.027***	
VD	Group A	12	57.40	11.458	80.98	15.765	87.88	16.262	93.78	15.526
	Group B		57.40	11.458	60.03	12.529	56.06	10.937	64.09	11.564
	Group C	6	89.35	17.988	89.35	17.988	89.35	17.988	89.35	17.988
	F value*		14.680		9.634		17.392		13.664	
	P value		***<0.001***		***0.001***		***<0.001***		***<0.001***	
F1	Group A	12	696.39	77.627	720.27	78.041	742.82	65.707	769.31	62.611
	Group B		696.39	77.627	687.53	72.358	681.73	71.404	679.28	71.524
	Group C	6	678.05	112.882	678.05	112.882	678.05	112.882	678.05	112.882
	F value*		0.111		0.691		2.260		4.875	
	P value		0.895		0.510		0.124		***0.016***	
F2	Group A	12	2245.60	186.186	2036.38	106.200	2194.33	113.348	2226.47	107.386
	Group B		2245.60	186.186	2317.60	154.239	2457.89	168.256	2395.08	161.448
	Group C	6	2307.92	152.039	2307.92	152.039	2307.92	152.039	2307.92	152.039
	F value*		0.287		14.993		9.939		4.353	
	P value		0.753		***<0.001***		***0.001***		***0.023***	

Table-12 : Multiple comparison between the groups for the sound /ja/ in medial (manjal) at various Stages using Tukey HSD Post-Hoc Test :

	GROUPS	Stage 1		Stage 2		Stage 3		Stage 4	
		Mean diff	P value	Mean diff	P value	Mean diff	P value	Mean diff	P value
AD	A vs B	0.00	1.000	15.52	0.055	19.68	***0.011***	25.09	***0.002***
	A vs C	-29.79	***<0.001***	-8.76	0.510	-3.52	0.892	2.12	0.961
	B vs C	-29.79	***<0.001***	-24.27	***0.012***	-23.19	***0.015***	-22.97	***0.019***
SP PK	A vs B	0.00	1.000	255.88	***0.010***	-60.95	0.749	50.07	0.803
	A vs C	-1489.70	***<0.001***	-608.78	***<0.001***	-451.41	***<0.001***	-223.61	0.071
	B vs C	-1489.70	***<0.001***	-864.67	***<0.001***	-390.46	***0.002***	-273.68	***0.023***
VD	A vs B	0.00	1.000	20.95	***0.006***	31.82	***<0.001***	29.69	***<0.001***
	A vs C	-31.95	***<0.001***	-8.37	0.513	-1.47	0.978	4.43	0.817
	B vs C	-31.95	***<0.001***	-29.32	***0.002***	-33.29	***<0.001***	-25.26	***0.005***
F1	A vs B	0.00	1.000	32.74	0.608	61.08	0.158	90.03	***0.022***
	A vs C	18.34	0.903	42.22	0.576	64.77	0.244	91.26	***0.066***
	B vs C	18.34	0.903	9.48	0.972	3.68	0.995	1.23	0.999
F2	A vs B	0.00	1.000	-281.22	***<0.001***	-263.57	***<0.001***	-168.61	***0.017***
	A vs C	-62.32	0.771	-271.53	***0.001***	-113.59	0.277	-81.45	0.485
	B vs C	-62.32	0.771	9.68	0.989	149.98	0.116	87.16	0.438

INTERPRETATION

Table 1 & 2 shows the descriptive statistics of the variables for the sound **/d/** at **initial** position **(dappa)** with mean and standard deviation and the comparison between the groups shows the significant difference among them at various stages.

VOT shows no statistical significance at stage 1, 3 and 4, only at stage 2 with the Mean of A=68.52, B=54.55, C=73.02, where Group B had a statistically significant decrease when compared to Control group with p value of **0.037**.

VD at stage 1, the Group A and B shows statistically significant decrease compared to Control group with the Mean of A & B=82.08, C=116.03 with p value **0.033**. At stage 3 and 4, Group B shows statistically significant decrease compared to Group A with the Mean of A=116.2 , B=74.34 at stage 3, and p value of **0.019**, and at stage 4, A=123.10, B=79.36 with the p value of **0.010**.

F1 at stage 4, Group B shows statistically significant decrease compared to Group A with the Mean, A=651.05 , B=576.74 and p value of **0.005**.

F2 at stage 4, Group A shows statistically significant decrease with Group B with the Mean, A= 1558.25, B=1638.5 and p value of **0.012**.

Table 3 & 4 shows the descriptive statistics of the variables for the sound **/d/** at **medial** position **(veedu)** with mean and standard deviation and the comparison between the groups shows the significant difference among them at various stages.

F1 at stage 3, Group A shows statistically significant increase compared to Group C with the Mean, A=473.72, C=382.03 and p value of **0.041**. At stage 4, Group A & B

shows statistically significant increase with Group C with the Mean of A=485.02, B=462.86, C=382.03 and p value of **0.009**.

F2 at stage 1, Group A & B shows statistically significant increase compared to Group C with the Mean, A & B=2031.14, C=1883.45 and p value of **0.031**. At stage 2, Group A (2085.43), Group B (2141.33) shows statistically significant increase compared to Group C (1883.45) with p value of **0.009** (Group A & C) and **0.001** (Group B & C). At stage 3, Group B (2163.68) shows statistically significant increase compared to Group A (1987.11) and Group C (1883.45) with p value of **<0.001**. At stage 4, Group B (2142.83) shows statistically significant increase compared to Group A (2009.03) with p value of **0.006** and with Group C (1883.45) with p value of **<0.001**. Group A (2009.03) shows statistically significant increase with Group C (1883.45) with p value of **0.037**.

Table 5 & 6 shows the descriptive statistics of the variables for the sound **/th/** at **initial** position **(thatha)** with mean and standard deviation and the comparison between the groups shows the significant difference among them at various stages.

FD at stage 1, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=16.05, C=28.85 and p value of **<0.001**. At stage 2, Group A (18.22), Group B (17.41) shows statistically significant decrease compared to Group C (28.85) with p value of **0.009** (Group A & C) and **0.001** (Group B & C). At stage 3, Group B shows statistically significant decreased compared to Group C with the Mean, B=17.41, C=28.85 and p value of **0.012**.

SP PK energy at stage 1 (A & B=4097.15) and stage 2 (A=4512.76, B=4476.91) where both Group A & B shows statistically significant decreased compared to Group C

(5116.03) with p value of **<0.001** (Group A,B & C) at stage 1 and **0.004** (Group A & C), **0.002** (Group B & C) at stage 2.

F1 at stage 4, Group B (498.68) shows statistically significant decrease compared to Group A (602.28) with p value of **0.005**.

F2 at stage 2, 3 and 4, Group A shows statistically significant increase compared to Group B & C with the Mean, at stage 2 (A=1794.88, B=1711.85, C=1656.28), stage 3 (A=1852.53, B=1683.91, C=1656.28), stage 4 (A=1943.53, B=1718.79, C=1656.28) with p value of **0.027** (A & B) & **0.002 (A & C)** at stage 2, **<0.001** (A & B, A & C) at stage 3 and 4.

Table 7 & 8 shows the descriptive statistics of the variables for the sound **/th/** at **medial** position **(pathu)** with mean and standard deviation and the comparison between the groups shows the significant difference among them at various stages.

FD at stage 1, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=45.02, C=72.58 and p value of **0.002**. At stage 2,3 and 4 Group B shows statistically significant decrease from Control group with the mean, B=51.56, 49.49, 51.42 at stage 2,3 & 4 respectively, C=72.58 at stage 2,3 & 4 and p value of **0.030**, **0.011** and **0.040** at stage 2,3 & 4 respectively. At stage 4, Group B shows statistically significant decrease from Group A with the mean, A=72.18, B=51.42, and p value of **0.012**.

SP PK at stage 1 and 2, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=4160.52, C=5291.12 and p value of **<0.001** at stage 1 and at the stage 2 with the mean of A=4731.36, B=4322.55, C=5291.12 with p value of **0.012** (A & C), **<0.001** (B & C). At stage 2, Group B also shows statistically

significant decreased compared to Group A, with the Mean, A=4731.36, B=4322.55, and p value of **0.026**. At stage 3 and 4, Group B shows statistically significant decreased compared to Group A and C, with the Mean, (A=5110.83, 5328.76), (B=4536.07, 4780.25), C=5291.12 at stage 3 & 4 respectively and p value of **0.003** (A & B), **0.001** (B & C) at stage 3 and **0.001** (A & B), **0.014** (B & C) at stage 4.

F1 at stage 4, Group B (491.6) shows statistically significant decrease compared to Group A (582.42) with p value of **0.004**.

Table 9 & 10 shows the descriptive statistics of the variables for the sound **/ja/** at **initial** position **(jannal)** with mean and standard deviation and the comparison between the groups shows the significant difference among them at various stages.

SP PK at stage 1 and 2, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=3854.59, C=4909.53 and p value of **<0.001** at stage 1, and at stage 2 with the mean of A=4352.51, B=4211.37, C=4909.53 with p value of **0.002** (A & C), **<0.001** (B & C). At stage 3, Group B shows statistically significant decreased compared to Group C, with the Mean, B=4396.23, C=4909.53 and p value of **0.004**.

VD at stage 1, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=53.76, C=84.38 and p value of **0.001**. At stage 3, Group B shows statistically significant decreased compared to Group C, with the Mean, B=58.87, C=84.38 and p value of **0.008**.

Table 11 & 12 shows the descriptive statistics of the variables for the sound **/ja/** at **medial** position **(manjal)** with mean and standard deviation and the comparison between the groups shows the significant difference among them at various stages.

AD at stage 1, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=39.11, C=68.90 and p value of **<0.001**. At stage 2, Group B shows statistically significant decreased compared to Group C, with the Mean, B=44.63, C=68.90 and p value of **0.012**.

At stage 3 and 4, Group B shows statistically significant decreased compared to Group A & C, with the Mean, A=65.38, B=47.51, C=68.90 and p value of **0.011** (A & B), **0.015** (B & C) at stage 3 and the Mean, A=71.02, B=45.93, C=68.90 and p value of **0.002** (A & B), **0.019** (B & C) at stage 4.

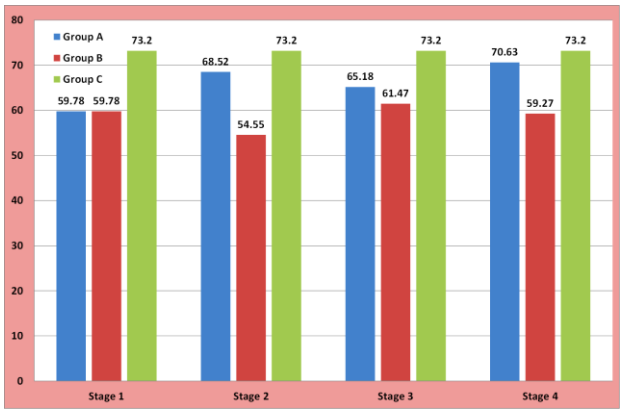
SP PK at stage 1, 2 and 3, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=3534.25, C=5023.95 and p value of **<0.001** at stage 1, and with the mean of A=4415.17, B=4159.28, C=5023.95 with p value of **<0.001** at stage 2 and with the mean of A=4572.54, B=4633.49, C=5023.95 with p value of **<0.001** (A & C), **0.002** (B & C) at stage 3. At stage 2, Group B shows statistically significant decreased compared to Group A, with the Mean, A=4415.17, B=4159.28 and p value of **0.010**. At stage 4, Group B shows statistically significant decreased compared to Group C, with the Mean, B=4750.27, C=5023.95 and p value of **0.023**.

VD at stage 1, Group A & B shows statistically significant decreased compared to Group C with the Mean, A & B=57.40, C=89.35 and p value of **<0.001**.

At stage 2, 3 and 4, Group B shows statistically significant decreased compared to Group A & C with the Mean, A=80.98, B=60.03, C=89.35 and p value of **0.006** (A & B), **0.002** (B & C) at stage 2, and with the mean of A=87.88, B=56.06, C=89.35 with p value of **<0.001** at stage 3 and with the mean of A=93.78, B=64.09, C=89.35 with p value of **<0.001** (A & C), **0.005** (B & C) at stage 4.

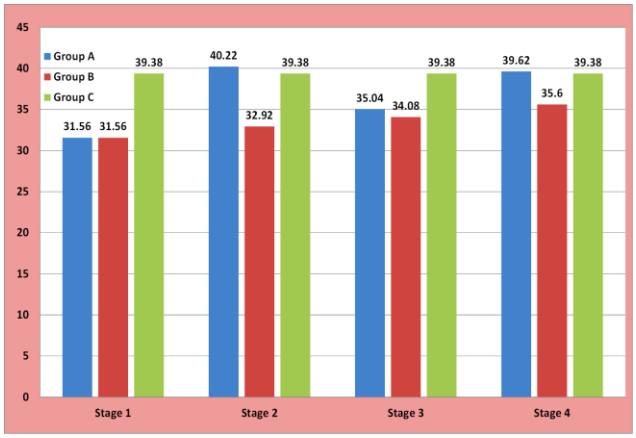
F1 at stage 4, Group A shows statistically significant increased compared to Group B & C with the Mean, A=769.31, B=679.28, C=678.05 and p value of **0.022** (A & B), **0.066** (A & C).

F2 at stage 2, Group A shows statistically significant decreased compared to Group B & C with the Mean, A=2036.38, B=2317.60, C=2307.92 and p value of **<0.001** (A & B), **0.001** (A & C) . At stage 3 and 4, Group A shows statistically significant decreased compared to Group B with the Mean, A=2194.33, B=2457.89, and p value of **<0.001** at stage 3 and, with the Mean, A=2226.47, B=2395.08, and p value of **0.017**.

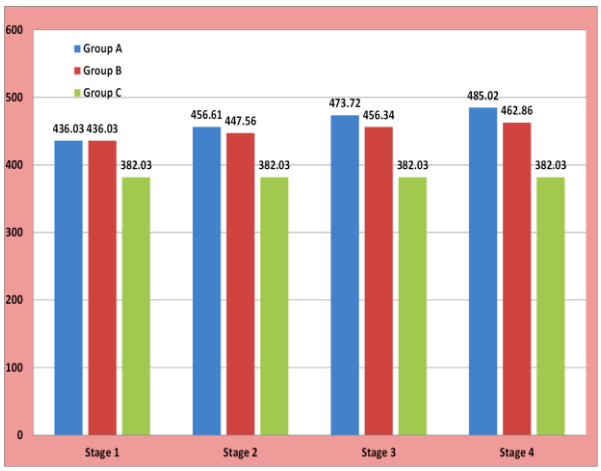


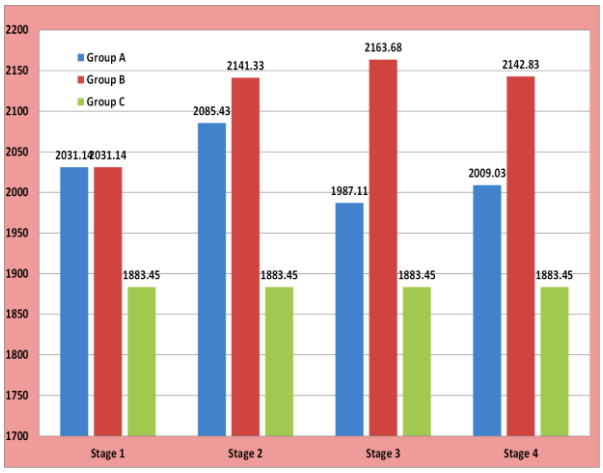
BAR 1 & 2.COMPARISON OF MEAN VALUES OF *VOT AND VD* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /d/ INITIAL (DAPPA)

BAR 3 & 4. COMPARISON OF MEAN VALUES OF *F1 AND F2* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /d/ INITIAL (DAPPA)

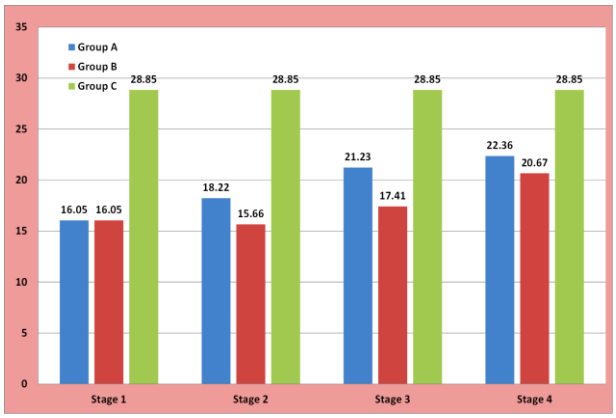


BAR 5 & 6.COMPARISON OF MEAN VALUES OF *CD AND VD* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /d/ MEDIAL(VEEDU)





BAR 7 & 8.COMPARISON OF MEAN VALUES OF *F1 AND F2* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /d/ MEDIAL(VEEDU)



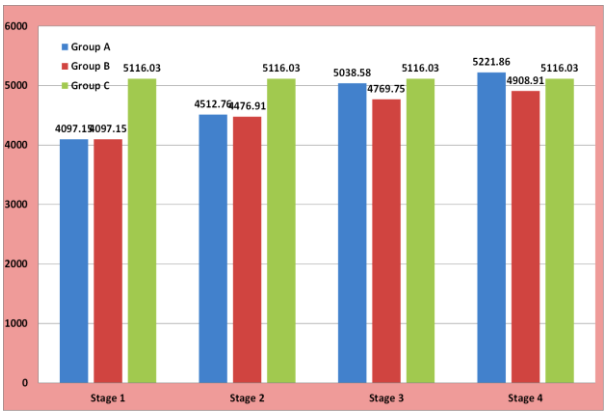
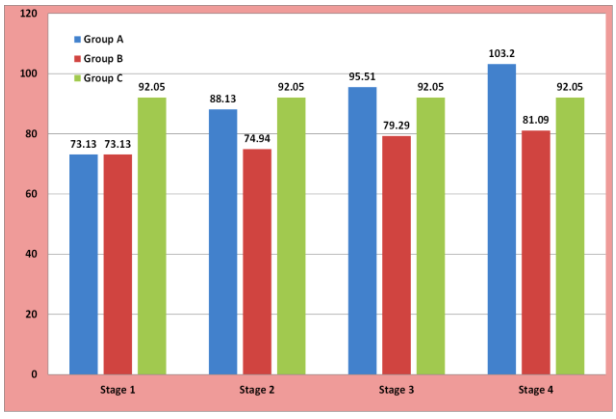


FIG 9 & 10.COMPARISON OF MEAN VALUES OF *FD AND SP PK* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /th/ INITIAL (THATHA)



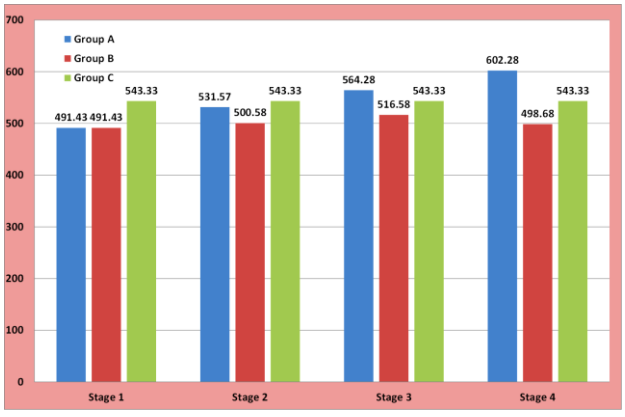


FIG 11 & 12. COMPARISON OF MEAN VALUES OF *VD AND F1* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /th/ INITIAL (THATHA)

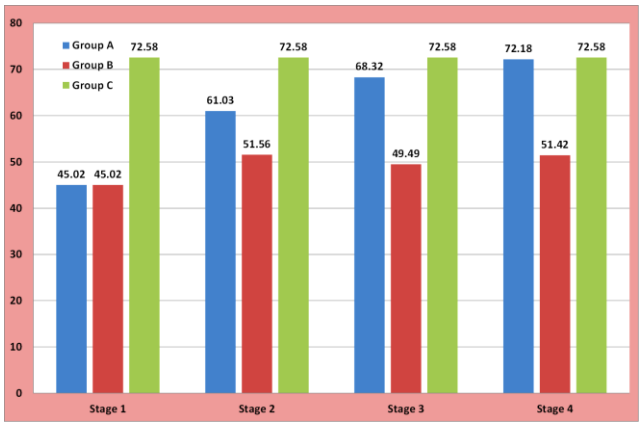
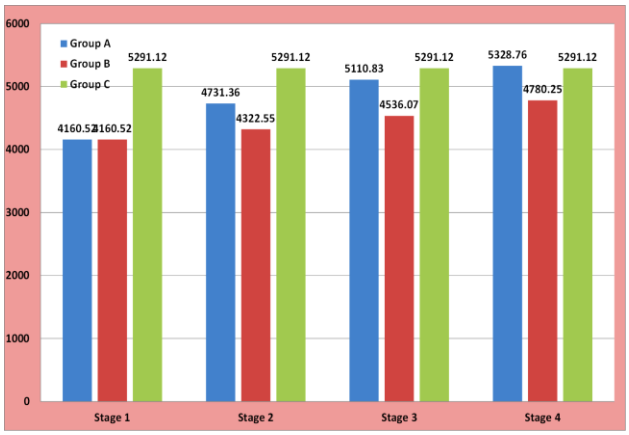


FIG 13 & 14.COMPARISON OF MEAN VALUES OF *SECOND F2 AND FD* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /th/ INTIAL(THATHA) & /th/ MEDIAL (PATHU) RESPECTIVELY



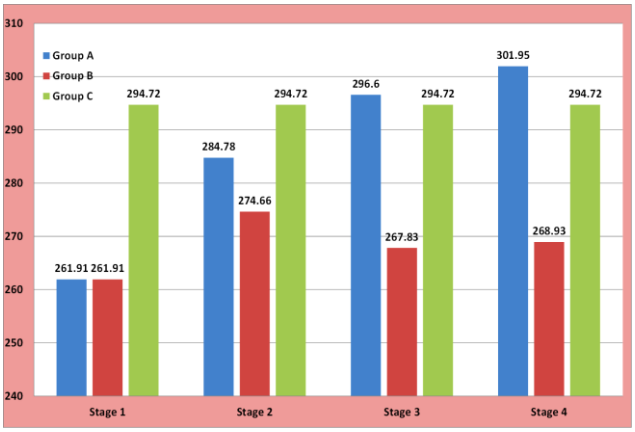
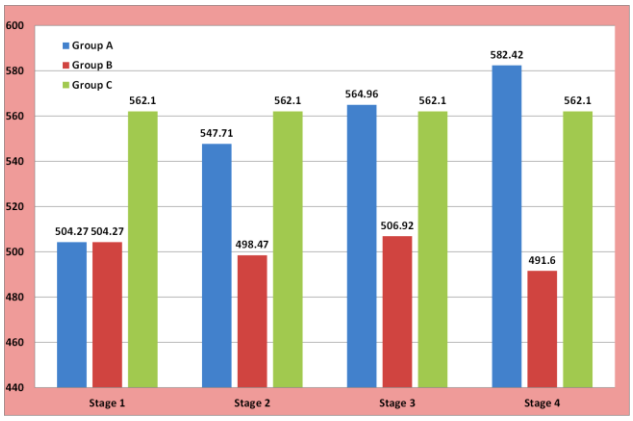


FIG 15 & 16 .COMPARISON OF MEAN VALUES OF *SP PK AND VD*AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /th/ MEDIAL(PATHU)



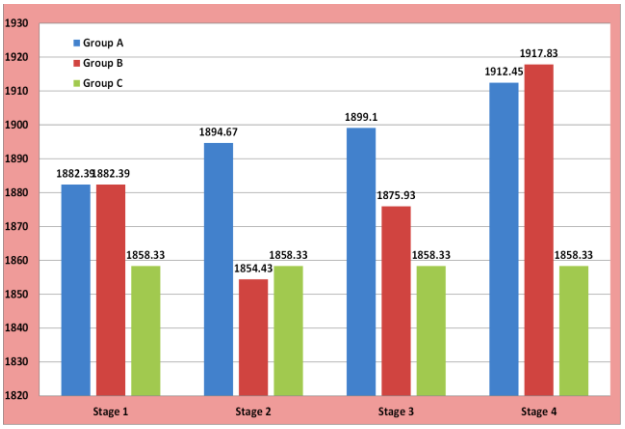


FIG 17 & 18 .COMPARISON OF MEAN VALUES OF *F1 AND F2* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /th/ MEDIAL(PATHU)

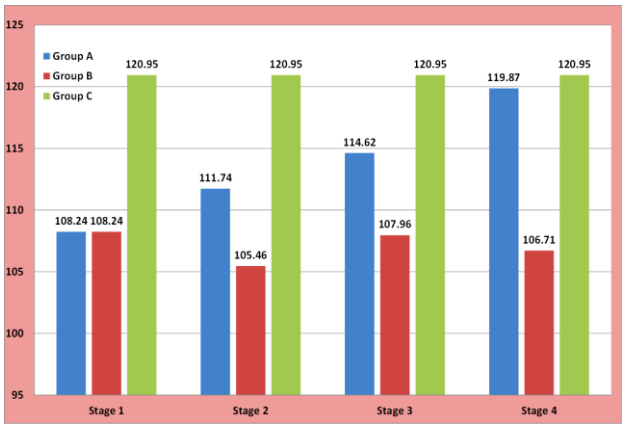
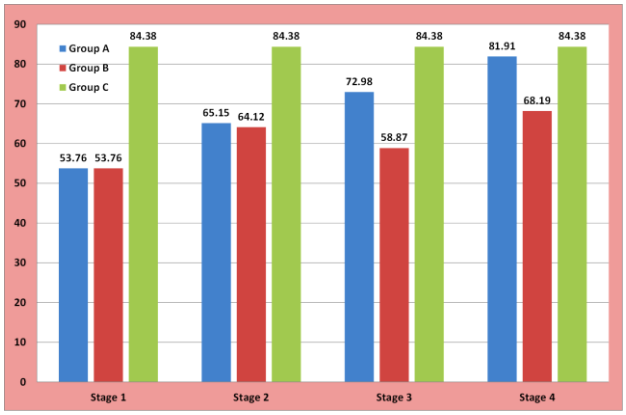


FIG 19 & 20 .COMPARISON OF MEAN VALUES OF *AD AND SP PK* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /ja/ INITIAL(JANNAL)



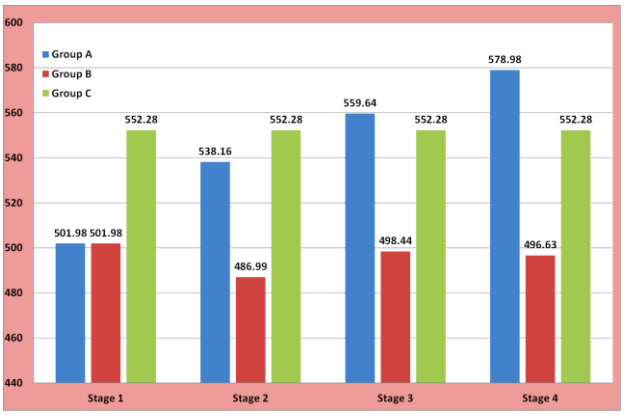


FIG 21 & 22.COMPARISON OF MEAN VALUES OF *VD AND F1* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /ja/ INITIAL (JANNAL)

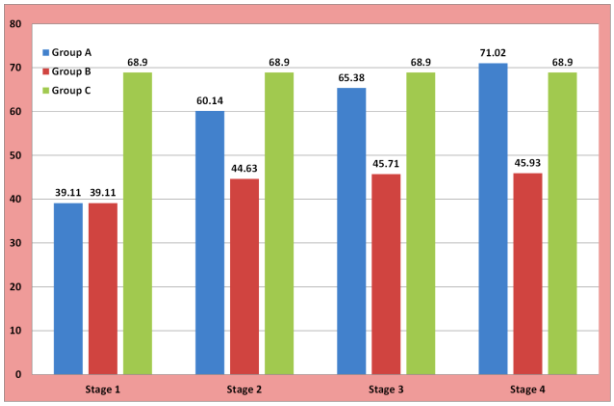


FIG 23 & 24 .COMPARISON OF MEAN VALUES OF F2 AND AD AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /ja/ IN INITIAL (JANNAL) & / ja/ IN MEDIAL (MANAJAL) RESPECTIVELY

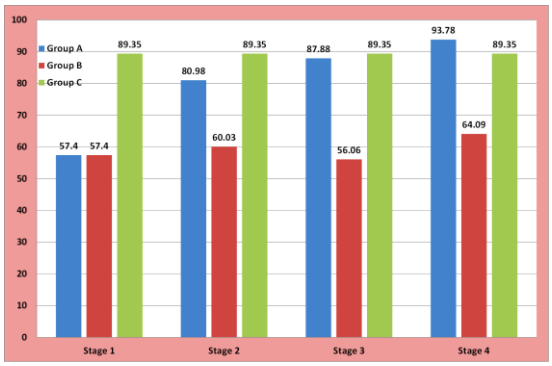


FIG 25 & 26. COMPARISON OF *MEAN VALUES OF SP PK AND VD* AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /ja/ IN MEDIAL (MANJAL)

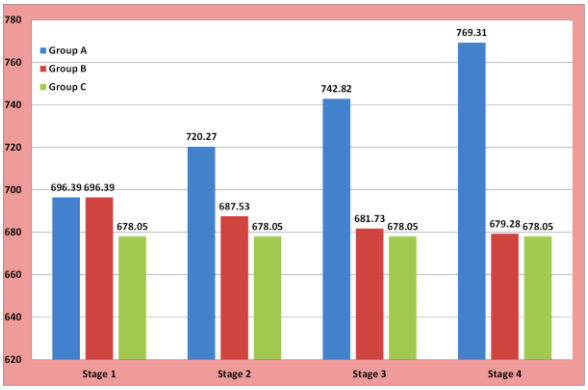


FIG 27 & 28.COMPARISON OF MEAN VALUES OF F1 AND F2 AMONG THE GROUP A, B & C AT VARIOUS STAGES FOR THE SOUND /ja/ IN MEDIAL (MANJAL)

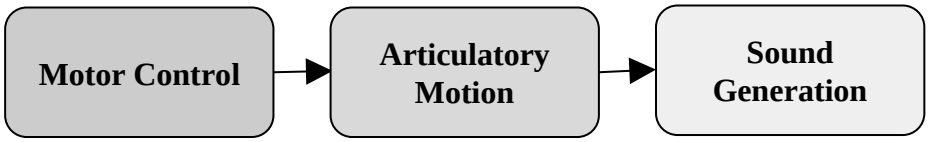
Speech generation in human beings is an exceptionally basic phenomenon which is knowledgeable about their everyday life and is additionally part of correspondence between them. Despite the fact that, speech production looks exceptionally straightforward from outside yet it's inside mechanism is extremely complex [58].

Individual can generate numerous assortments of sounds whose recurrence spectrum and also the loudness changes quickly. This is conceivable due to the sharp and exact articulatory activity control of the organs of speech generation mechanism. The articulatory activity control is performed by human brain via sensory nerve system interfacing brain to the speech generation organs, for example, lungs, vocal cords, jaw, tongue, teeth, lips, larynx and so on, it is named as Motor Control .

It is intriguing to understand quantitative and qualitative parts of the speech generation organs for

precise speech evaluation and synthesis through modeling.

The entire speech generation mechanism comprises of basically three functions which are displayed through the diagram [59].



HUMAN SPEECH GENERATION MECHANISM

Motor control function is guided by human brain which produces a considered of what to speak and in like manner it gives control signals via sensory nerves to the speech generation organs.

The speech generation organs move and take proper shape as indicated by the words to speak or sound to be delivered ,on accepting the control signals from the unit of motor control and this whole mechanism, named as Articulatory Motion. Sound generation is

the third function which comprises of the air that released from the nasal cavity and the mouth and is heaved in the open space as acoustic wave.

MOTOR CONTROL FUNCTION

The generation of speech begins with initiation of thought in the brain about what to talk. This thought initiation is transferred onto the human vocal apparatus via sensory nerves.

The entire process is named as control function and it is further partitioned into two sections,the motor commands generation and the language processing [60].

The auditory (Broca's area) gets input in the kind of visual gestures and listening via other sensory organs for language preparing, serving it to choose what to talk or what sound to deliver [61].

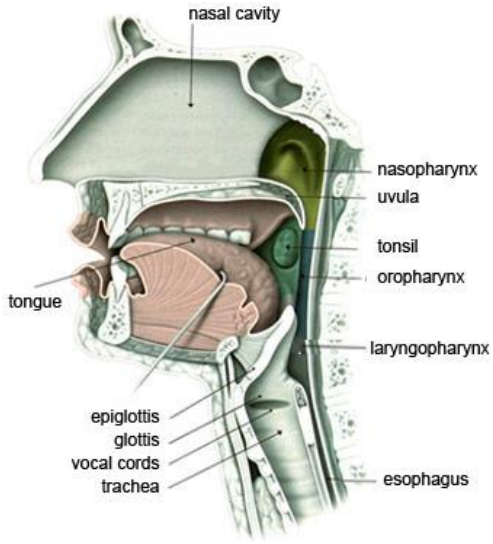
In like manner the motor control area (Wernicke‟s district) creates control signals for movement of the vocal tract apparatus and other speech generation organs, for example, lungs, vocal cords, jaw, glottis, lips, tongue, teeth, larynx and so forth.

ARTICULATORY MOTION

Different organs are involved in the creation of speech and sound by the individuals. These organs are adaptable in nature and their size and shape adjusts on the summon of motor control signals got from the brain, according to the sort of sound and speech to be created.

Speech can be described as waves of pneumatic stress made via air stream squeezed out of the lungs and coming out from the mouth and nasal cavities. The air goes through the vocal chords by means of the way from the lungs via vocal tract, vibrating them at diverse frequencies [62].

Different organs from which the air goes amid the procedure of generation of sound and speech are appeared in the Fig below,



"HUMAN VOCAL APPARATUS"

The Vocal tract: The air sections over the larynx are well known as the vocal tract. The tract can be partitioned into the nasal tract (inside the nose), and the oral tract (the pharynx and mouth). The upper cavities are known as the resonating cavities which includes pharynx, nose and mouth. The portions of the vocal tract that can be utilized to form the sounds are known as articulators. The last can be sub-partitioned into passive (which are immovable, e.g. hard palate) and active (which are mobile , e.g. tongue).

The Pharynx: It is conventionally partitioned into three sections: the nasopharynx, the oropharynx and the laryngopharynx.

The Glottis: Its essential function is to cover the entrance to the larynx amid swallowing, subsequently blocking food from entering the trachea. Because the epiglottis is attached with the base of the tongue, the entire can be stepped back and down in the direction of the wall of pharynx in the creation of unique sounds.

The Velum: Its primary function is to isolate the nasal cavity from the oral cavity. On the off chance that the velum is raised, it presses against the posterior wall of the pharynx, and keeps air from experiencing the nose.This is known as velic closure, and

happens in the generation of so called oral sounds. On the off chance that the velum is lowered,air goes through both the nose and mouth. In the event that a brought down velum is joined with an obstruction sooner or later in the oral cavity, the resultant sound is nasal. Sounds which are professed with concurrent oral and nasal articulation are said to be orinasal.

The Tongue: The tongue is the most movable articulator and can take up nearly limitless number of positions, both laterally and vertically. The tongue is the fundamental organ in the creation of vowel sounds. In the generation of vowels, the tongue tip for the most part stays low behind the lower teeth.

The Teeth and Lips: The teeth, especially the different anatomy of upper teeth are imperative for the production of numerous consonants. The lips–helps with the formation of both consonants and vowels.They can likewise be squeezed together they created bilabial sounds (e.g. /b/,/p/), or the lower lip can express with the upper teeth, bringing about labiodental sounds (e.g. /v/,/f/).

Larynx: Sound is produced in the larynx, and that is the organ where volume and pitch are manipulated. The expiration strength from the lungs additionally adds to loudness.Fine control of the larynx is utilized to create a source sound with a distinct fundamental frequency. This source sound is adjusted as it goes via the vocal tract arranged diversely based on the position of the lips,tongue, mouth & pharynx. The way toward changing a source sound as it goes via the filter of the vocal tract makes the a wide range of vowel and consonant and vowel sounds of the different languages and also tone.

The magnificence of the entire articulatory motion is that even in the wake of having such a large number of complexities it can respond quickly taking into account the quick changing speech parameters.

PHONEMES

For the most part individuals speak in language as per the district they are raised in. One needn't bother with exceptional training or knowledge to talk in their native language. Children figure out how to talk at an early age of one year by comprehension the sound and visual signs. The language signals of any language can be vocalized with the assistance of symbols called phonemes.All the words with various tones of any language can be pronounced utilizing least set of phonemes. Any language spoken on the planet have 20 to 60 phonemes[63,64].

Phonetics of any language comprises broadly two sorts of phonemes, the Vowels and the Consonants.

Vowels

Speech sounds generated by voiced stimulation of the open vocal tract are known as vowels. These are voiced sounds. In the generation of a vowel, the vocal tract typically keeps up a moderately stable shape and offers negligible obstacle to the airflow.

Acoustically vowels are described by spectrum, fundamental frequency, duration, and formant pattern.

Vowel Duration: It can be categorized as overlong, long and short. The elements that impact vowel span are: vowel height, tense-lax (long-short) component of the vowel, syllable stress, talking rate, voicing of a previous or taking after verbalization of going before or taking after consonant, and different semantic or syntactic variables, for example, utterance position or word recognition.

Formants: Among the sound of human voice, formants are especially critical in light of the fact that they are fundamental components in the coherence of speech. The frequencies of the vocal formants determined by the process of articulation. Sundberg has recognized bits of the vocal anatomy which he relates with the formant frequencies.

The main variable for the primary formant (F1) is the jaw opening, which expands the vocal tract toward the lip end and contracts it toward the glottal end. As the jaw is opened more extensive,this formant frequency rises. The second formant (F2) is most delicate to the form of the tongue and changes chiefly with tongue position, and the third formant (F3) is most delicate to the tip of the tongue.

It shows up, then, that to recognize a vowel and even to set up relationships amongst perceptual and acoustic parameters, a vowel formant pattern can be utilized.

Consonants

Speech sound that is articulated with fractional or complete closure of the vocal tract. These are articulated speech sounds. Vowels are contrasting with consonants.

They can be categorized based on: Place of articulation, Manner of articulation, and Voicing.

Place of articulation basically implies the passive and active articulators involved in the creation of a specific consonant. A place of verbalization is a state of contact for delivering a speech sound. It is the vocal arrangement vital for the generation of sounds.Examples: Bilabial, Labiodental, Linguo-Palatal etc.

Manner of articulation is the kind of closure and the level of the impediment of the air stream by the articulators. It depicts in the matter of how the lips,tongue, jaw, and other speech organs are included in making contact. Examples : Nasal, Plosives, Fricatives and Affricatives etc.

Voiced sounds: Speech sounds produced with a periodical glottal source are named voiced. The larynx muscles frame the vocal bands and when these muscles vibrate, they produce voicing.

Unvoiced sounds: For this state, there is no vibration at vocal fold. In this state, nonetheless, the folds are nearer together and more stretched than in the breathing state, hence permitting for turbulence to be produced at the folds themselves.

Speech sounds related to the present study is reviewed underneath in detail :

Linguo –Palatal Sounds:

Group of sounds wherein the tongue is the active articulator and the palate being static articulators.These sounds (like. S, t, z, d, l and v) are generated when the valve created by contact of the tongue tip with the most foremost portion of the palate or the lingual sides of the front teeth. Sibilants like s, sh, ch, z and j (with j and ch being affricatives) are the alveolar sounds, on the grounds that the tongue and alveolus frames the controlling valve. The sounds /d/ and /t/ are primarily stop (plosive) consonants, where /d/ is a voiced and /t/ is unvoiced sound.

Voice onset time –VOT gives data with respect to duration between articulatory release of stop and the onset of vocal fold vibration. It is a assessment of time among supraglottal event and, the onset of voicing. The VOT was evaluated for the sound : /d/ in the initial position “dappa”.

Closure duration- In the generation of a word-medial stop consonant, closure duration is the time distinction among the onset of the closure of articulator and the articulatory discharge. The closure duration was evaluated for the sound : /d/ in the medial position “veedu”.

Frication duration – The turbulent airflow is called Frication which is generated by forcing air via a constricted channel formed by placing two articulators close to each other. The duration of the fricative were evaluated for the sounds: /th/ in initial “thatha” and /th/ in medial position “pathu”.

Affrication duration- It is a consonant that starts as a stop & releases as a fricative, usually with the similar place of articulation. The affrication duration were evaluated for the sounds:

/ja/ in initial "jannal" and /ja/ in medial "manjal".

Spectral Peak energy – The highest peak energy for the affricates and fricatives. Spectral Peak energy were evaluated for the sounds: /th/ in initial "thatha" and /th/ in medial position "pathu", /ja/ in initial "jannal" and /ja/ in medial "manjal".

Vowel Duration- It is the time distinction among the onset and offset of vowel. Vowel duration were evaluated for all the sounds and the groups.

Formant frequencies- Formant frequencies relies on the place of articulation of tongue with the palate. As the place moves forwards, frequency shows increases. F1 formant frequency associated to supero-inferior placement of tongue, F1 differs inversely with the height of tongue. F2 formant frequency for the vowels associated to tongue advancement, it increases as tongue moves forwards. The formant frequencies were evaluated for all the sounds.

Speech has dependably been the most remarkable medium for the transmission of thoughts and during the time it has been one of the foremost strengths for the human advance. As mentioned earlier, various organs takes part in the generation of speech are the components of the oral cavity and any modification of the structures in that will unfavorably influence speech. Hence, being a prosthodontist we should be careful while replacing the lost structures like teeth, we usually add extra to the palatal region that have no structural losses. As palatal region is the most critical area for the verbalization of speech by adding extra or by giving smooth polished surface instead of duplicating the

natural anatomy i.e palatal rugae to this area, speech sounds shows alterations predominantly the linguo-palatal sounds.

The significance of duplicating the rugae on the denture base has dependably been a point discuss from decades. Some recommend that the rugae duplication would simply add on to the bulk of the denture palatal surface, which would be inconvenient for phonation like studies done by **LG Jordan (1954)**,**Rothman R (1961)**[18] quoted a study done by **Boghosian and Spangenberg**, **George Chierici and Lucie Lawson (1973)**[22] they quoted a done study by Landa study, while different authors have perceived the significance of palatal form of the denture for improved phonation like studies done by **Dirkson LC (1954)**[12], **FW Shaffer, RA Kutz (1972)**[20], **John. M.Palmer (1979)**[27], **Christina A. Gitto et al (1999)**[38].

Since, speaking science is a behavioral study, evaluation of speech quality is vital alongside the quantitative investigation. In this manner this study has been intended to assess the different changes happening in linguo-palatal sounds amid the adjusted condition of the oral cavity, which is amid the edentulousness, to the accommodative time of one month post insertion of denture . Consequently, to assess the progressions in quantitative part of speech from the edentulous stage to restoration with denture over a timeframe. Also compare the phonetics of completely dentulous subjects with the subjects restored with and without denture. Furthermore, to correlate the articulation of linguo-palatal sounds of customized palatine rugae duplicated on upper complete denture with conventional upper complete denture up to a duration of 4 weeks after denture insertion.

A total of 12 subjects, who were completely edentulous from past min. 1 to 3 months and were new/first time complete denture wearers were selected. In the age range of 45-60 years and were native speakers of Tamil language with no neurological and no hearing deficits.

Another, 6 subjects, with natural complete dentition were selected randomly for control group.In the age range of 45-60 years and were native speakers of Tamil language with no neurological and no hearing deficits.

The subjects were divided into 2 groups: Control and Study group. Study group was further divided into Group A and Group B. **Control group:** 6 subjects, with natural complete dentition. **Study group:** 12 subjects, who were completely edentulous.

Group A: were rehabilitated with conventional complete dentures with the palatine rugae duplicated on maxillary dentures.**Group B:** were rehabilitated with duplicated complete dentures without the palatine rugae duplicated on maxillary dentures.

Tamil Articulation Test [(USHA.D (1986)] was regulated to each subject (control and study group) and recorded. 3 Linguo-palatal phonemes in Tamil [d (), th (), ja (),] were selected for this study. The target phonemes were recognized in the medial and initial position of words like for /d/: dappa, veedu; /th/: thatha, paththu; /ja/: jannal, manjal which are part of Tamil Articulation Test and were evaluated **Acoustically** by Speech Pathologists. The recordings were executed in a soundproof room. For the control group recordings were done only once but for study groups (Group A and B) recordings were done under the accompanying stages-Edentulous stage – **STAGE 1,** Immediately after post insertion - **STAGE 2,** 10 days after denture insertion - **STAGE 3**, 4 weeks after denture insertion - **STAGE 4**

At each stage from stage 1 to 4, recordings were done of 6 words with 2 trials and this was administered to acoustic analysis.

As **A.J.Hassel et al** stated that speech problems are commonly noticed after complete denture insertion fundamentally communicated as issues with consonants, particularly linguo palatal sounds[47]. Therefore, in the present study, linguo palatal sounds were evaluated .

As per **Sinescu et al.**, a few sounds, for example, /d/s/t/sh/ and /z/ are more sensible and more frequently compromised because of the alterations of oral structures and in view of the interest for additional precise verbalization movements. Hence, these sounds were considered in this study[65].

S. Inukai et al stated that, in relation to a prosthetic treatment, the patient psychological behavior can likewise influence the speech patterns. Patients, who mentally acknowledged their dentures, not long after they began wearing them, additionally had less speech problems than the individuals who did not acknowledge the dentures and concluded that normally it takes 2-4 weeks for speech adaptation to new dentures post insertion[49] and **A.Petrovik (1985)** concluded that patient's adaptation to the dentures was accomplished during first 30 days post denture insertion Therefore, in this study adaptation period was used for 4 weeks. He also stated speech distortion changed with the palatal plate thickness of the denture and increased immediately after 1mm of thickness[32]. Hence, in this study thickness of the dentures maintained 1mm for all the groups.

As per **J.M.Palmer**[27], denture factors like occlusal plane, tooth position, vertical dimension and thickness of denture base must be considered first. And according to **Hyung-Jun Kong et al**, exact estimation of palatal forms of a maxillary denture to a patient's tongue can enhance speech clarity, if different variables, for example, occlusal

plane, position of tooth, and vertical dimension are up to standard [9]. Hence, in this study duplication of denture was done to preserve the same.

The outcomes were classified and subjected to proper statistical test for correlation between the control group with the study groups:

At stage 1, Subjects without the dentures in group A and B shows statistically significant decrease in almost all the spectral and temporal parameters as compared to control group. This could be due to the absence of teeth, which affected the tongue position during articulation. Except in sound /d/ at medial position where F1 and F2 were not decreased and F2 in /ja/ initial position. This could be due to the fact that /d/ is voiced sound, so there will be vocal constriction and overall tract area also decreased, therefore no significant alteration noted for /d/ sound. This result coincide with the result observed by the **H Ghi and G P McGivney** they concluded that patients without the prosthesis, the time duration to pronounce /s/ sound was increased and the accuracy for speech movement for the /s/ sound production was being affected by the presence of tooth proprioception [26].

At stage 2, Immediately after denture insertion mostly all the parameters shows improvement from stage 1, specially with the group A as compared to group B but compared to group C both A & B shows statistically significant decrease. This result coincide with the result observed by the **H Tanaka (1973)**[21], he analysed the relationship between palatal contour and speech production through study of changes in speech pattern before and after the denture insertion in various stages, conclusions drawn were: Speech intelligibility improved with denture insertion, the improvement in intelligibility was directly associated to duration for which denture used. This observation disagrees with the result obtained from **Hamlet, Geoffrey and Bartlett (1976)**, they determined

that the intelligibility of speech was significantly decreased by prosthesis wearing, especially before the subject had time to adapt to the new condition[25].

The closure duration of the sound /d/ at medial position shows significant decrease in group B with group A. Group A was more closure to control group, this might be because of the presence of rugae, which helped in superior articulation. The spectral peak energy for bath the group A & B shows statistically significant decrease as compared to group C, this might be due to insufficient constriction for production of adequate energy after denture insertion.

F1 at this stage shows no statistically significant difference among all the groups. This might be due to alteration in the size of oral cavity after denture insertion and resulted in increase in formants.

Voice onset time for Group B decreased when compared to group A and C, it depends on the co-ordination among the release and onset of voicing, which shows improvement with group A as compared to group B.

Immediately after insertion, both Group A and B when compared with the group C, most of the parameters of group A were near to the group C. So, the results shows improvement with rugae incorporated denture as compared to conventional denture.

At stage 3, Vowel Duration, Frication duration and Spectral peak energy of Group A showed significant improvement from the Group B and was more closer to the Control group. This shows that Group B with smooth polished base of denture requires additional efforts for proper speech articulation as compared to rugae incorporated denture this could be due to lack of resistance for the tongue during speech articulation. This signify that for precise articulation, the duplication of rugae contributed as compared to the finely polished surface. This result coincide with the result observed by the **FW**

Shaffer, RA Kutz[20] suggested that the palatal rugae could be reproduced physiologically would aid in enhancing the speech of the patient. **John. M.Palmer (1979)** tactile function of the tongue and speech can be enhanced by replicated rugae and an incisive papilla[27].

Even after the duration of 10 days, most of the parameters of group B and few of group A shows statistical significance with group C, coincides with the study of **S. Inukai et al**[49] and **A.Petrovik (1985)**[32] concluded that patient's adaptation to the dentures was accomplished during first 30 days post denture insertion.

To summarize, denture with replicated palatal rugae shows less adaptation duration to the new dentures as compared to the conventional dentures.

At stage 4, few parameters of group B still shows significance with the group A and C, like spectral peak energy, frication and affrication duration.

Even though all the parameters of group A and B were improved towards group C, but denture with replicated palatal rugae showed a static advancement as compared to conventional dentures without rugae duplication.

The results of this study disagrees with the results concluded from the studies conducted by, **LG Jordan (1954)** noticed that prominent artificial rugae on the tongue surface of upper dentures is often detrimental than beneficial, especially to phonetics[11], and **Rothman R (1961)** reviewed mechanism of speech production in general and mechanics of the production of sound units of dental concern in particular, they quoted a study done by **Boghosian and Spangenberg** suggested rugae should not be replicated on dentures, in order to make the anterior portion of the upper denture base as thin as possible[18], and **George Chierici and Lucie Lawson (1973)** they quoted Landa study who had reported that rugae replication will unnecessarily increase the bulk of the

denture base which has negative effects on speech[22]. **L. B. Allen (1959)**[66] cocluded that the most generally utilized technique to enhance denture phonetics is the arbitrary thinning of the whole maxillary palatal surface to make extra space for the tongue.

The results from this study coincide with the studies done by **Dirkson LC (1954)** suggested to that nearness of rugae on denture base would give an about tissue-like surface, opposite to which the tongue would work in a more regular way amid speech[12]. **FW Shaffer, RA Kutz (1972)**[20] suggested that the palatal rugae could be reproduced physiologically and the so developed form of the palate by using the soft wax would aid in enhancing the speech of the patient. **John. M.Palmer (1979)**[27] quoted a study of Bloomer et al who have proposed nearly exact duplication of the natural contours into the denture base, and have supported the replication of the rugae, but this was not verified.He concluded that tactile function of the tongue and speech can be enhanced by replicated rugae and an incisive papilla. **Christina A. Gitto et al (1999)** proposed that incorporating rugae in a newly constructed and existing complete denturecould be a tool for the remedy of speech problems encountered by the patient's[38]. **Raghavendra Adaki et al (2013)**[3] stated that pronunciation of ‘t’,‘s’, ‘sh’, ‘d’ was less clearer with conventional denture than the rugae incorporated denture.**Hala M. Abdel Hamid et al (2014)** they concluded that the palatine rugae plays a significant role in speech pronunciation, in the presence of few anatomical landmarks where tongue can identify and produce best particular sound [53]. **Hamada Zaki Mahross and Kusai Baroudi (2015)**[55] they have concluded that it is advocated to reproduce the rugae area in dentures because the phonetic quality of conventional denture was inferior to the complete denture with reproduced rugae.

Speech has dependably been the most remarkable medium for the transmission of thoughts and during the time it has been one of the foremost strengths for the human advance. As mentioned earlier, various organs takes part in the generation of speech are the components of the oral cavity and any modification of the structures in that will unfavorably influence speech. The speaking sounds are delivered from the contact of tongue with the teeth and palate. These contact regions are either supplanted or secured by complete denture. Inability to form the palatal contours to suit ordinary tongue contact as a rule brings about poor speech. Therefore, for the success or coming to nothing of dental rehabilitation, speech production quality is a vital criterion.

In this manner this study has been intended to assess the different changes happening in linguo-palatal sounds amid the adjusted condition of the oral cavity, which is amid the edentulousness, to the accommodative time of one month post insertion of denture. Primarily, to assess and correlate the speech pronunciation (linguo-palatal sounds) of subjects with customized palatine rugae duplicated on upper complete denture and subjects with conventional upper complete denture and subjects with the natural dentition upto a duration of 4 weeks after denture insertion.

A total of 12 subjects, who were completely edentulous from past min. 1 to 3 months and were new/first time complete denture wearers were selected. In the age range of 45-60 years and were native speakers of Tamil language with no neurological and no hearing deficits.

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At each stage from stage 1 to 4, recordings were done of 6 words with 2 trials and this was administered to acoustic analysis.

The outcomes were classified and subjected to proper statistical test for correlation between the control group with the study groups:

At stage 1, subjects without the dentures shows statistically significant decrease in almost all the spectral and temporal parameters as compared to control group. This could be due to the absence of teeth, which affected the tongue position during articulation.

At stage 2, Immediately after denture insertion mostly all the parameters shows improvement from stage 1, specially with the group A as compared to group B but

compared to group C both A & B shows statistically significant decrease. So, the results shows improvement with rugae incorporated denture as compared to conventional denture.

At stage 3, Vowel Duration, Frication duration and Spectral peak energy of Group A showed significant improvement from the Group B and was more closer to the Control group. This shows that Group B with smooth polished base of denture requires additional efforts for proper speech articulation as compared to rugae incorporated denture this could be due to lack of resistance for the tongue during speech articulation. To summarize, denture with replicated palatal rugae shows less adaptation duration to the new dentures as compared to the conventional dentures.

At stage 4, few parameters of group B still shows significance with the group A and C, like spectral peak energy, frication and affrication duration.

Even though all the parameters of group A and B were improved towards group C, but denture with replicated palatal rugae showed a static advancement as compared to conventional dentures without rugae duplication.

This study was primarily directed to assess the effect of rugae on speech articulation. Evaluation was done by acoustic analysis and within the limitations of this study, some of the conclusion were drawn:

- Without the dentures, almost all the spectral and temporal parameters as compared to control group showed statistically significant decrease except for the voiced sound.
- Immediately after denture insertion mostly all the parameters shows improvement from edentulousness, specially with the rugae replicated dentures as compared conventional dentures but compared to group C both showed statistically significant decrease.

- The closure duration of the sound /d/ showed significant decrease with conventional dentures as compared to rugae replicated dentures. This might be because of the presence of rugae, which helped in superior articulation.
- Hence it can be concluded that adaptation with the new dentures immediately after insertion, was superior with the rugae replicated dentures as compared conventional dentures.
- After 10 days, Vowel Duration, Frication duration and Spectral peak energy of rugae replicated dentures showed significant improvement from the conventional dentures and was more closer to the Control group. It can be concluded that for precise articulation, the replication of rugae contributed as compared to the finely polished surface, which requires additional efforts for proper speech articulation.
- Even though, with duration all the parameters of both the dentures were improved towards group C, but denture with replicated palatal rugae showed a static advancement as compared to conventional dentures without rugae duplication.
- Limitation of this study was small number of subjects and less number of phonemes.

Henceforth, the conclusion drawn from this study is advocated to reproduce the rugae area in dentures because the phonetic quality of conventional denture was inferior to the complete denture with replicated rugae.

Exceptional consideration should be given to the anterior palatal region during denture fabrication. With little modification in this region, which requires insignificant measure of time, gives the better outcomes with respect to pronunciation, in this manner improving patient's certainty. By including this in our daily practice, we can do better justice to the patient’s.

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Ref No: R. C. NO: 0420/DE/2016
Sub: IEC review of the research proposals,

date : 29-03-2016

Title of the work: Evaluation of speech and effect of customization of palatal rugae in complete denture rehabilitation.

Principal Investigator: Dr.Vinay Bharti
II year , MDS

Department : Department of Prosthodontics
Tamil Nadu Govt. Dental College & Hospital , Chennai-3

Thank you for submitting your research proposal , which was considered at the Institutional Ethics Committee meeting held on the 03.03 2016, at TN Govt. Dental College and the documents related to the study referred above were discussed and the modifications done as suggested and reported to us through your letter dated 28-03-2016 have been reviewed.

The decision of the members of the committee , the secretary and the Chairperson IEC of TN Govt. Dental College is here under:

Approved	Approved and advised to proceed with the study
Approved with suggestions	----------
Revision	----------
Rejected	----------

The principal investigators and their team are advised to adhere to the guide lines given below:

1. You should get detailed informed consent from the patients / participants and maintain confidentiality.
2. You should carry out the work without affecting regular work and without extra expenditure to the Institution or the Government.
3. You should inform the IEC, in case of any change of study procedure, site, and investigating guide.
4. You should not deviate from the area of work for which you have applied for ethical clearance.
5. You should inform the IEC immediately in case of any adverse events or serious adverse reactions. You should abide to the rules and regulations of the institution(s) .
6. You should complete the work within specific period and if any extension of time is required, you should apply for permission again to do the work.
7. You should submit the summary of the work to the ethical committee every 3 months and on completion of the work.
8. You should not claim any kind of funds from the institution for doing the work or on completion/ or for any kind of compensations.
9. The members of the IEC have the right to monitor the work without prior intimation.
10. Your work should be carried out under the direct supervision of the guide/ Professor.

MEMBER SECRETARY,
INSTITUTIONAL ETHICS COMMITTEE
Tamil Nadu Govt. Dental College & Hospital
Chennai

CHAIRPERSON
INSTITUTIONAL ETHICS COMMITTEE
Tamil Nadu Govt. Dental College & Hospital
Chennai

PARTICIPANT INFORMATION SHEET

- We are conducting a study on **"EVALUATION OF SPEECH AND EFFECT OF CUSTOMIZATION OF PALATAL RUGAE IN COMPLETE DENTURE REHABILITATION"** among patients attending TNGDC&H and for this study, we are selecting patients.

- The identity of the patients participating in the research will be kept confidential throughout the study. In the event of any publication or presentation resulting from the research, no personally identifiable information will be shared.

- Taking part in the study is voluntary. You are free to decide whether to participate in the study or to withdraw at any time. Your decision will not result in any loss of benefits to which you are otherwise entitled.

....

Name of the patient Signature / Thumb impression

....

Name of the investigator Signature Date

ஆராய்ச்சி பற்றிய தகவல் படிவம்

ஆராய்ச்சி மேற்கொள்பவர் பெயர்	:	**மருத்துவர்.வினய் பார்தி**
வழிநடத்துபவர்	:	**மருத்துவர்.அ.மீனாட்சி, M.D.S.**
ஆராய்சி நிறுவனத்தின் பெயர்	:	**தமிழ்நாடு அரசு பல் மருத்துவக் கல்லூரி மற்றும் மருத்துவமனை, சென்னை.**

ஆராய்ச்சியின் தலைப்பு :

மேல் அன்னத்தின் மடிப்புகளை தனிப்பட்ட நபருக்கு ஏற்றவாறு, முழு செயற்கை பல் செட்டில் பொருத்துவதன் மூலம் ஏற்படும் விளைவுகளையும் மற்றும் அந்த சிகிச்சைக்கு முன்னும் பின்னும் நோயாளிகளின் பேச்சுத்திறனையும் மதிப்பிடுதல்-ஒரு ஆய்வு.

ஆராய்ச்சியின் நோக்கம்:

தனிப்பட்ட நோயாளிகளுக்கு ஏற்பவாறு உள்ள மேல் அன்னத்தின் மடிப்புகளை முழு செயற்கை பல் செட்டில் பொருத்துவதனால் ஏற்படும் விளைவுகளையும் மற்றும் அந்த சிக்சை முன்னும் பின்னும் நோயாளிகளின் பேச்சுத்திறனையும் கண்டறிதல்.

இரகசிய காப்பு

நோயாளி பற்றிய குறிப்புகள் பிறர் அறியா வண்ணம் ஆராய்ச்சி முடியும் வரை இரகசியமாக பாதுகாக்கப்படும். அதை வெளியிடும் நேரத்தில் எந்த நோயாளிகளின் தனி அடையாளங்களும் வெளியிட வாய்ப்பு கிடையாது.

தன்னார் பங்கேற்பு

இந்த ஆராய்ச்சியில் பங்கு பெறுவது நோயாளியின் தனிப்பட்ட முடிவு மற்றும் நோயாளிகள் இந்த ஆராய்ச்சியில் இருந்து எப்பொழுது வேண்டுமானாலும் விலகிக் கொள்ளலாம். நோயாளிகள் இந்த முடிவு அவருக்கோ அல்லது ஆராய்ச்சியாளருக்கோ எந்தவித பாதிப்பும் ஏற்படாது என்பதை தெரியப்படுத்துகிறோம்.

இந்த ஆராய்ச்சியின் முடிவுகள் நோயாளிகளுக்கு ஆராய்ச்சி முடியும் தருவாயிலோ அல்லது இடையிலோ தெரிவிக்கப்படும். ஆராய்ச்சியின் பொழுது ஏதும் பின்விளைவுகள் ஏற்பட்டால் அதை சரிசெய்ய தகுந்த உதவிகள் அல்லது தேவையான கிசிச்சைகள் உடினடியாக மேற்கொள்ளப்படும்.

<u>பங்கேற்பதினால் விளையும் நன்மைகள்</u>

நோயாளிகளுக்கு இத்தகைய செயற்கை பல் செட்டு பொருத்தி புணர்வாழ்வு பெறுவதற்கான சிகிச்சை அளிக்கப்படும்.

நோயாளியின் பெயர் **கையொப்பம்/கைரேகை**

<u>ஆராய்ச்சி தொடர்புடைய தகவல்களுக்கு</u>
மரு.வினய் பார்தி,
முதுநிலை மாணவர், செயற்கை பல் கட்டும் துறை,
தமிழ்நாடு அரசு பல் மருத்துவக்கல்லூரி மற்றும் மருத்துவமனை,
சென்னை-600 003.

INFORMED CONSENT FORM

_____"EVALUATION OF SPEECH AND EFFECT OF CUSTOMIZATION OF PALATAL RUGAE IN COMPLETE DENTURE REHABILITATION".

Participant ID No:

"I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions I have asked have been answered to my satisfaction. I consent voluntarily to participate as a participant in this study and understand that I have the right to withdraw from the study at any time without in any way it affecting my further medical care."

.....	.....	.....
Date	Name of the Participant	Signature/thumb impression of the participant

[The literate witness selected by the participant must sign the informed consent form. The witness should not have any relationship with the research team; If the participant doesn't want to disclose his/her participation details to others, in view of respecting the wishes of the participant, he / she can be allowed to waive from the witness procedure (This is applicable to literate participant ONLY). This should be documented by the study study staff by getting signature from the prospective participant]

.....

.....

"I have witnessed the accurate reading of the consent form to the potential participant and the individual has had opportunity to ask questions. I confirm that the individual has given consent freely".

.....	.....	.....
Date	Name of the Witness	Signature of the Witness

.....	.....	.....
Date	Name of the Witness	Signature of the Witness

ஆராய்ச்சி ஒப்புதல் படிவம்

ஆராய்ச்சி தலைப்பு	:	மேல் அண்ணத்தின் மடிப்புகளை தனிப்பட்ட நபருக்கு ஏற்றவாறு முழு செயற்கை பல் செட்டில் பொருத்துவதன் மூலம் ஏற்படும் விளைவுகளையும் மற்றும் அந்த சிகிச்சைக்கு முன்னும் பின்னும் நோயாளிகளின் பேச்சுத்திறனையும் மதிப்பிடுதல்-ஒரு ஆய்வு.
ஆய்வாளரின் பெயர்	:	மரு.வினய் பார்தி
வழிகாட்டி பெயர்	:	மரு.அ.மீனாட்சி, M.D.S.,
மருத்துவமனை பெயர்	:	தமிழ்நாடு அரசு பல் மருத்துவக்கல்லூரி மற்றும் மருத்துவமனை

பெயர் : புறநோயாளி எண் :

வயது/பால் : ஆராய்ச்சி சேர்க்கை எண் :

முகவரி :

தொலைபேசி :

நான் .....வயது.....என்னுடைய சுயநினைவுடன் மற்றும் முழு சம்மதத்துடனும் இந்த மருத்துவ ஆராய்ச்சியில் சேர்ந்து கொள்ள ஒப்புதல் அளிக்கிறேன் இந்த ஆராய்ச்சியின் நோக்கமும் அதன் சிகிச்சை முறைகளும் எனக்கு திருப்தி அளிக்கும் வகையில் அறிவுறுத்தப்பட்டது.

இந்த பரிசோதனைக்காக எனது பேச்சுத்திறனை மதிப்பிடுவதற்கான ஒரு கருவி பயன்படுத்தப்படும் என்பதை அறிகிறேன்.

என் உடல் நலம் பாதிக்கப்பட்டாலோ அல்லது எதிர்பாரத வழக்கத்திற்கு மாறான நோய் குறிகள் தென்பட்டாலோ உடனடியாக என் மருத்துவருக்கு தெரிவிக்க ஒப்புகொள்கிறேன்.

என் மருத்துவ குறிப்பேடுகளை இந்த ஆராய்ச்சியில் பயன்படுத்த சம்மதிக்கிறேன். இந்த ஆராய்ச்சி மையமும், ஆராய்ச்சியாளரும் என் அடையாளத்தை ரகசியமாக வைத்திருப்பதாக அறிகிறேன்.

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நோயாளியின் பெயர்	கையொப்பம்	தேதி
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ஆராய்ச்சியாளரி பெயர்	கையொப்பம்	தேதி