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AUTOLOGOUS FAT GRAFTING FOR MILD TO MODERATE VELOPHARYNGEAL INSUFFICIENCY: Our Experience

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DECLARATION

I, Doctor Elizabeth Alexia Xoagus, hereby declare that the work, on which this thesis/dissertation is based, is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree to this university or any other university. I empower the university to reproduce either for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signed by candidate

17/2/2018

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To my beloved husband Manti Makakole, thank you very much for the love, support, faith and dedication you have shown me through all these years. I appreciate all that you have done to make this easy and possible for me.

To my beloved daughter Sheila, thank you for the love and understanding you have shown during my studies.

To my mother and family, thank you for everything you have done for me.

To my supervisors, Professor Donald Hudson and Doctor Saleigh Adams, thank you for your support and assistance.

Above all, I thank God for His faithfulness. To Him be the glory.

CONTENTS OF DISSERTATION

PART 1: a) INTRODUCTION

AUTOLOGOUS FAT GRAFTING FOR THE TREATMENT OF MILD TO MODERATE VELOPHARYNGEAL INSUFFICIENCY

The traditional surgical treatment of refractory velopharyngeal insufficiency (VPI) includes revision palatoplasty, posterior pharyngeal flap surgery and sphincter pharyngoplasty.[2] These procedures are not without complications the worst being iatrogenic obstructive sleep apnoea,[2] and can also be challenging to the occasional cleft surgeon.

With the introduction of posterior pharyngeal wall augmentation, a lesser and simpler surgical procedure, various materials have been used for this purpose with limited success and variable complication rates. Augmentation of the velo-pharynx with autologous fat has been practiced for decades at some centres.[4] Autologous fat has multiple advantages compared to the other biological and synthetic materials used for augmentation of the velopharynx. Autologous fat is readily available, has low donor site morbidity, does not migrate, injects easily and is non-allergenic. The outcome of fat grafting for VPI is good and stable long term, albeit unpredictable due to the resorption of fat. Treatment of VPI with fat grafting may therefore require repeat procedures in order to achieve the desired results.

The aim of this study is to evaluate and document the outcome of autologous fat grating for the treatment of mild to moderate VPI in children at the Red Cross War Memorial Children's Hospital (RCWMCH). All the patients who underwent autologous fat grafting since its inception as a treatment modality for VPI at our unit were included in the study. A retrospective folder review of these patients was performed to extract the necessary data for the study.

The purpose of the study was:

- To assess and document the first reported third world experience with autologous fat grafting as a treatment modality for VPI.
- To compare our results, technique and complications with the first world centres.
- To ascertain wether autologous fat grafting should be an alternative first line treatment for mild and moderate VPI?
- To ascertain wether autologous fat grafting should be an adjunct to the standard first line treatment procedures for VPI?
- To ascertain wether autologous fat grafting should be a standard second line treatment modality for failed first line mild and moderate VPI treatment procedures?
- To classify velopharyngeal insufficiency.
- To suggest a treatment plan for VPI based on the degree of VPI.

PART 1: b) PROTOCOL

AUTOLOGOUS FAT GRAFTING FOR THE TREATMENT OF MILD TO MODERATE VELOPHARYNGEAL INSUFFICIENCY: Our experience

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a) INTRODUCTION

A cleft palate is one of the most common congenital craniofacial abnormalities. It significantly affects the craniofacial morphology, cosmesis and function particularly speech. Therefore, the primary goal of cleft palate surgery is to restore normal speech. Velopharyngeal insufficiency is a common finding following cleft palate repair. A significant number of patients require secondary surgery to treat VPI unresponsive to speech therapy.

b) BACKGROUND

The velopharyngeal sphincter or port is created by the soft palate (velum) anteriorly, the lateral pharyngeal walls, and the posterior pharyngeal wall. [5]

Normal velopharyngeal function involves composite movement of the palate postero-superiorly, the posterior pharyngeal wall anteriorly, and the lateral pharyngeal walls medially in order to close the port. Closure of the port separates the oral and nasal cavities which is important for normal speech and swallowing. The sphincter should remain open for normal breathing and for the production of nasal consonants (/m, /n/, and /ng/). Complete closure of the sphincter on the other hand is required for the production of oral pressure consonants for example, /p/, /b/, /t/, /d/, /k/, /g/, /s/, /z/, /f/, and /v/. In addition, closure is required for sucking, swallowing, and blowing.[2]

Velopharyngeal dysfunction (VPD) is a general term describing any abnormal function of the velopharygeal sphincter. The are three different subtypes of velopharyngeal dysfunction, these are:

· Velopharyngeal insufficiency (VPI) is VPD caused by any structural abnormality at the level of the palate(velum) or pharyngeal wall.

· Velopharyngeal incompetence is caused by impaired neuromotor control of the palate or pharyngeal wall.

· Velopharyngeal mislearning is VPD not caused by structural or neuromotor abnormalities.

The causes of velopharyngeal dysfunction are:[1]

Velopharyngeal Insufficiency (VPI) (insufficient tissue or mechanical restriction)	**Velopharyngeal Incompetence** (lack of neuromotor competency)	**Velopharyngeal Mislearning** (maladaptive articulatory habits)
Unrepaired cleft palate	Dysarthria (myotonia)	Compensatory misarticulation
Post-cleft palate repair	Apraxia	Phoneme-specific nasal air emission
Palato-pharyngeal disproportion (such as chromosome 22q11 deletion syndrome)		Persistent post-op nasal air emission with no VPI
Mechanical interference (tonsils, webbing, stricture)		Hearing impairment

Velopharyngeal function is evaluated by subjective and objective means which include transoral examination by a plastic surgeon, perceptual assessment by a speech and language therapist, nasoendoscopy, multiview fluoroscopy and aerodynamic vocal tract measurements (eg. nasosometry and pressure-flow testing).

The perceptual evaluation by an experienced speech and language therapist is the criterion

standard for the diagnosis of VPI. The objective assessment confirms the diagnosis of VPI and also provides more information on the timing of closure, closure pattern, palatal and pharyngeal wall mobility, competence of the velopharynx, and the degree of incompetence.

Velopharyngeal insufficiency is characterized by nasal air emission and/or hypernasality on speech. This can result in unintelligible speech in severe cases.[2]

The goal of cleft palate repair is to facilitate normal speech. However, up to 30% of patients develop VPI after primary cleft palate repair and require secondary surgical procedures.[3]

Surgical treatment of VPI includes pharyngeal flap, sphincter pharyngoplasty or posterior pharyngeal wall augmentation. The aim of these techniques is to either lengthen the soft palate to a more posterior position or to move the posterior pharynx anteriorly closer to the soft palate. The outcome of speech following these secondary techniques is generally good. However, these more invasive and extensive procedures are not without significant risks, these include significant bleeding, airway obstruction, iatrogenic obstructive sleep apnoea, middle ear disorders and hyponasality when overcorrected.

Posterior wall augmentation is a less invasive alternative to the treatment of VPI and has been performed using both synthetic and biological material. These include paraffin, silicone, petrolatum, Goretex, Teflon, Protoplast, porous polyethylene, calcium hydroxyapatite, acellular dermal matrix, hyaluronin and autologous cartilage. The major drawback with these materials is resorption, extrusion, migration and granuloma formation. The use of autologous fat to augment velopharyngeal structures can avoid the complications associated with alloplastic and other biological materials.

Adipose tissue transfer in the form of fat as a natural filler is widely performed in reconstructive and aesthetic surgery. Autologous fat has the properties of an ideal

filler. These include abundance, availability, non-migratory, non-immunogenic, non-inflammatory, and the ease of harvesting and transfer. Autologous fat grafting of the velopharyngeal structures has emerged over the past decade as an increasingly attractive option for the treatment of VPI.[4] There is however, a paucity of literature on this treatment modality as only eleven case series of fat grafting for the treatment of VPI have been reported to date with variable results. [4]

c) PROPOSED STUDY

The aim of the proposed study is to assess the outcome of autologous fat grafting performed as treatment in children at the Red Cross children's hospital with mild to moderate velopharyngeal insufficiency. We wish to determine, for the first time, whether autologous fat grafting is effective in our population group, as established in studies from the developed world.

The proposed study is a retrospective folder review of all patients who underwent velopharyngeal fat grafting for the treatment of velopharyngeal insufficiency from September 2011 to December 2014. Cases will be ascertained using the ICD10 coding (Q30.9) via the primary surgeon's data base collection and the Bio-informatics Department of Red Cross children's hospital.

Data will be collected on: the age of patient at the time of surgery, primary diagnosis, type of cleft palate repair surgery, speech after cleft palate repair surgery, grade of speech abnormality, fat grafting date, amount of fat transferred, areas fat grafted, speech after fat grafting, video-fluoroscopy findings before and after fat grafting and complications. The pre- and post fat grafting data will be compared to assess the outcome of fat grafting as treatment modality for mild to moderate velopharyngeal insufficiency. Our data will also be compared to those from other studies in the developed world.

d) HYPOTHESES:

Autologous fat grafting is an effective lesser alternative surgical option for the treatment of mild to moderate velopharyngeal insufficiency.

This pilot study will serve as the basis for future larger prospective studies on autologous fat grafting as treatment for mild and moderate velopharyngeal insufficiency in South Africa.

e) ETHICAL CONSIDERATIONS

This retrospective folder review will adhere to the principles of ethical medical research on human subjects stipulated in the world medical association declaration of Helsinki.

Research data will be identified by a participant number and not by patient name. Only the research team members will know the identity of the participants and their clinical data. Data collected in paper form will be kept securely locked in a locker in room 24 in ward D1 at Red Cross children's hospital. Computer based records will only use participant research number and the data will be available through access privileges and passwords. No reference will be made to the patient's name or personal information in academic discussions, reports or publications of the data. All identifiable information will be destroyed as soon as the purpose of data collection has been achieved.

The senior medical superintendent of Red Cross Children's hospital will be approached for consent of this retrospective folder review once ethics approval is obtained.

Professor Donald Hudson (Head of division of plastic and reconstructive surgery at Groote Schuur hospital) and

Dr Saleigh Adams (specialist consultant at Red Cross and Groote Schuur hospitals) have agreed to supervise the project.

f) REFERENCES:

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And velopharyngeal insufficiency. PRS 2011;128:342e.

3. Lam E., Hundert S., Wilkes G. H. Lateral pharyngeal wall and velar movement and tailoring velopharyngeal surgery: determinants of velopharyngeal incompetence resolution in patients with cleft palate. PRS 2007;120: 495-505.

4. Bishop A., Hong P., Bezuhly M. Autologous fat grafting for the treatment of velopharyngeal insufficiency: State of the art. JPRAS 2014; 67:1-8.

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PART 2: STRUCTURED LITERATURE REVIEW

LIST OF CONTENTS OF LITERATURE REVIEW

a) OBJECTIVES:

- Understand the classification of velopharyngeal dysfunction (VPD).
- Ascertain the incidence of velopharyngeal insufficiency (VPI).
- Identify the causes of VPI.
- Understand the pathogenesis of velopharyngeal insufficiency.
- Analyse and understand the current treatment modalities for VPI.
- Evaluate the use of autologous fat grafting as a treatment modality for VPI, including the:
    - properties of autologous fat as a filler
    - history of autologous fat grafting of the velopharynx
    - indications for the use of autologous fat as a treatment modality for VPI
    - techniques of fat grafting of the velopharynx
    - volume of fat transferred
    - response to autologous fat grafting for the treatment of VPI
    - complications of fat grafting
- Identify the indications for autologous fat grafting for the treatment of VPI.
- Evaluate the outcome of autologous fat grafting as a treatment modality for VPI.
- Comparison of autologous fat grafting with other treatment modalities.

b) LITERATURE SEARCH METHODS:

- Pubmed and Medline search engines were used to acquire the appropriate journal articles.
- Only articles published in the English language were used.
- Search words/phrases used:
    - speech outcomes
    - cleft palate repair
    - velopharyngeal insufficiency
    - velopharyngeal dysfunction
    - velopharyngeal inadequacy

- hypernasality
- obstructive sleep apnoea
- fat grafting
- Coleman technique
- fat transfer
- pharyngoplasty
- sphincter pharyngoplasty
- pharyngeal flap
- cleft palate speech and language therapy
- videofluroscopy
- nasoendoscopy

- Related citations suggested by the search engine were used.
- References obtained from the journal articles were used to further expand the search.

c) SUMMARY OF LITERATURE REVIEW

1. INTRODUCTION

➢ VELOPHARYNGEAL ANATOMY AND FUNCTION

The production of speech starts as sound waves that are generated by the movement of air through the vocal cords and are then transmitted to the vocal tract where they are further amplified. The pharynx, oral and nasal cavities form the vocal tract. [1]

The velopharynx is a dynamic anatomic structure that is slightly rectangular in shape at rest. The anterior border is formed by the soft palate or velum, the posterior border by the posterior pharyngeal wall, and the left and right borders by the lateral pharyngeal walls (Figure 1).[2] In a normal functioning velopharynx, the velum moves posteriorly and superiorly, the posterior pharyngeal wall moves anteriorly in a diffuse or focal manner (ie. Passavant's pad), and the lateral pharyngeal walls move medially. This coordinated movement of the walls forms the velopharyngeal (VP) sphincter. Apposition of the velopharyngeal walls closes the VP port or valve, which normally occurs at a level below the adenoid pad.[3-8]

The velopharynx separates the nasal cavity from the oral cavity during speech and swallowing. The VP sphincter needs to remain open for breathing and nasal consonant production such as /m/, /n/, /ng/ in the English language, but requires closure for the production of oral sounds such as the remaining consonants and all vowels, and swallowing. Normal speech production requires rapid coordinated coupling and uncoupling of the oral and nasal cavities. Any disruption of this mechanism would fail to separate the two cavities resulting in nasal regurgitation of food and abnormal speech production. The abnormal speech manifests as hypernasality or hyponasality, nasal emission and/or a facial grimace. In addition, the patients may develop compensatory articulations in an attempt to adapt to the VP dysfunction.[8-10]

Warren suggests that the articulation errors seen in patients with cleft palates may be a strategy developed to satisfy the special requirements of the speech regulating and motor control system.[12] The author further argues that the compensatory speech behaviour the patients adopt, paradoxically does not enhance their speech performance but worsens it.[12] The undesired perceptual speech that may persist despite primary palatoplasty is thought to be partly due to the speech-motor control pathway prioritizing the aerodynamic performance of speech over the acoustic accuracy.[13-16]

2. CLASSIFICATION OF VELOPHARYNGEAL DYSFUNCTION

There is no consistency in the terminology used to describe disorders of velopharyngeal function. The four commonly used terms are velopharyngeal inadequacy, velopharyngeal incompetence, velopharyngeal dysfunction (VPD) and velopharyngeal insufficiency (VPI).[17] More recently, Trost et al.[18] proposed a comprehensive classification system based on aetiology (Table 1). Thus, velopharyngeal dysfunction is the generic term used to denote any abnormality of velopharyngeal function.[18] The classification system subsequently gained favour with many experts, replacing VPI, the generic term previously used.[1] The subcategories of VPD are as follows: [17-20]

- **Velopharyngeal insufficiency** is caused by any structural abnormality of the velum or pharyngeal walls. There is either a deficiency of tissue to close the VP port, or mechanical obstruction or interference to closure of the velopharyngeal port. The causes are most commonly congenital or it can be acquired post trauma or ablative surgery.

- **Velopharyngeal incompetence** is caused by impaired neuromotor function of the velum or pharyngeal wall. Dysarthria and apraxia are pathognomonic articulations seen in patients with neuromotor disorders.

- **Velopharyngeal mislearning** occurs when the patient develops abnormal usage of the velopharyngeal mechanism in the absence of any structural or neuromotor abnormalities. These patients generally don't require surgery and can be treated with speech therapy.[17-20.]

The causes of velopharyngeal dysfunction are numerous, and the treatment of the patient depends on the cause.

3. MANAGEMENT OF VELOPHARYNGEAL DYSFUNCTION

a) ASSESSMENT

A multidisciplinary team evaluates the patient with VPD. The management principles applied include careful history taking, physical and intra-oral examination, perceptual speech assessment, instrumental assessment and treatment.[8]

1. Speech assessment

The perceptual assessment by an experienced speech and language therapist (SLT) is the cornerstone of VPI diagnosis.[8,21.] Hopper et al. [8] emphasize that the diagnosis and management of VPI should be performed by a SLT trained in the field as some of the speech characteristics can be misperceived for VPI. However, there is inconsistency in the methods used for speech assessment.[21-23.] Lohmander et al.[24] and Kuehn et al.[25] highlighted the need for standardization of speech assessment. Subsequently, Golding-Kushner[26] and John et al.[27] among others, proposed systems to standardize the assessment of speech, but none has been adopted widely or universally.[21] More recently, Henningson[21] et al. proposed a universal system in order to standardized the assessment of speech. The system is comprised of five parameters. These include hypernasality, hyponasality, audible nasal air emission or turbulence, consonant production errors and voice disorder. The Pittsburgh Weighted Speech Scale (PWSS) is an example of such a system and has been validated and widely used (Table 3). [8,28.]

The perceptual outcome of speech does not solely rely on the velopharyngeal gap size, but also depends on oral and nasal airway resistance, respiratory effort and the patient's articulation ability.[6] However, there is evidence showing a correlation between the perceptual outcome of speech (hypernasality) and the velopharyngeal gap size.[28-30.]

2. Instrumental assessment

Once the diagnosis of VPD is established on perceptual assessment, objective and/or subjective instrumental assessment of the velopharynx is performed in order to determine the cause of the VPD, to assess the extent of the VPD and to plan treatment accordingly.

Instrumental assessment can be classified into direct or indirect, objective or subjective, using acoustic or aerodynamic tools. Direct instruments enable the clinician to observe the activity of the velopharyngeal valve. Indirect instruments provide information on the vocal tract behaviour and inferences are made from information obtained from it.[11]

Direct Instrumental techniques

- **Lateral cephalometric radiography** is performed at rest and during a sustained "ee" sound production. It provides information on the soft palate excursion. Addition of barium allows visualization of the margins of the velopharyngeal walls. Johns et al. report a 90% accurate prediction of the need for a pharyngeal flap with this technique.[11]

- **Videofluoroscopy** provides two-dimensional information on the motion of the velopharynx from multiple views such as the sagittal, coronal and transverse views. It subjects the patient to ten times less radiation compared to the cinefluoroscopy, and the images can be recorded and replayed. It can be performed in children 2 to 3 years of age and older. Static and dynamic images obtained are further enhanced with barium. The frontal view allows assessment of the lateral pharyngeal walls and the lateral view allows evaluation of the velum and posterior pharyngeal wall excursion. It also provides information on the attempted level of closure of the velopharynx and

the compensatory movements that occur during speech. It has the least variability compared to the other techniques.[11]

- **Nasoendoscopy** procedures can be performed in children 4 – 5 years of age and older, but may require anaesthesia in the unco-operative patient. A nasopharyngoscope is inserted into the nostril to view the velopharyngeal port closure during speech. It allows quantitative and qualitative bird's-eye view assessment of the velopharynx. It provides information on the closure pattern and the size of the gap. Its disadvantages include the inability to identify small gaps and the exact level of the gap.[11, 31] The four bird's-eye view patterns of velopharyngeal closure first described by Skolnik et al.[31] and further modified by Croft et al.[32] have widely been accepted.[26,33,34] and are the universal standard for reporting on nasoendoscopy (Figure 2).

  Lipira et al.[35] show that the estimation of VPI gap on nasoendoscopy (NE) and videofluoroscopy (VF) correlate, but the interpretation of the data is subjective.[35] Nasoendoscopy and videofluroscopy are the most commonly used modalities to assess VP function. However, the choice of modality and report using these instruments vary from centre to centre.[23, 36] Pigott et al. [37] consider the use of nasoendoscopy and multiview videofluoroscopy complimentary and indispensable, but Cohn et al. and others[38,39] recommend the sole use of lateral videofluroscopy due to cost and the difficulty of using nasoendoscopy in younger patients. On the contrary, Golding-Kushner et al. [26] consider the estimation of the velopharyngeal gap size on videofluoroscopy not useful.

- **Computerized tomography (CT) scan and Magnetic resonance imaging (MRI)** are adjuncts to velopharyngeal function evaluation. They provide detailed information on the velopharyngeal port anatomy.[9] MRI has gained favour as it is non-invasive, does not expose the patient to radiation and provides better three dimensional soft tissue imaging. However, these modalities are costly, require patient co-operation and gravity may distort the velopharyngeal mechanism in the supine position.[11, 40.]

- **Aerodynamics (pressure/flow) and Acoustics (nasometry)** modalities provide objective data, but are not routinely used.[11]

Indirect Instrumental techniques

- **Nasometry (acoustic)** requires the co-operation of the patient and can be performed in children 3 – 4 years of age and older. It is non-invasive and provides objective evaluation of nasalance.[8] The velopharyngeal port size is subsequently calculated from the data obtained. The port size is classified as follows:
  - $<10mm^2$ = normal airflow
  - $10 – 20mm^2$ = mild – moderate hypernasality
  - $>20mm^2$ = severe hypernasality [6,41-43.]

- **Electromyography** is a minimally invasive technique using electrodes to study the electrical activity of the contracting muscles of the velopharynx. Its disadvantages include discomfort caused by the electrode needle and the small displacement of the velopharyngeal muscles.[11]

- **Phototransduction** is when light transmission from a fibreoptic device is used to gather information on the velopharyngeal port. The device is introduced via the nostril until the light source is below the port and the electronic detector above the port. Quantitative information on the closure and the opening of the velopharyngeal port is obtained.[11, 43.]

- **Movement transduction** is a combination of mechanical and electrical devices used to transduce velopharyngeal movement. It is more often used as a biofeedback tool than an assessment tool.[11]

3. Treatment of velopharyngeal insufficiency

VPI occurs in 20% to 30% of patients following primary palatoplasty,[44, 45] and in 5% to 10% of patients with submucous clefts.[46] Speech therapy (ST) is aimed at correcting articulation errors (distortions, substitutions, and omissions), and surgery is directed at correcting hypernasality and nasal air escape.[9, 47] Only 5% of patients require secondary surgery to treat VPI post primary palatoplasty .[44] The treatment options are surgical or non-surgical.[23]

A) Non-surgical treatment

a) Speech therapy

Correcting articulation errors is the main focus of speech therapy. Certain articulation errors are generally regarded as compensatory articulations, and different authors described different types of compensatory articulations (Table 2).[47] The approaches used to treat articulation errors include traditional articulation therapy, phonetic, phonological, psycholinguistic, input modelling and oral motor activities (Figure 3). However, there is a paucity of literature on the effectiveness of speech therapy. The techniques used vary and little evidence is available to show the effectiveness of one technique compared to the other.[48]

Folkins [49] suggests that improved outcomes of speech following speech therapy in patients with VPI may partially be attributed to the flexibility, or physiological variability and plasticity which is the patients ability to modify the rules of the motor system of the velopharyngeal-oral motor system. However, the extent to which this occurs is not known. The author [49] argues that the patients with VPI do not require complete closure of the VP port to produce intelligible speech. Thus, patients can voluntarily control the velopharyngeal mechanism through these processes, and produce intelligible speech through movement patterns that may be different from normal patients. In addition, a certain degree of mechanical restriction of the velopharyngeal mechanism is generally expected post cleft palate surgery due to swelling, scarring and reduction in muscle strength from

inflammation. The quality of speech is expected to improve to a certain degree as the inflammatory process subsides.

b) Prosthetics:

Prosthetic management of VPD is effective and is indicated in a small number of patients. It may be the best option in patients unfit for surgery due to poor cardio-pulmonary or neurological reserves, biomechanical limitations such as cervical spine deformities, microstomia, or in patients with medial internal carotid arteries. Other indications are high risk patients with obstructive sleep apnoea (OSA), or cases of patient refusal owing to financial or socio-economic reasons. The devices commonly used are as follows:

- **Velopharyngeal obturators, speech bulb prosthesis (SAP)** is indicated in patients with short, scarred soft palates, or when the soft palate length to nasopharyngeal depth ratio is decreased. The obturator substitutes the deficient tissue and functions as a nasopharyngeal section that is shaped to conform to the activity of the velopharyngeal port during speech and swallowing.[44]

- **Palatal lift prosthesis (PLP)** is indicated in patients with long, supple soft palates with poor excursion due to neuromotor dysfunction, and when the soft palate length to nasopharyngeal depth ratio is normal. The function of the PLP is to approximate the soft palate to the posterior pharyngeal wall.[50]

- **Lift-orator** is a combination of an obturator and a palatal lift device. It is used when elevation of the soft palate alone is inadequate.[10, 50-51.]

- **Nasal valve** is a device with a one way valve fitted into one nostril allowing air to enter on inspiration, but closes on expiration and speech to prevent nasal airflow.[52]

B) Surgical treatment

The aim of the surgical procedures is to narrow the velopharyngeal port and thus prevent air escaping during speech production. Sphincter pharyngoplasty and pharyngeal flaps are the workhorse flaps for the treatment of VPI. However, there is no consensus on the indications and the efficacy of these procedures.[53, 54.]

The approach commonly used is based on the VP closure pattern and gap size.[53-57] The recommended approach is as follows: [10]

- Minimal circular gap: Furlow's Z-Plasty (FZP) or Intravelar veloplasty (IVV).
- Moderate circular gap or sagittal closure pattern: Pharyngeal flap
- Large circular gap or bow tie gap, coronal closure pattern: Sphincter pharyngoplasty.

Armour et al. recently showed that VP closure pattern does indeed affect the success of pharyngeal flaps. [58]

SURGICAL TECHNIQUES

1. Furlow's Z-plasty

It was initially proposed for primary palatoplasty, but is now used as first line treatment for VPI at many centres in previously repaired clefts and submucous clefts.[95,96] It lengthens the soft palate and repositions the abnormal anterior insertion of the levator veli palatini muscle.[2, 10, 59, 60] It has a lower risk of obstructive sleep apnoea, and has been shown to offer superior outcomes compared to the sphincter pharyngoplasty and pharyngeal flap techniques, particularly in small VP gaps, gaps less than 1cm in depth, or gaps less than 20%.[2,95,96]

2. Intravelar veloplasty

Palatal re-repair as advocated by Sommerlad is indicated as first line treatment for VPI at some centres if primary intravelar veloplasty is inadequate and the levator veli palatine remains anteriorly directed. It has similar advantages to the FZP technique.[2, 60]

3. Posterior Pharyngeal Flap

Passavant performed the first attempted pharyngoplasty through the adhesion of the soft palate to the posterior pharyngeal wall. Schoenborn subsequently described the first pharyngeal flap in 1875, and several modifications of the flap ensued. The flap can be based superiorly, inferiorly or transverse. The flap attached to the soft palate creates a midline obstruction between the nasal and oral cavities with two lateral openings. As a result, a flap that is too wide will obstruct the lateral openings and cause mouth breathing, hyponasality and obstructive sleep apnoea. A narrow flap will not resolve the problem and VPI stigmata will persist.[62-65] In view of this challenge, Hogan et al. [10] introduced the concept of "lateral port control" demonstrating that nasal air escape is audible when the port cross sectional area is above 20mm^2. In addition, Sprintzen et al. [55] introduced the "tailor made flaps" concept, suggesting that the flap width should be based on lateral pharyngeal wall excursion. Subsequently, Riski et al. [57] and Lam et al. [66] amongst others, supported the notion that the flap should be tailored to the nature and the size of the defect. On the contrary, Karling et al. [63] suggest that sphincter mechanism depends on complex mechanisms as narrow flaps increase lateral pharyngeal wall excursion and decrease with wider flaps. Sprintzen [54] and Sullivan et al. [61] report a 78% and 97% success rate with this technique respectively.

Most studies report no difference in speech outcome between the superiorly and inferiorly based flap types. Despite being the most advocated procedure for the treatment of VPI,[54] it has lost favour with recent authors due to its high peri-operative complication rates and variable healing rates.[65]

4. Sphincter Pharyngoplasty (SPP)

This technique is considered safer and more physiological compared to the pharyngeal flap.[54] The procedure entails construction of a static and dynamic sphincter with flaps raised from the posterior tonsillar pillars bilaterally and inset to the posterior pharyngeal wall. It is indicated in patients with poor lateral pharyngeal wall movement, and with a short antero-posterior component. Hynes et al. described the first sphincter pharyngoplasty. Orticochea subsequently modified the technique by suturing the tonsillar flaps onto an inferiorly based posterior pharyngeal wall flap, whereas Jackson uses a superiorly based flap instead.[2,10.]

The added advantages of the SPP is that the previously repaired soft palate does not have to be opened for flap inset as is performed in pharyngeal flap surgery, and if revision surgery is required, the flaps can simply be re-elevated and advanced to achieve the desired results. It is generally agreed that the outcome of the procedure is determined by the level of the flap inset.[10,55.] Pryor et al. report a revision rate of 16% due to low flap inset. The authors report a success rate of 84% following the first operation and 98% after the second operation.[57] Riski et al [68] report comparable results, 74% with the first procedure and 84% following revision surgery.

Sphincter pharyngoplasty in combination with Furlow's Z-plasty is effective and the preferred technique in patients with a large VP gap and poor lateral wall movement,[97] since treating this "black hole" would require a wide pharyngeal flap which increases the risk of airway obstruction.

<u>Velocardiofacial syndrome (VCFS):</u>

The pharyngeal flap has been the flap of choice for the treatment of VPI in patients with VCFS due to the 20% incidence of medial internal carotid arteries.[69] More recently, Losken et al.[70] report safe and effective management of VPI with sphincter pharyngoplasty in patients with VCFS. Pre-operative imaging to identify the course of vessels is controversial. Even though no morbidity has been reported related to the anomalous cervical vessels, the safest recommended approach is to perform pre-operative computerized tomography angiography (CTA), magnetic resonance angiography (MRA) or pharyngoscopy in these

patients. Witt et al. [71] however argue against the routine use of angiography (MRIA/CTA) in these patients. The authors[71] and most of the cleft surgeons who participated in their study use nasoendoscopy as an instrument to identify the pulsation of the deviated internal carotid vessels, and reported safe and effective pharyngoplasty without any pre-operative angiography. The low reported morbidity related to the deviated internal carotid arteries highlights the importance of patient selection, surgical planning, diligent pre- and intra-operative velopharyngeal examination and meticulous surgical technique.

Sphincter pharyngoplasty versus pharyngeal flap

Post-operative bleeding of 1% to 7% and obstructive sleep apnoea (OSA) of 3% to 8% are the most common and potentially life threating complications associated more with the pharyngeal flap than with the sphincter pharyngoplasty.[65, 72, 73] Pensler et al. [74] report sleep apnea in 4% of patients with the flap and none in the sphincteroplasty group. Sirois et al. [75] report abnormal early polysomnograms in 35% of the patients with complete recovery months later.

The pharyngeal flap is two to three times more likely to eliminate hypernasality compared to the sphincter pharyngoplasty at three months post surgery, but no significant difference was noted in outcomes and complication rates between the two procedures at one year post surgery.[53, 67] More studies with strong evidence are required not only to show the superiority of one procedure over the other, but to standardize the approach to the treatment of VPI.

Posterior Pharyngeal wall augmentation

The morbidity and mortality associated with the standard pharyngoplasty procedures lead to the emergence of a simpler, safer and easier alternative treatment modality for small VPI gaps. The aim of posterior pharyngeal wall augmentation is to displace the wall anteriorly with an implant or injectable material, in order to achieve adequate velopharyngeal port closure during speech. Various synthetic, alloplastic and autologous materials have been used for this purpose.[2,76] These include silicone, paraffin, porous polyethylene, Teflon, Gortex, Protoplast and calcium hydroxyapatite. Complications such as extrusion, migration and foreign body reactions are major disadvantages of the synthetic materials.[76-78.] Biological

materials including cross-linked hyaluronan[80], acellular dermal matrix,[81] cartilage,[82] fat[83] and fascia[2] were subsequently used to avoid the complications associated with the use of synthetic materials. The results using these materials were unimpressive and the donor site morbidity, infection and resorption associated with it discouraged its use.[2]

In view of all the above, the ideal material to augment the posterior pharyngeal wall would then be one that is cheap, safe, readily available, easy to use, inert, effective and long lasting. With the advent of autologous fat grafting as pioneered by Coleman, [84] autologous fat has been widely used in both cosmetic and reconstructive surgery as a filler. It meets all the criteria of the ideal material to augment the posterior pharyngeal wall.[85- 87.] Autologous fat grafting has recently become an attractive less invasive alternative to the standard pharyngoplasty techniques for the treatment of minor VPI.[79] There is a paucity of literature on autologous fat grafting for the treatment of VPI. Some authors injected the posterior pharyngeal wall only, whereas others injected different sites to increase the surface area grafted and thus the fat graft take. A majority of the authors report good outcomes in patients with small to moderate velopharyngeal gaps.[79] Comparative studies are however not possible as most reports are retrospective case series with variable patient profiles, selection criteria, site of injection, volume of fat injected and outcome measure parameters.[79, 88.] Filip et al. [89] recently showed significant reduction in velopharyngeal distance and improved hypernasality, but no significant correlation between MRI findings and speech outcome.

A group of plastic surgeons consider the use of autologous fat grafting safe for augmentation of various medical defects.[85] The main disadvantage of autologous fat is the unpredictable outcome at 40% - 80% graft take, due to variable resorption of fat over time and replacement by scar tissue.[86, 87.] The procedure as a result may need to be repeated to achieve the desired results.

The complications of autologous fat grafting to the velopharynx for the treatment of VPI are low compared to the traditional surgical techniques.[79] Only one case of OSA has been reported following fat grafting to the velopharynx due to significant weight gain after surgery.[90] Other complications following fat grafting to the head and neck include blindness

and cerebrovascular accident.[91-93.] Filip [94] suggests the following steps to minimize the risk of fat embolism during fat grafting to the velopharynx.

- Routine magnetic resonance imaging without contrast to assess the VP gap and vascular anatomy of the pharyngeal wall.
- Inspection and palpation of the posterior pharyngeal wall prior to injection.
- Intra-operative ultrasound doppler (8MHz) of the posterior pharyngeal wall to exclude large and small vessels at the injection site.
- Posterior pharyngeal wall injection is performed close to the midline and directly under mucosa.
- A blunt tip cannula is used to transfer fat to the recipient site.
- Fat is transferred slowly with a 1ml syringe. A maximum of 3ml of fat is injected to the posterior pharynx of a child and 4ml in an adult.
- Care should be taken when injecting patients with 22q11.2 deletion syndrome due to the medial deviation of the internal carotid artery.

CONCLUSION

The assessment and treatment of VPI is complex. It requires multidisciplinary management with standardized protocols. The treatment of patients should be individualized as multiple patient and clinician factors will influence the best treatment selection process for each patient. The numerous advantages of autologous fat grafting make it an attractive minor alternative treatment modality for small to moderate VPI gaps compared to the standard invasive pharyngoplasty procedures. It is a useful adjunct to the armamentarium of the cleft surgeon. However, more studies are required to define the indications and to standardize the approach of fat grafting for the treatment of VPI.

d) AIMS AND OBJECTIVES OF CURRENT STUDY

- Document the efficacy of autologous fat grafting for the treatment of mild to moderate VPI.
- Describe our technique of fat grafting of the velopharynx for the treatment of VPI.
- Document the complications of autologous fat grafting of the velopharynx.

- Document the long term outcome of autologous fat grafting for VPI.
- Compare our results of autologous fat grafting for the treatment of mild to moderate VPI to results of other centres.
- Classify VPI using lateral view videofluoroscopy.
- Suggest a treatment plan for VPI based on the lateral view videofluoroscopy classification.

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PART C: JOURNAL ARTICLE

AUTOLOGOUS FAT GRAFTING FOR THE TREATMENT OF MILD TO MODERATE VELOPHARYNGEAL INSUFFICIENCY

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ABSTRACT

Objective: To assess speech results following the treatment of mild to moderate velopharyngeal insufficiency (VPI) with autologous fat grafting to the velopharynx.

Method: A retrospective study was conducted on nine consecutive patients who underwent velopharyngeal fat grafting for the treatment of VPI at the Red Cross War Memorial Children's hospital from 2010 to 2014. All the patients had had primary palatoplasty performed previously and subsequently developed VPI. Patients were assessed pre- and post-operatively by two cleft surgeons, and an experienced speech and language therapist with the aid of lateral view videofluoroscopy (VF).

Outcome measure: Pre-operative and post-operative perceptual speech assessments were performed by a dedicated speech and language therapist. Two senior cleft surgeons performed pre- and post-operative videofluoroscopy interpretations.

Results: Eleven fat grafting procedures were performed on 9 patients and an average of 5.64 ml (range 1 ml to 7 ml) of autologous fat was transferred to the velopharynx. The average age at the time of operation was 6.5 years (range 3 years to 14 years) with a follow up period of 18 months (range 7 months to 34 months). Most of the patients (7 out of 9) showed improved speech following fat grafting. There were no complications related to the fat grafting procedure.

Conclusion: This small study suggests that fat grafting is an effective, minimally invasive

surgical alternative for the treatment of mild to moderate VPI and to our knowledge, is the first reported study from Africa.

KEY WORDS: velopharyngeal insufficiency, lateral videofluoroscopy, fat grafting, perceptual speech assessment.

INTRODUCTION

Velopharyngeal insufficiency (VPI) is the inability to close the velopharyngeal sphincter and separate the oral cavity from the nasal cavity during the production of speech and deglutition. [1,2]

The normal upward and backward movement of the velum, and the simultaneous mesial movement of the lateral pharyngeal walls and the anterior movement of the posterior pharyngeal wall separate the oral cavity from the nasal cavity during speech and deglutition.[1] When the normal space and functional relationship between the velum and the pharynx is lost, the sphincter mechanism is lost and this results in velopharyngeal incompetence.[3] The increased nasal airflow as a result of VPI is characterized by hypernasality, nasal emission and compensatory changes such as glottal stops, particularly during the production of plosive and sibilant consonants. It can affect the intelligibility of speech depending on the severity of the insufficiency.[4,5,6] Patients with velopharyngeal incompetence often develop articulation errors in an attempt to compensate for the inability to close the velopharyngeal port. These include glottal stops, pharyngeal stops, pharyngeal fricatives, palatal stops and velar fricatives.[7]

Velopharyngeal dysfunction is a general term with multiple subtitles and descriptions defining any abnormal function of the velopharyngeal sphincter irrespective of the cause.[2,8,9,10] For the purpose of this study, velopharyngeal insufficiency is used as a single generic term denoting any insufficient tissue or mechanical restriction of the velopharynx.

Dejonckere was among the first authors who reported on fat grafting of the posterior pharyngeal wall.[11] Despite its numerous advantages and the predictable use of fat grafting as

a treatment modality for soft tissue augmentation[12,13,14], there is a paucity of data on the outcome of speech following autologous fat grafting of the velopharyngeal structures for the treatment of VPI.[15,16] The reduced risk of complications compared to more invasive surgery makes it an attractive alternative treatment modality for mild to moderate grades of VPI. This study documents our results of autologous fat grafting of the velopharynx for mild to moderate VPI in 9 children over a 4-year period.

MATERIALS AND METHODS

This study included all the patients who underwent fat grafting for the treatment of mild to moderate VPI from February 2010 to January 2014 at the Red Cross War Memorial Children's hospital. The patients previously underwent cleft palate surgery at the same unit. Those patients who presented to the cleft clinic with VPI were assessed by a cleft surgeon and a speech and language therapist. A lateral view videofluoroscopy was performed on all the patients to confirm the clinical diagnosis of VPI and to obtain more information on the velopharyngeal valve closure, excursion of the velum and posterior pharynx, point of knuckling of the velum, level of contact or closure between the pharynx and velum and the amount of apposition between the velum and posterior pharynx. The videofluoroscopy findings were interpreted by two senior cleft surgeons and patients were selected using a lateral view VF-based classification system (see table 1).[17,18,19] Patients with class II to class IV are eligible for fat grafting and patients with class V are treated with standard pharyngoplasty techniques (see table 1). An experienced speech and language therapist performed the perceptual assessment of speech intelligibility, hypernasality/hyponasality and nasal air escape. Hypernasality was graded as mild, moderate or severe.

Table1. Lateral view videofluoroscopy-based velopharyngeal closure classification and treatment plan.[17,18,19]

CLASS	**Velopharyngael AP GAP**	**RATING**	**TREATMENT**
Class I	Tight VP seal over at least 1cm.	Normal closure.	None
Class II	VP closure with ~2mm contact.	Mild VPI	FZP and/or VP fat injection.
Class III	VP touch closure.	Mild VPI	FZP and/or VP fat injection.
Class IV	VP gap < 2mm.	Moderate VPI	FZP and/or multiple VP fat injection.
Class V	VP gap >2mm.	Severe VPI	Pharyngeal flap/sphincter pharyngoplasty.

AP = antero-posterior. VP = velopharynx. VPI = velopharyngeal insufficiency. FZP = Furlow Z-plasty.

Video 1: Pre-op video of class IV VPI.

Patients with mild (class III) to moderate (class IV) VPI were treated with fat grafting of the velopharynx. A single surgeon performed the surgery. The fat was harvested from the anterior abdominal wall and a modified Coleman technique (centrifugation at 2000rpm for 1 minute) was used to process the fat. The fat was transferred to the posterior pharyngeal wall via a stab incision made with a number 15 blade below the adenoid pad. The fat was deposited as high and as close as possible to the contact point, behind the upper part of the adenoid pad. It is transferred in lines radiating upwards from the incision. A homemade modified J-shaped cannula (figure 1a) was used to transfer the fat to the posterior pharynx as the use of a standard straight cannula is technically challenging. A vertical incision is used to allow easy closure with a single 5'0 vicryl suture in order to prevent fat graft loss through the incision. Fat transfer to the palate was performed with a blunt tip cannula from the oral aspect onto the nasal aspect posteriorly over the anticipated contact area.

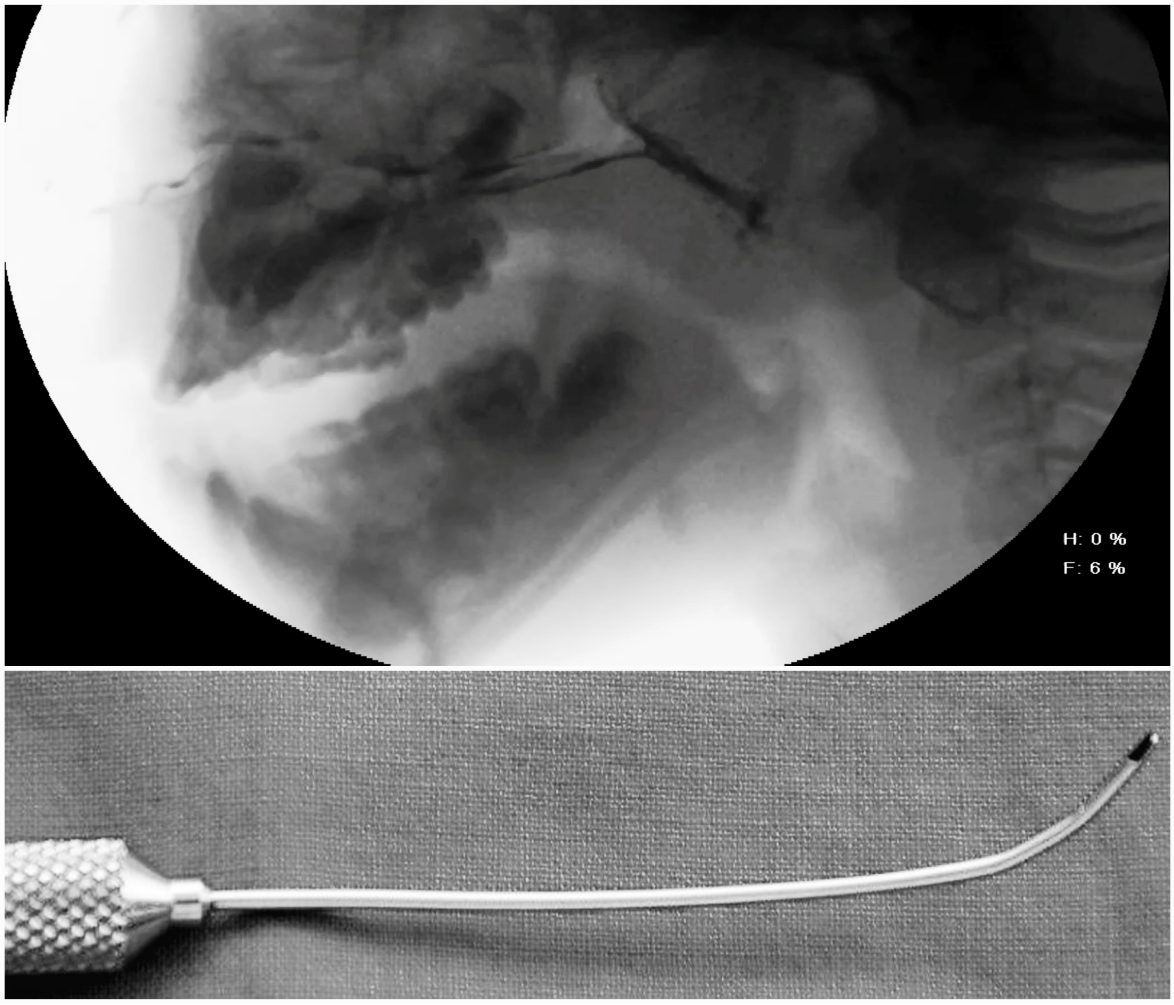

Figure 1. **(a)** Below: Modified homemade J-shaped cannula

(b) Above: Class I VPI closure on lateral VF. Post single fat graftingprocedure, at 36 months follow-up.

VF = videofluoroscopy. VPI = Velopharyngeal insufficiency.

There were no complications, and all the patients were discharged one day after the procedure.

The outcomes were assessed clinically and with lateral view video-fluoroscopy by two cleft surgeons. A speech and language therapist performed the perceptual speech assessments. The pre-operative and post-operative findings were compared and changes in speech characteristics including intelligibility, hypernasality, hyponasality and nasal emission as well as changes in videofluoroscopy were noted. The average follow-up period was 18 months with a range of 6 months to 34 months.

DEMOGRAPHICS

The descriptive data of the study population are presented in table 2. The average age at the time of fat grafting was 6.5 years (range of 3 years to 14 years) and there were six girls and three boys with a primary diagnosis of a cleft palate. The primary treatment of the cleft palate was either with a Furlow Z-plasty or an intravelar veloplasty.

Table 2. Consecutive demographic data, diagnosis, treatment, VPI grade based on VF and volume of fat transferred.

Patient No	Sex	Age (years)	Diagnosis	Treatment	VPI Pre FG	VPI After FG	Total Volume of FG
1	M	7yrs	Complete UCLP	IVV	III	III	6ml
2	M	7yrs	Complete UCLP	IVV	III	III	6ml
3	F	13yrs	Complete CP	FZP	III	II	7ml
4	F	5yrs	Incomplete CP	IVV	IV	I	5ml
5	F	15yrs	Complete CP	VFlap & VLB	III	II	1ml
6	F	8yrs	Complete CP	IVV	IV	III	2ml 6ml 4,8ml
7	F	7yrs	Incomplete CP	IVV	III	II	6ml
8	F	8yrs	Incomplete CP	IVV	IV	III	4ml
9	M	7yrs	SMCP	FZP	III	II	3ml

Abbreviations: CP (cleft palate), UCLP (unilateral cleft lip and palate), IVV (intravelar veloplasty), FZP (Furlow Z plasty), V Flap (vomerine flap), VLB (von Langenbeck), SMCP (submucous cleft palate), VF (videofluoroscopy), FG (fat graft).

RESULTS

The average volume of fat transferred was 5,64 ml (range, 1 ml to 7 ml) and all except one of the patients (number 6) underwent one fat grafting procedure. The majority of the patients (7 out of 9 patients) improved both on perceptual speech assessment (degree of hypernasality) and velopharyngeal function as assessed on lateral view videofluoroscopy.

The outcome of VPI on videofluoroscopy following fat grafting is presented in table 3. Six patients had class III (mild) VPI before undergoing fat grafting. Four of these patients improved to class II after one fat grafting and two patients (numbers 1 and 2) did not improve. Three patients had class IV (moderate) VPI before fat grafting, two of the patients improved to class III (mild) and one patient (number 4) had near normal speech (class I, figure 1b) after only one fat grafting procedure. One patient with class IV VPI (number 6) did not improve after one fat graft procedure, but subsequently improved to class III after two additional fat grafting procedures.

Table 3. Videofluoroscopy pre- and post fat grafting.

VF before fat graft	**VF after fat graft**
Class III (n=6)	Class II (n=4) Class III (n=2)
Class IV (n=3)	Class III (n=2) Class I (n=1)

Abbreviations: n=number of patients. VF=videofluoroscopy.

Video 2: Post op video with class 1 contact after a single episode of fat grafting.

DISCUSSION

The traditional treatment of VPI of a structural cause is surgical and includes a Furlow Z-plasty[20], if not previously performed[18], posterior pharyngeal flap or sphincter pharyngoplasty.[21,22] Pharyngeal wall augmentation with various synthetic and autologous materials is an alternative to the traditional techniques, and prostheses are reserved for patients not suited for surgery.[2,4,5]Speech therapy also forms an integral part of the management of VPI.

Apart from perceptual speech assessment, the modalities used to assess VPI include videofluoroscopy[23], nasopharyngeal endoscopy[24,25], computerized tomography[26] and magnetic resonance imaging.[27,28,29] Pigott and Makepeace[30] consider the use of nasal endoscopy and videofluoroscopy indispensable and complementary providing both qualitative and quantitative information, respectively. On the other hand, Cohn E. R.et al.[31] and Birch M. J. et al.[23] consider the use of lateral view videofluoroscopy with and without barium adequate and reliable. They report that it provides adequate information of the velum, pharynx and any concurrent abnormalities. Videofluoroscopy is cost effective, minimally

invasive, and does not require sedation.[32] It is our preferred method for the assessment of dynamic velopharyngeal function. In this study the perceptual assessment of speech (hypernasality) correlated with the videofluoroscopy grading of VPI both before and after fat transfer to the velopharynx.

Overall, both speech resonance (hypernasality) and VPI grading on videofluoroscopy improved in 80% (7 out of 9 patients) of the patients. The majority of these patients (6 out of 9 patients) improved with only one fat grafting procedure and only one patient improved after two additional fat grafting procedures.

The outcome of fat grafting to the velopharynx for the treatment of VPI is variable in the current study as two patients with mild VPI (class III) did not improve although 6 out of 9 patients did improve following one fat grafting procedure. There was no correlation between the volume of fat transferred and the degree of VPI. The volume of fat graft take is unpredictable[14,33], and this could explain the variable outcome of VPI treatment with autologous fat transfer in this study. The outcome of fat grafting for VPI can be explained by the improved excursion of the velopharyngeal structures due to improved tissue pliability of previously scarred and tethered tissue, in addition to volume replacement.[13]
There was no correlation between the total volume of fat transferred and the outcome of speech resonance (hypernasality) or videofluoroscopic changes. In contrast, Filip et al. reported a correlation of total volume of fat injected with the improvement in hypernasality.[29]

Obstructive sleep apnoea (OSA) is one of the most common complications following pharyngeal flap surgery for VPI with an incidence of 35%.[34] Autologous fat grafting to the velopharynx, although a less invasive procedure does not completely eliminate the risk of OSA,[35] but it did not occur in this study.

The advantages and benefits of autologous fat grafting are numerous. The risk of complications is less and the procedure is technically less challenging compared to the traditional surgical techniques used for the treatment of VPI. There were no complications in the current study and similarly, other studies reported minimal complications following autologous fat grafting for the treatment of VPI.[15,16] All the patients in the present study

were discharged one day after the procedure. The simplicity of the technique, shorter hospital stay, quicker recovery time and less invasive nature of the technique makes it attractive to us as a treatment modality for mild to moderate VPI.

There is a paucity of literature on autologous fat grafting of the velopharynx for the treatment of VPI. Bishop et al.[15] in their review article subsequently supported by Nigh et al.[16] underscored the need for randomized control trials in order to reach consensus on the patient selection criteria for AFG as treatment for mild to moderate VPI, sites of injection, volume of fat for injection, standardized speech assessment scales and instrumental assessment scales. The assessment modalities used and hence the definitions of mild and moderate VPI vary.[35-41] Nasoendoscopy (NE) and videofluoroscopy (VF) are the commonly used modalities to assess the degree of VPI. A nasopharyngoscopy based 5-point scale to grade and accordingly treat VPI has been reported.[42,43]A lateral view VF-based classification is used at our unit to grade patients with VPI,[17,18,19]and the appropriate treatment is selected depending on the degree of the VPI (table 1). A similar approach to AFG of the velopharynx for the treatment of mild to moderate VPI has not been reported in other studies.[15,16,35-41] Our results were obtained by injecting fat submucosally into the velum without perforation and as high as possible into the posterior pharyngeal wall where the velum is expected to make contact with the posterior pharyngeal wall. We elected not to inject fat into the lateral pharyngeal walls in order to avoid inadvertent intravascular injection. On the contrary, other authors have reported intramuscular injection into the superior constrictors and into the lateral pharyngeal walls with no complications.[42,43]

CONCLUSION

Autologous fat grafting of the velopharynx is an attractive, low risk alternative and/or adjunct for the treatment of VPI in patients with mild to moderate VPI. This study reports on the results of autologous fat grafting for the treatment of mild to moderate VPI at our unit using a lateral view VF-based classification to select patients and their subsequent treatment. As far as we know, it is the first reported study of autologous fat grafting for the treatment of mild to moderate VPI from Africa.

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PART D: ADDENDUM

Figure 1. Velopharyngeal anatomy[1]

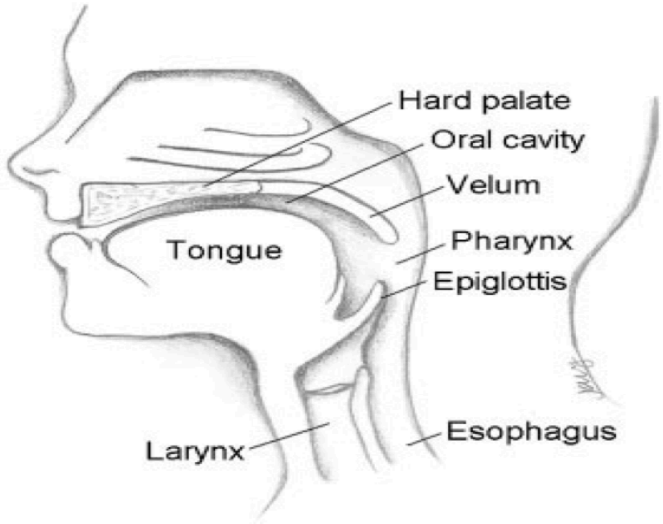

Table 1: Classification and aetiology of Velopharyngeal dysfunction.[18]

Velopharyngeal Insufficiency (VPI) (insufficient tissue or mechanical restriction)	**Velopharyngeal Incompetence** (lack of neuromotor competency)	**Velopharyngeal Mislearning** (maladaptive articulatory habits)
Unrepaired cleft palate	Dysarthria (myotonia)	Compensatory misarticulation
Post-cleft palate repair	Apraxia	Phoneme-specific nasal air emission
Palato-pharyngeal disproportion (such as chromosome 22q11 deletion syndrome)		Persistent post-op nasal air emission with no VPI
Mechanical interference (tonsils, webbing, stricture)		Hearing impairment

Figure 2: Pittsburg Weighted Speech Scale (PWSS)[28]

PITTSBURG WEIGHTED SPEECH SCALE (PWSS)

Weighted Values for Speech Symptoms Associated with Velopharyngeal Incompetence

NASAL AIR EMISSION *Score most patent nostril and provide only the highest value. Maximum Score = 3*	RIGHT LEFT
Not Present	0
Inconsistent, Visible	1
Consistent, Visible	2
Nasal escape on nasals appropriate Reduced Absent	0 0 0
Audible	3
Turbulent	3

Presence of **FACIAL GRIMACE**	2

NASALITY / RESONANCE	
Normal	0
Mild Hypernasality	1
Moderate Hypernasality	2 (- 3)
Severe Hypernasality	4
Mixed: Hyponasality - Hypernasality	2
Cul de Sac	2
Hyponasality	0

PHONATION / VOICE	
Normal	0
Hoarseness OR Breathiness Mild Moderate Severe	 1 2 3
OR:	
Reduced Loudness Tension in System	2 3
Other:	

ARTICULATION	
Normal	0
Developmental Errors	0
Errors from other causes not related to VPI	0
Errors related to anterior dentition	0
Reduced intraoral pressure for sibilants	1
Reduced intraoral pressure for other fricatives	2
Reduced intraoral pressure for plosives	3
Omission of fricatives or plosives	2
Omission of fricatives or plosives plus hard glottal attack for vowels	3
Lingual-Palatal sibilants	2
Pharyngeal fricatives, plosives, backing, snorts, inhalations, or exhalation substitutions	3
Glottal stops	3
Nasal substitutions for pressure sounds	4

Probable Nature of Velopharyngeal Valve:	
Competent	0
Boderline Competent	1 – 2
Borderline Incompetent	3 – 6
Incompetent	7 and Up.

TOTAL

Figure 3: Velopharyngeal closure patterns[31,31]

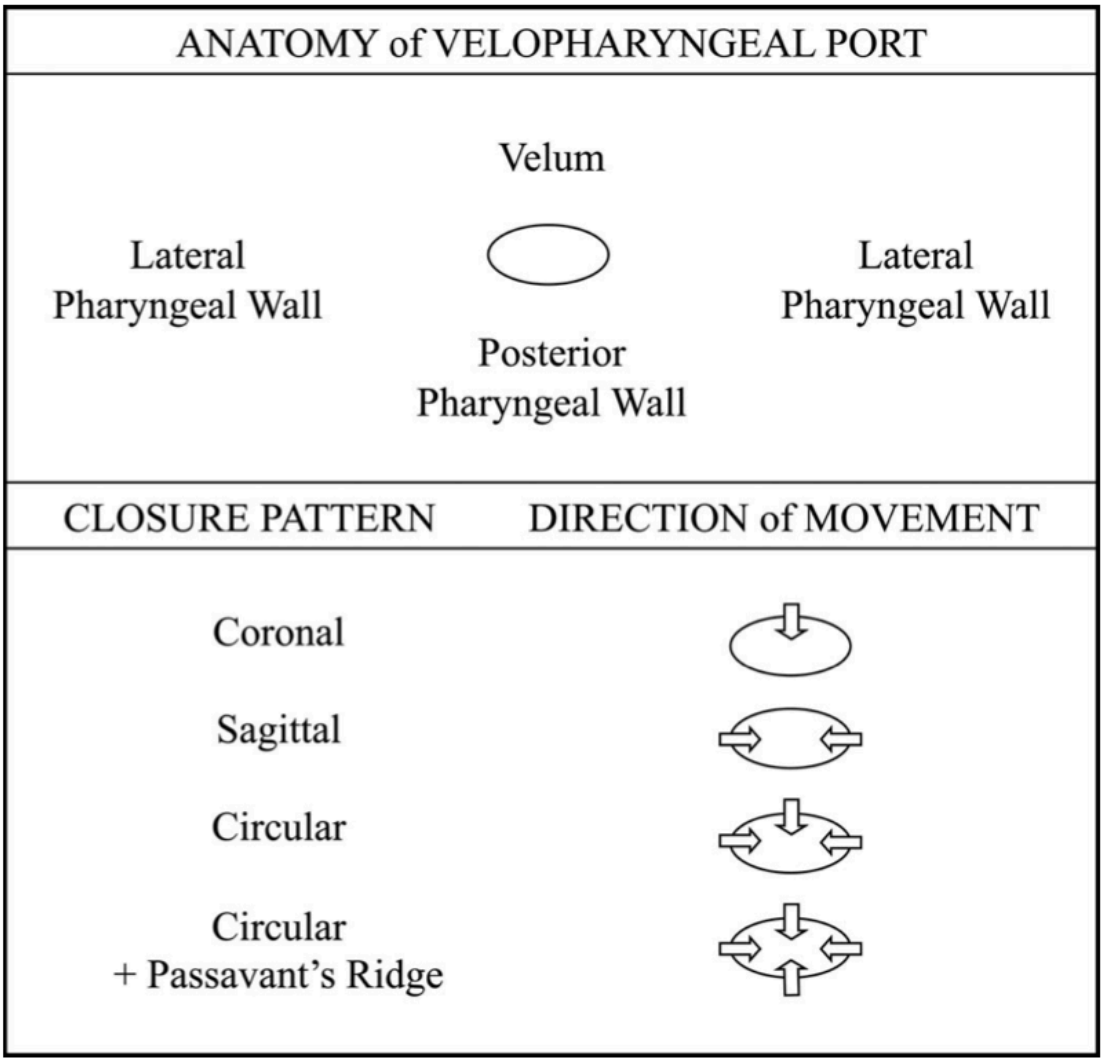

Table 2: Types of compensatory articulations[47]

CA type	Where?	How?	Main substitutes
Glottal stop	Larynx	Glottal closure	Plosives
Pharyngeal stop	Pharynx	Base of the tongue contacts the posterior wall	Velars
Pharyngeal fricative	Pharynx	A fricative made in the pharynx	Sibilant fricatives
Pharyngeal affricate	Larynx Pharynx	Combines fricative and glottal stops	Oral affricates
Posterior nasal fricative	Pharynx	Constriction between the velum and posterior pharyngeal wall	Sibilant fricatives and affricates
Middorsum palatal stop	Midpalatal area	Tongue contact central area of palate	Plosives /t/, /k/, /d/, /g/
Nasal fricative	Nose	Nonturbulent nasal emission	Fricative

PART E: GLOSSARY AND ABBREVIATIONS

SPEECH TERMINOLOGY

- **Nasal emission:** is increased nasal airflow which mostly occurs during the production of pressure consonants (plosives [p,b,t,d,k,g], fricatives [f,v,s,z,sh,th], affricates [ch,j]).
- **Hypernasality:** is an increased reverberation of nasally escaping air in a confined postnasal space. It occurs mostly during production of vowels.
- **Hyponasality:** opposite of the above.
- **Nasal rustle/turbulence:** is a distinct fricative sound on the voiced pressure consonants b, d, g.
- **Grimace:** is an aberrant facial muscle movement produced on an attempt to inhibit abnormal nasal airflow by the constriction of the nares.
- **Nasal substitution:** occurs when an appropriately positioned oral consonant is converted to its nasal equivalent eg. b becomes m, d becomes n.
- **Compensatory articulation:** production of plosives or fricatives despite VPD by inappropriately positioned articulators. Closure occurs at glottal/pharyngeal level.
- **Sibilant distortion:** is the production of sounds s, z with incorrect tongue placement, often results from malocclusion.