**UNIVERSITY OF THE WESTERN CAPE**
**Faculty of Dentistry**
**& WHO Collaborating Centre for Oral Health**

# The reliability and validity of the Facial Anthropological Device

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**KEY WORDS**

1. Occlusal Vertical Dimension
2. Mechanical Methods
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5. Freeway Space
6. Centric occlusion
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8. Facial Anthropological Device
9. Willis gauge
10. Dividers

## ABSTRACT

It is generally agreed that the most troublesome procedure during the fabrication of complete dentures is the measurement of the Vertical Dimension at rest.

The aim of this study was to test the reliability and validity of a new instrument called the Facial Anthropological Device (FAD). The measurements recorded were compared to the Willis gauge (being the gold standard) and dividers, which are mechanical aids used to quantify lower third facial height during denture construction. This thesis presents data on 35 edentulous and 35 dentate patients in the age range of 30 to 70 years, who presented at the University of the Western Cape Dental faculty.

The FAD incorporates a 'spirit-level' and uses more anatomical landmarks than any other measuring device noted in the literature. It measures facial landmarks in the midline and is not only used to measure the vertical dimension of the face, but with further research, may also be used in forensic studies. The Willis gauge is designed to measure the distance from the lower border of the septum of the nose to the lower border of the chin, and the distance from the outer canthus of the eye to the corner of the relaxed lip with the teeth in occlusion. The dividers measures two arbitrary points on the face.

The study showed that the FAD was most similar to the Willis gauge where reliability and reproducibility was compared. There were no statistically significant differences ($P > 0.05$) between the two devices.

The FAD has shown to be a reliable and valid instrument that could be used to measure facial vertical dimension in the edentulous as well as dentate patients, however with some modifications to its design.

**DECLARATION**

I declare that '*The reliability and validity of the Facial Anthropological Device'* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Monique Jo-anne Rayner 15th October 2009

Signed: .....

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## INTRODUCTION

The Occlusal Vertical Dimension (OVD) is defined as the height of the lower third of the face when the teeth are in complete occlusion (Fayz and Eslami, 1988). It is unanimously agreed, that there is no completely accurate method of determining this measurement in edentulous patients. Neither has the literature managed to accurately demonstrate significant advantages of one procedure over another. The only differences publicized according to Fayz and Eslami (1988) are in relation to: the duration of the technique and its instrument requirements.

This measurement is important, as it is one of the most critical steps in constructing complete dentures, which are functionally adequate and aesthetically pleasing (Dixon, 2000). Its purpose is important in all aspects of Prosthodontics and according to Mack (1991), as well as Chou and co-workers (1994) facial proportion and the location of the occlusal plane are the primary determinants for establishing an appropriate OVD.



The OVD of the lower third of the face is determined by a measurement of the distance between 2 points: one on the maxilla and the other on the mandible (Mack 1991). A variety of mechanical and physiological methods have been suggested and confirmed by Fayz and Eslami (1988) as methods employed in recording the OVD in dentate and edentulous patients. Common mechanical methods used, include the use of instruments such as the Willis gauge, dividers or rulers. The physiological methods used, complement the mechanical devices and these two methods are seldom used in isolation. These include, among others: functionally acquired jaw positions associated with speech, swallowing, cephalometric radiographs, the use of pre-extraction records and electromyography (Fayz and Eslami, 1988).

This thesis will test and investigate the reliability and validity of a new instrument developed by a South African dental technician, called the Facial Anthropological Device (FAD). It will provide original contributions to the body of knowledge about Occlusal Vertical Dimension and its related terminologies. Current views around the measurement of OVD will be discussed, by identifying the instruments and methods frequently used today.

The instrument, literature reviews, the results and suggestions presented in this thesis aim to provide a solid foundation for further research and hopefully bring the goal of measuring OVD closer to being achieved more successfully.

## CHAPTER 1

## LITERATURE REVIEW

The topic of occlusal vertical dimension (OVD) is an old one and early articles on this subject were largely restricted to clinical case studies. According to Laney and Gibilisco (1983), for about 25 years prior to the 1980's, the topic of facial vertical dimension was researched more than any other topic in Prosthodontics. Current articles on this famed subject are now limited. Few have shown to compare OVD measuring systems or have tested their reliability in recent years. This literature review will attempt to critically compare the recent studies performed on the subject matter, as well as concentrate on common methods currently used for recording and establishing the OVD.

It is widely recognized, that facial ageing is a natural occurrence and an unavoidable fact of life. When a person becomes edentulous the original vertical dimension is no longer preserved (Miljkovic *et al*, 2001). According to Mack (1991), this is due to the loss of tooth contacts, as well as a large disparity in physical characteristics of people. Numerous authors the world over have stated that, there is not a single method that can flawlessly determine nor reproduce the vertical dimension of occlusion in edentulous persons (Bissasu, 1999; Chou *et al*, 1994; Mack, 1991; Fayz and Eslami, 1988).



Some authors' report of superior measurements of bony landmarks compared to soft tissue markers. One such author Mack (1991), states that craniofacial vertical dimension is a more accurate measure of facial proportion (Fig 1), as compared to mid and lower soft tissue measurements mentioned by Geerts and co-workers, in 2004 (Fig 2). Although that may be the case, not many dentists in the Western Cape have immediate access to radiographic units which may allow cranio-facial anatomical points to be isolated. In addition, the taking of radiographs for this purpose is unjustifiable and therefore, other safer mechanical or physiologic methods have to be sought.

When measuring OVD, the facial midline and the occlusal plane are its principal determinants (Mack, 1991). The facial midline is defined by three anatomical markers as shown in (Fig 1): the nasion (N) which is the root of the nose; the subnasale (Sn), being the base of the columella and the gnathion (Gn) or menton (M), being the lower edge of the mandible. The nasion is the point deemed to be the most stable of these three anatomical landmarks (Farkas, 1994). The FAD uses this anatomical point in its measurement of OVD.

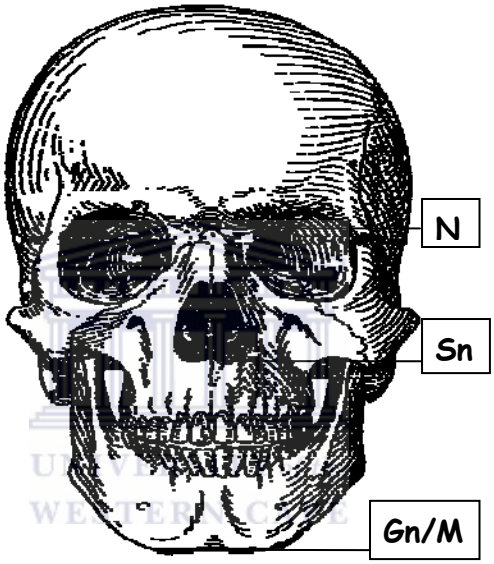



**Fig 1: A Skull depicting the 3 bony anatomical landmarks**

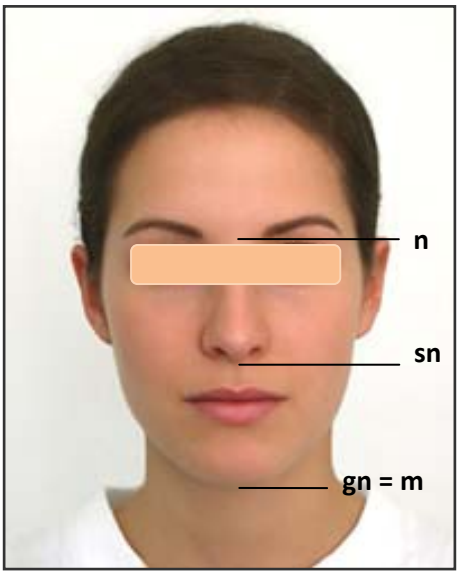



**Fig 2: A face depicting the corresponding soft tissue landmarks**

Farkas (1994) agreed with Mack (1991), that in a 'normal face' the profile is orientated to the vertical plane via paired symmetrical features as shown in (Fig 3).

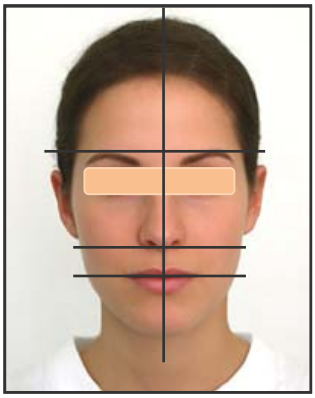


**Fig 3: The face depicting paired symmetries**

These paired features include the upper borders of the eyebrows, the insertion points of the alae of the nose and/or the corners of the lips. For the most favourable alignment of the profile to the vertical plane, at least one of these paired features need to be present (Farkas, 1994).



In order to successfully assess vertical dimension with regards to facial proportions, Mack (1991) states that clinicians need to be familiar with the concept of 'Golden Proportion'. He reported that this term was first described by Phidias, the Greek Sculptor, and refers to *'an ordered relationship specifically related to parts in nature that are instinctively appreciated as beautiful'*. Leonardo Da Vinci (1452-1519) in his book 'Anatomical Studies' further illustrated several observations in facial proportions and the lower one third of the face, which he called divine proportions (Harper and Misch, 2000). Mack (1991) concludes that by understanding these facial proportions, the dentist is able to appreciate the impact that negative consequences of these dimensions produce on facial aesthetics.

The vertical dimension of occlusion is influenced by an individual's teeth, nerves, muscles and bones. It is represented by two measurements: the first being the length of the face when the posterior teeth are in maximum intercuspation or the mandible is in centric occlusion, known as the Occlusal Vertical Dimension (OVD) (Harper and Misch, 2000) (Fig 4). In dentate patients, centric occlusion may not coincide with centric relation. Centric relation relates to the position of the condyles lying within the glenoid fossa. The condyles articulate with the thinnest avascular portion of the articular disks, and are positioned in the most anterior-superior position against the articular eminences (Parker, 1993).

According to Dixon (2000), it is this centric relation record with regards to edentulous patients, which is the '*most important and the most complex maxillo-mandibular relation record to make'*. It is a ligamentous, bone-to-bone relation, which is independent of tooth contact. In edentulous patients these two centric positions are made equal.



**Fig 4: Centric occlusion in a dentate individual**

The second measurement is the length of the face when the teeth are separated and the mandible is in the physiologic rest position, known as the Resting Vertical Dimension (RVD) or rest position. Both vertical dimensions are subject to change resulting from the loss of teeth (Fayz and Eslami, 1988). The difference between the two dimensions is generally in the range of 2-4 mm relative to the intercuspal position. This may be known as the Inter-occlusal Distance or more commonly - Freeway space (Harper and Misch, 2000).

In the rest position, the mandibular condyles are in an acquired centric position. According to Harper and Misch (2000), it is positioned anteriorly along the condylar translation pathway. It is widely agreed that this position is relatively inconsistent. It may be a static relationship in theory, but because it lacks dependable boundaries, it is believed that it should not be used as a starting point in the determination of the OVD (Mack 1991; Chou, *et al* 1994). However, even though researchers have questioned its theory of stability; in the initial preparation RVD is still used as a starting point by most dentists' today (Olsen, 1964; Chou *et al*, 1994; Weinberg, 1982).

Authors' such as Harper and Misch (2000), agree that the RVD is not completely reproducible. They state that it can be easily influenced by a number of factors which include: neck position, the presence or absence of dentures, speech and stress. Since the facial muscles in this position are not entirely static and do demonstrate minimal electromyographic activity, the term 'rest position' is considered rather ambiguous (Weinberg, 1982).



The determination of OVD is one of the most critical steps in the fabrication of dentures for the edentulous patient (Chou *et al*, 1994; Mack, 1991; Weinberg, 1982). Its eventual inaccuracy creates a whole series of problems, both aesthetically and functionally, and thus compromises the success of the prosthetic treatment (Baba *et al*, 2000). Determining this measurement creates a dilemma for the dental practitioner in practice, as to the 'correct' instrument or technique used to record the OVD in edentulous individuals. The literature generally confirms that there are no strict rules available for determining this measurement, but combinations of methods have been suggested (Fayz and Eslami, 1988; Laney and Gibilisco, 1983).

## PHYSIOLOGIC METHODS

### Pre-extraction records

Archiving pre-extraction records have proven to be quite valuable. They include recorded facial and dental measurements, diagnostic casts and radiographs. If these files are lacking, the utilization of measurements obtained from old photographs may prove helpful (Fayz and Eslami, 1988). Photographs showing the front teeth, even when the patient was a teenager gives an indication of their size and display. Often the picture is clear enough to reveal quite a distinctive dental outline, which when included in the set up, may be instantly recognisable. However, the fact that teeth change in shape; colour and size over time, should be taken into consideration before the final completion.

Some authors claim landmarks obtained from old casts have shown to be quite useful too (Bissasu, 1999). One such landmark used in the maxilla deemed to be stable, is the incisive papilla (Bissasu, 1999). While the mandible does not have any such markers, Bissasu (1999) claimed he successfully measured the height of mandibular central incisors to the lingual frenum. He concluded that this distance could be used on pre-extraction diagnostic casts as a record for determining the original vertical position of the mandibular anterior teeth. Bissasu however, only used 18 individuals in his study. He also stated that the lower impressions were recorded while the tongue was raised and the frenum claimed to be in function. With the tongue raised, the impression tray filled with impression material and the mouth slightly ajar, the level of the frenum, all be it a couple of millimetres, is unpredictable.

Silverman (1955) believed that the overjet and overbite relationships of the natural dentition should be recorded before dentectomy occurs and incorporated as closely as possible in the complete dentures. He states that by duplicating these measurements, the aesthetics and phonetics will be maintained, and will therefore prevent the patient from appearing and sounding

older than they should. He adds that a large number of sounds are made by the position of the tongue to the upper anterior teeth. He further states, that by not changing this relationship in the new fabricated dentures, the similarity to the natural dentition will add to its success. However, for a dentectomy to be advocated, the teeth may have been in a diseased state, which discludes the use of the overjet and overbite, as it would not be the natural readings of the patient. It is the author's opinion that if these records were recorded during routine examinations when the natural teeth were still healthy, Silverman's statement would hold merit.

Numerous studies have suggested using facial proportions to estimate OVD (Chou *et al*, 1994; Fayz and Eslami, 1988). One such study performed by Chou and co-workers, (1994) stated that left ear-eye distances could be used to predict chin-nose distances with reasonable accuracy. Their study sample however, was limited to white and Asian men and woman. They concluded that despite their findings, *'the algorithm for making this prediction was not the same for combinations of sex and ethnic origins'*. Another study which proved successful, suggested measuring the inter-pupillary and the brow-to-chin distances from old photographs, calibrating the results and comparing them to the current measurements in the same patient (Fayz and Eslami, 1988).



Bhat and Gopinathan (2006) questioned the reliability and accuracy of pre-extraction records over a long period of time. This was clarified by a study done by Fiske and co-workers in 1998, where they pointed out that the length of time is not a problem because, although teeth may wear away and move due to disease factors, the bone remains reasonably stable for up to 50 years. They believed that fabricating an artificial dentition with pre-extraction records, gave validity to the replacement of teeth.

According to the Health Professions Council of South Africa (2007), medical and dental records should be kept for a minimum of 6 years. If these records are available, the literature confirms that pre-extraction records will always be a valuable source of evidence of the patient's details, which existed before the loss of the natural dentition (Olsen, 1964). When no pre-extraction records exist, dentists should rely upon the aesthetic appearance of the patient and their own clinical judgement, supported by methods to be discussed.

## Speech

In the 1950's Silverman (1955) deduced that there should be no space between the incisors when the mandible is at its '*closest speaking distance*' in relation to the maxilla. He defined it as being: '*the space between the occlusal surfaces of the teeth when the mandible is elevated to maximum extent during speech'.* This space should not be mistaken for the freeway space. He believed and strongly recommended that this space be recorded for all patients aged 20 years and older, so that proof of the patients' natural vertical dimension could be stored for future use (Silverman, 1953). This measurement would be used when full dentures were indicated, thus closely reproducing the OVD of the patient and allowing problems which may have caused unnatural sounds and lisps to be avoided. His theory is however based on the assumption that the '*closest speaking space*' remains constant throughout life. This statement remains highly debatable.



Harper and Misch (2000) however reported that patients wear the same dentures on average for 14 years. During this time they report that a patient loses 10 mm of their OVD and yet are still able to pronounce sounds eg: 'Mississippi'. They argue that if speech is said to be related to the original OVD, then these patients would not be able to pronounce these sibilant sounds.

In another study proving speech to be advantageous, suggests that approximately 20% of the denture population has an atypical “s” sound, i.e. no matter how much the OVD changed, the anterior teeth still remained significantly separated when “s” sounds were made (Chou *et al*, 1996). Similarly, other reports were made confirming consistent results when measuring occlusal vertical dimension using phonetic means.

In a study done by Miralles and co-workers (2001), speech was used as one of the methods for indirectly measuring the OVD. They compared three techniques which measured freeway space and then subsequently calculated the vertical dimension. Adhesive tape was placed on the more prominent parts of the nose and chin of each subject and the OVD was recorded after: swallowing saliva, pronouncing “Mississippi”, and assessing resting facial height.



Miralles and co-workers (2001) concluded that the amount of freeway space depended on the technique being used to measure it. He further concluded, that methods using speech only were not as reliable as swallowing when recording OVD. Earlier in 1997, Rivera-Morales and Goldman performed a study testing whether speech-based techniques were reliable in determining OVD. They concluded that it was difficult to assess sounds in edentulous patients, as well as in dentate patients who had no posterior teeth. They too concluded that speech-based methods were not as reliable when measuring OVD. Their study advocated techniques which used freeway space measurements; as well as instruments which measure soft tissue profiles.

Chou and co-workers (1996) were also in agreement about the negative effects of using speech-based methods only when recording and establishing OVD. They however, reported that measuring OVD by calculating the amount of Freeway space was only a rough guide, because muscle tone which determines the space,

is variable. These findings highlight the importance of using other clinical guidelines besides speech in assessing a patient's OVD.

## Electromyography (EMG)

Assessment of the vertical dimension requires that we having an understanding of facial neuromusculature and its effects. The muscle cell or sarcomere has a highly adaptive capacity to a change in its resting length (Mack, 1991). It is this potential that provides some flexibility for the dentist when restoring dentitions, especially at an altered vertical dimension.

A study substantiating this fact done in 1996 by Mohindra, automatically increased the OVD of newly constructed dentures of 21 patients. The adjustment ranged from 3mm to 19mm, with a mean increase of 9.7mm. Although swallowing was used to establish the OVD, this study shows how adaptive muscles are to changes in vertical dimension. The OVD's in only three out of the twenty one cases were adjusted after completion. The entire sample filled out questionnaires describing their opinions about their new dentures. All the participants reported they were regularly wearing their dentures and 86% (i.e. 18 out of 21), thought their dentures were better than the previous set.



The author however, stressed that these patients were pre-selected, and cautioned applying this type of treatment to all patients needing new dentures. This study highlights the merits of traditionally limiting increases in vertical dimension by 2-3mm at a time, as well as the necessity of good clinical history taking when estimating how much the vertical dimension may be increased by. Furthermore, the problem of over diagnosing is a major concern, because no scientifically acceptable disease definition exists for the vertical dimension of occlusion (Kazuyoshi *et al*, 2000).

Many articles have been written on EMG and its relation to facial dimensions. Atwood (1966) reports that electromyography does not per se measure OVD, only the tonus of masticatory muscles while they are in the rest position. Some authors suggest that a *'single channel high gain differential EMG'* may be used successfully to determine the centric positions, specifically the physiologic rest position (Baba *et al*, 2000; Dixon, 2000). However, Dixon (2000) reminded us that centric relation is not truly a resting mandibular position. She further reports that it definitely is repeatable with EMG, but stresses that such records should be made at the appropriate level of OVD.

Another such study performed by Miljkovic and co-workers (2001) compared the results obtained from phonation, swallowing and electromyography, in order to determine the best method of the three used to establish OVD. They concluded that electromyography was more accurate, compared to phonation and swallowing.



While EMG can indeed measure jaw muscle activations and jaw positions, adequate cost-effectiveness and cost-beneficial analyses have yet to be adequately conducted (Baba, 2000; Kazuyoshi *et al*, 2000). Watt and McGregor (1976) agree that cost needs to be considered, but also add that the technique is too complicated to be used in general practice. They believe that a considerable amount of experience is needed in the field of muscle physiology before proper interpretation of the tracings may be useful.

## Cephalometrics

Numerous successful studies have been reported using cephalometry (Bhat and Gopinathan, 2006 and Mack, 1991). One such study, performed by Mariotto and co-workers (1989) suggested that accurate indications of the vertical dimension could be obtained through anatomical reference points using cephalometric radiographs. They concluded that their results were aesthetically accurate and

adequately functional. However, the method they proposed could be executed more easily on mounted casts rather than patients.

A clinical study performed by Bhat and Gopinathan (2006), used cephalometric radiographs as a pre-extraction reference record. They recorded the distance between the base of the nose and the chin radiographically, before dental clearance occurred. A complete denture was then fabricated for each of the study participants which comprised of only 10 patients. The same measurement was recorded during the clinical stages of denture construction. They found that there was a significant difference between the two measurements and concluded that cephalograms would be an effective pre-extraction aid for determining the OVD.

Another use for cephalometrics was in a technical study performed by Domitti and Consani (1978) where they derived a mathematical equation. They did this by measuring cephalometric points derived from 380 patients with complete natural dentition. This proved successful and allowed them to determine both the physiologic rest position and the vertical dimension of occlusion of edentulous patients. However, their sample population was not defined.



Mack (1991) stated that the location of the occlusal plane should be evaluated aesthetically, functionally and cephalometrically. He added that, the long-term steadiness and comfort of the occlusion was a sign of the stability of the condyles and physiologic muscle balance. Orthlieb and co-workers (2000) confirmed that cephalometric measurements, regardless of its limitations, could help the practitioner obtain a more accurate measurement of the facial vertical dimension of occlusion.

However, with all the positive studies conducted on cephalometric radiographs, Dixon (2000) states that the practice of measuring and recording the OVD via this

method was not commonly used. According to Atwood (1966), the dose of x-radiation exposure is very small, due to intensifying screen and fast film usage. Be that as it may, this does set some restrictions to this type of methodology. Justification of unnecessary radiation exposure for the recording of a measurement, where other safer methods exist, all be its accuracy questionable, remains debatable.

## Swallowing

The use of swallowing as a method for recording centric relation is a widely accepted practice. It is a 24-hour function that occurs in everyone. According to Abdel-Hakim (1982), the mandible travels from the rest position to centric relation and back to rest the position during swallowing. This pattern remains fairly constant throughout life.

Traditionally, the term centric relation has many meanings. Some authors believe that the centric relation position of the mandible related to the maxilla occurs when a person swallows (Dixon, 2000). However, the problem arises when the meaning of centric relation or centric position is considered, because even though swallowing brings the mandible to the retruded position, it is possible for a person to swallow in a position which is not in retruded contact position (Abdel-Hakim, 1982).

Millet and co-workers, (2003) performed a study recording OVD and centric position. They then compared the swallowing technique to a technique using acrylic base plates and a Boley gauge, both measuring the same variables. They made a significant conclusion, that swallowing can definitely be used to determine the vertical position, but not as a reference position in the sagittal plane. In their study swallowing was found to be 2mm anterior to the centric relation position, and moderately reproducible.

In another study done by Koller and co-workers, (1992) speech and the rest position was compared to swallowing, and then orientated to the occlusal plane to measure OVD. They concluded that there were no statistically significant differences between the mean OVD with both methods. However, the time spent with the swallowing technique to orientate the occlusal plane was significantly much less than with the speaking method.

Swallowing, because of its fairly consistent nature, proves to be a valuable method in establishing the OVD. However, it needs to be used in conjunction with other methods to increase its reliability.

## Anthropology

As mentioned by Farkas (1994), the nasion is a point on the facial midline. It is deemed to be the most stable landmark of the three. The FAD uses this marker in its measurement of the OVD.



Studies done by Delic and co-workers (2000 and 2003) examined relationships between different craniofacial distances and vertical determinations of the face. In 2000, they studied the distance: subnasale – gnathion (Sn-Gn), which represents the lower third of the face, and 2003: nasion – gnathion (N-Gn), which represents the lower two-thirds of the face.

They concluded that the N-Gn measurement was better than the Sn-Gn, but that neither was absolutely reliable and should be used in conjunction with other methods of determining OVD.

## MECHANICAL METHODS

Mechanical methods of OVD measuring systems make use of instruments which measure soft tissue landmarks. The literature speaks of a number of studies which have calibrated instruments in order to measure bony landmarks through the skin (Mack, 1991; Olsen, 1964). When employing these methods the thickness of facial tissue, asymmetry of the face and human skilfulness limits its accuracy.

There are several articles (Geerts *et al*, 2004; Morikawa *et al*, 1988) written on devices designed or specifically invented to measure facial OVD. They range from simple modified caliper-type measuring devices i.e.: 'TOM gauge' to Intra-oral hydraulic jacks to computerised systems which guide dentists by way of recording dimensions and making observations thereof i.e.: 'Byte-Ryte'. The instruments commonly used at the University of the Western Cape to date, are the Willis gauge and the dividers. These will be discussed in more depth.



According to Chou and co-workers, (1994) the Willis gauge is designed to measure the distance from the lower border of the septum of the nose to the lower border of the chin, and the distance from the outer canthus of the eye to the corner of the relaxed lip with the teeth in occlusion. In theory, these measurements should be equal. However, the asymmetrical character of faces makes the average measurements with these anatomical landmarks questionable (Tina-Olaivar and Olaivar, 1998).

A study performed by Tina-Olaivar and Olaivar (1998), proved the doubtful nature of the above statement to be true. They found that the upper facial measurement was in fact longer than the lower facial measurement by 3mm.

Another study done in Nigeria, reported measuring the OVD using a Willis gauge as well (Olusile *et al*, 2003). They measured Resting Facial height and OVD and

subtracted the two to determine the Freeway space. This study used gender as the main variable, and concluded that there were no statistically significant differences ($P$ = 0.17) in the measurement of Freeway space with regards to dentures between females and males. They added that the mean freeway space they found in their study was 3.3mm.

The reliability of skin markers in the determination of OVD was tested using dividers, which was performed by Carossa and co-workers, (1990). They found substantial differences between skin markers and bone measurements. This was confirmed by Mack (1991), who ascertained that bone OVD measurements were more accurate than soft tissue measurements. These bone measurements involve utilizing radiographic landmarks to quantify its dimension (Olsen, 1964), the concerns of which have already been expressed.

A study comparing instruments namely: dividers and the Willis gauge was performed by Geerts and co-workers (2004). This study used pre-doctoral students to measure the OVD. In their study, the dividers measured the distance between two reference points on the tip of the nose and the chin. They concluded that the use of the dividers was significantly a more reliable method of determining the OVD.

Another such study performed by Johnson and co-workers (2002), used 72 dentate subjects and measured freeway space using the Willis gauge and sprung dividers. They measured both inter and intra-operator variability. The Willis for both Inter and Intra-operator variability was the same at 3.3 mm, while the dividers were 3.1 for intra and 2.9 for inter-variability. They concluded that there were no statistically significant differences between any of the combinations ($P$ > 0.05), however individual measurements within the 2 measuring methods showed statistically significant differences ($P$ < 0.05).

Hence, the debate continues with regards to the effectiveness of several commercially available methods that are used to aid the measurement of OVD. According to the literature, no appropriate reliability testing of devices have adequately been conducted and therefore none of the instruments reviewed can be said to be more accurate than the other. They are merely supplementary devices and should be used in combination with one another (Rivera-Morales and Goldman, 1997).

When determining the OVD, it is the final result that matters. In order for the skilled reproducibility thereof Mariotto and co-workers, (1989) advises that continuous practice of the measuring instruments prior to the actual measurement is crucial.



This review agrees with current literature, that combination approaches of mechanical and physiological methods are fundamental. The act of swallowing during the bite registration and try-in stages to find the RVD has proven quite valuable. In addition, the pronunciation of letters such as ‘m’, during the try-in stage and the subsequent evaluation of the level of the upper anterior incisors relative to the lips is a useful guide.

No matter what the procedure, the result should be satisfactory to the dentist and the patient from an aesthetic perspective. Moreover, it should not induce degenerative changes from a functional viewpoint. The OVD must be determined carefully by the dentist for a successful prosthesis.

# CHAPTER 2

## BACKGROUND

## INTRODUCTION

It is generally agreed that modern dentistry has progressed at a rapid pace and research has become the main focus for developing and presenting these new ideas. Thus, with the introduction of dental implants in the mid 60's, to its increased commercial use in the late 70's, the awareness of preserving natural tooth and bone structure has become a huge focus over recent years. This has led to a decline in the teachings of complete denture construction in the curriculum of most undergraduate dental schools, especially in developed countries (LaBarre *et al*, 2007). It is the author's opinion that this is due to a surge in an individual's awareness of his/her social reassurance and attraction. This in turn has led to an increase in cosmetic surgery in first world countries, which is fast being adopted by developing countries such as South Africa.



Conversely, in developing countries denture construction and teachings thereof remain the chief prosthetic rehabilitation techniques due to lack of awareness, finances and resources. In this context, it is clear that affordability and access to basic dental services plays an important role in an individual's sense of well-being or hardship.

When fabricating complete dentures, many clinicians believe they are competent enough to offer patients a varied range of options for their treatments. However, quite a vast number confess that complete denture fabrication sometimes triggers feelings of nervousness and inadequacy in them (LaBarre *et al*, 2007).

It is generally accepted that most clinicians make mistakes when complete denture fabrication is attempted initially. These blunders cause inexperienced dentists to lose confidence in their ability and in addition increased cost to the

treatment budget. The only way to overcome this is to gain sufficient clinical skill in constructing functionally accurate complete dentures, by performing a number of clinical cases. This will allow dentists to master the progression from the initial primary impression stage to the adjustments made at the recall visit. LaBarre and co-workers, (2007) believes that the practice of constructing 50 dentures is sufficient to gain adequate clinical experience and be confident when fabricating future complete dentures. In addition to a good clinical knowledge of denture construction, a sound awareness of the laboratory aspects can prove invaluable.

It would be beneficial for both the clinician and patient to be involved in assessing the existing or previous dentures merits and problems. This may be done by assessing the old dentures aesthetics, phonetics, comfort and function. By identifying and considering the negative traits of the old denture, a new opinion may be formed so that the clinician has a treatment plan specific to the needs of the patient.



This thesis focuses discussions on OVD in relation to removable denture construction, in particular complete denture fabrication and has discluded any fixed treatment options available in Prosthodontics. The hypothesis which prompted the present investigation is based on the fact that OVD in edentulous patients is troublesome to record and it is generally agreed that there is no completely accurate method of determining this record in edentulous individuals (Geerts *et al*, 2004; Meier *et al*, 2003; Chou *et al*, 1994; Weinberg, 1982).

There are however certain forces which act on natural teeth in order to facilitate movement thereof towards an optimal functioning natural dentition. Similarly, in full denture construction, these same forces continue to act and it is our duty to try and understand how this comes about, so we have a comparable optimally functioning artificial dentition. For the purpose of this thesis, the principle

importance of this vertical relationship of the face continually referred to: is its effect on occlusion and how it compares and influences the vertical and horizontal dimensions of the face.

## Concept of Occlusion

It is generally accepted that there are many characteristics which distinguish mammals from other vertebrates, however the following are key components when measuring OVD: a lower jaw consisting of one single bone and the temporomandibular joint. In addition to these, the masticatory system also known as the 'functional unit' which includes: a heterodont dentition; neuromuscular system and cranio-facial structures are important (Harper and Misch, 2000). When constructing adequately functional complete dentures, a sound knowledge of these features are needed, as well as a good understanding of the denture bearing mucosa, and the structures surrounding and influencing its limitations.



According to Davies and co-workers (2001), traditionally complete denture Prosthodontics was the forerunner in the study of occlusion, as most of the terminologies used derived its basis from this subject matter (fig 5).

**Terminology**

| | | |
|---|---|---|
| Centric Relation (CR) | = | Retruded Contact Position (RCP) |
| Centric Occlusion (CO) | = | Intercuspation Position (ICP) |
| Working Side | = | Non-balancing Side |
| Balancing Side | = | Non-working Side |

Occlusal Vertical Dimension (OVD) = Vertical Dimension of Occlusion (VDO)

Resting Vertical Dimension (RVD) = Resting Facial Height (RFH)

**Fig 5: Terminology used in Occlusion**

The terms ‘centric occlusion’ and ‘centric relation’ will be used, instead of its counter parts: ‘intercuspal position’ and ‘retruded contact position’ respectively. The working and balancing side terms are based on the viewpoint of complete denture occlusion, where the balancing side refers to the region not being used when chewing and the working side refers to the region grinding/chewing during lateral excursive movements of the mandible against the maxilla. The terms occlusal vertical dimension and resting vertical dimension have previously been mentioned.

It is extensively documented that occlusion in complete denture construction is an important consideration; because the correct occlusal scheme has a direct and substantial impact on the stability of the denture (Harper and Misch, 2000; Watt and McGregor, 1976). In addition, it ultimately determines the overall success of the prostheses. It is also generally accepted, that forces within the jaws cause a tooth to erupt until it meets its counterpart from the opposing dentition. If this meeting does not occur, the tooth in question will keep erupting until it meets the opposing alveolar ridge. When the opposing teeth meet up, eruption ceases and the OVD is created in the natural dentition.



When patients become edentulous, the importance of prosthetic intervention at this point, is to produce a substitute which would sufficiently restore this portion previously served by the natural dentition. In doing so, it should re-establish the lost aesthetics, speech and mastication. Remarkably, in this edentulous state it is important to remember that although the teeth have been removed, the previous vertical and horizontal relationships continue to influence the type of the movement of the mandible (Watt and McGregor, 1976).

In order to understand this, one needs to consider that when referring to occlusion, it is normal for dentists to look at it from a ‘tooth’ point of view, but

there are certain processes occurring in the brain which need to be considered. According to Watt and McGregor (1976), subconsciously there exists a blue-print of *'sensory feedback'* from the mouth to the brain. This allows the brain to remember the original relationship between the muscles and tooth positions. The sensory nerves supplying the teeth, periodontium, joints and muscles, contribute to creating this *'stored'* pattern.

If the pattern is disturbed in any way, for example by faulty tooth contacts, the muscles tend to adjust, allowing closure to continue until a recognisable pattern is established (Watt and McGregor, 1976). Every distorted occlusal contact creates a feedback, whereby the patient tries to find the missing pattern. If unsuccessful, a changed occlusion is established leading to a habitual position. Similarly, Harper and Misch in 2000 agreed and reported that the tempero-mandibular joint (TMJ) as well as the periodontium possess an adaptive capacity. They add that it is the fluid compartments within these structures which respond first to trauma and thereby modify themselves in response to the strained positions.



When this happens to both the occlusion and its related structures, it is foolhardy to fabricate any future prostheses until the uncoordinated muscle activity and inaccurate occlusion are corrected (Watt and McGregor, 1976). The longer the problem persists, the more difficult it will be to correct and ultimately result in an undesired change in morphology of the TMJ.

These long-standing changes may result in a number of problems. They include: facial pain, limited opening of the mandible and deviation of the mandible to the affected side on opening. These have proven to be the most common problems and in the authors opinion, poses the greatest difficulty in the management of complete dentures.

To re-establish the lost mastication, aesthetics and speech the unique horizontal and vertical relationship of the mandible to the maxilla needs to adequately be recorded. Its success depends on the dentists' ability to produce the correct vertical relationship in harmony with the opposing occlusal contacts. These occlusal contacts in turn, need to be in agreement with the optimal functioning of the masticatory muscles, as well as the temporomandibular joint (TMJ). In addition, it has to produce a good quality connection between the prosthesis and the denture bearing mucosa and oral musculature (Harper and Misch, 2000).

McCord and Grant (2000), report of various methods of registering the bite of an edentulous patient. These methods enable the centric relation (CR) position to be recorded. Each, they say have their varied levels of success.

**Methods of Registering the 'bite':**

1. Wax squash bite
2. Wax rims
3. Intra-oral tracing (Gothic arch tracing)



**Fig 6: Methods for registering the centric relation position**

In the 'wax squash bite' technique, the lower bite block is reduced to incorporate a folded or double-sided, horse-shoe shaped layer of wax between the opposing bite blocks. The mandible is manipulated into centric relation and the bite recorded. In this method, the CR position is not assured and the OVD not entirely controllable. In addition, if the wax is not heated sufficiently, it would distort the actual registration procedure.

In the 'Wax rim' method, which is the preferred method of bite registration when fabricating complete dentures at UWC, upper and lower bite blocks are used. The bite blocks are evaluated in the patient's mouth for optimal retention and the

chief aesthetic control markings are recorded on the upper trial base. With only the upper in position, the occlusal plane is established. This is done by melting the wax to an acceptable level, i.e. parallel to the ala-tragus line and according to good clinical judgement (UWC). A Fox plate may be used in order to ensure this measurement is recorded as accurately as possible. Once completed satisfactorily, the RVD is recorded using either of the mechanical methods described in this thesis i.e.: Willis gauge, dividers or the newly developed FAD. At least two methods are advocated by the University in order to double check the height (UWC). These methods should include one physiological method and one mechanical method in order to ascertain the accuracy of the recorded dimensions. Thereafter the CR position may be practiced by persuading the patient's mandible towards its most posterior position along the terminal hinge pathway (UWC).



In completely edentulous individuals, the centric relation position equals the centric occlusal position. From the RVD measurement 2-3 mm is deducted which indicates the amount of freeway space or interocclusal distance between the opposing rims. The difference equates to the estimated OVD. The lower wax block is then placed in the patient's mouth and reduced evenly until the desired resting length is achieved. The lower rim is governed by the height of the upper rim. It is then continuously assessed to ensure there is sufficient freeway space provided. The measurements may also be compared to the previous dentures (UWC). Sometimes, it may be necessary to adjust the upper if the lower is too large, which may cause problems in stability or too short which may compromise the space available for the setting up of teeth.

Lastly, the appearance of the patient should be evaluated; as well as the patient's profile and peri-oral tissues should be appraised. Once an acceptable practice routine for the position of the CR has been achieved, keys are cut in the upper wax block in the vicinity of the first and second molars. In a position adjacent to

the keys, a section of the lower block is removed. Aluwax is heated and placed on the lower wax block in the region prepared and the CR recorded (PIC?). With the aid of petroleum jelly on the upper keys, the bite may be re-evaluated for any premature contacts or interferences in CR and the necessary changes, if any, may be made (UWC).

Assessment of the bite registration includes the following - When outside the mouth: if the wax rims do not occlude completely or if the posterior flanges contact, the registration should be rejected (UWC). When inside the mouth: if the OVD looks incorrect; or upon repeated closure the keys fail to match up evenly and without interferences, the bite should be retaken. It should also be retaken if the freeway space is inadequate; or the patient's appearance is unpleasing or the stability compromised (UWC).



Numerous authors, (Dixon (2000); Parker (1993); Watt and McGregor (1976)) agree that probably the most important position on the horizontal path of movement is the CR position. They state, that it is from this position that the excursive movements of occlusion start and also the position where the teeth eventually meet after closure. It is the retruded mandibular position which is independent of tooth contact; it is more specific than the vertical dimension and is reproducible (Dixon, 2000). It is at this point: the actual recording of the CR, where significant inaccuracies may arise.

Harper and Misch (2000) advocate that there are two foundational principles which dictate OVD. They include: Firstly, when measuring the OVD its commencement should be from the centric relation position. Secondly, the restoration of the OVD must be within the neuromuscular limitation of the patient. If these are adhered to, they believe the OVD may be increased. The challenge is to produce both of these limits on an individual patient basis every time a complete denture is made.

When recording CR, some patients have the ability to relax their muscles so that adequate manipulation of the mandible is possible in an up and down motion, as it rotates about the condyles. This makes it easier for the mandible to be directed posteriorly towards the CR position. Others however, find it hard to unwind or loosen their muscles sufficiently, thus a useful method for them would be placement of their tongues in a curled back position, directed towards the postdam area. This allows their jaws to 'fall back' into CR and the position recorded. In addition, it helps to practice methods of recording the CR position repeatedly before the actual measurement is taken.

In the Gothic arch tracing technique (fig 7), attempts to record this position uses both horizontal mandibular movements and to some degree vertical mandibular movements, which relate to the hinge-axis markings. The hinge-axis is a line between the mandibular condyles around which the mandible can rotate without translator movement.



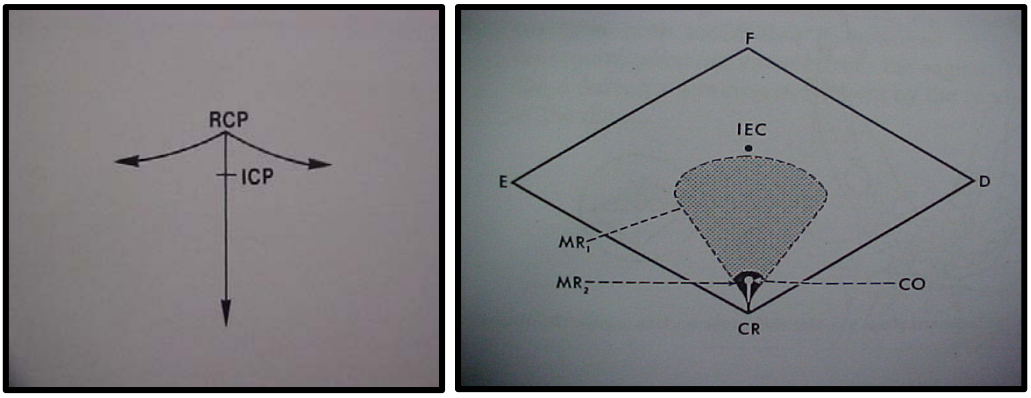



**Fig 7: Gothic Arch Tracing - horizontal plane, observed from the incisal area.**

McCord and Grant (2000) eagerly reported that for them, the best method of registration is the Gothic arch tracing, for the simple reason that, when performing lateral excursive movements, it repeatedly recognises the CR position of the mandible relative to the maxilla. Their article however, used light-cured

polymethylmethacrylate (PMMA) bases attached to metal bars or screws and the procedure is a bit complicated. This method is not very practical for every patient having complete dentures fabricated.

After recording the jaw relation in clinical practice, the dentist is able to provide the dental technician with a correct vertical and horizontal relationship. It also defines the required shape of the dentures. Once the jaw relation is recorded, the models with the established bite are then mounted on an articulator. The technician now has a three dimensional prescription of the patients' mouth and is able to then set-up the teeth according to the specific guidelines provided by the clinician.

Whatever the method of registration, for the success of the prosthesis, all these relations need to be correctly recorded and transferred to the articulator, where the existing movements of the patient can be replicated. In addition to the three-dimensional bite registration and the aesthetic control markings recorded on the upper record block, a facebow recording may be done on the patient, which increases the accuracy of occlusion. If the denture recordings are unsuitable for the dimensions of the patient's mouth, the dentist should be well-informed to detect the inability of the patient to cope with the new denture provided. It is the author's opinion that dentists be aware of the stages involved in every aspect of denture construction, both clinical and laboratory supported, as this provides an invaluable basis for problem solving and thus lessening the amount of time and money spent on fixing problems which may arise.

Proper evaluation of the OVD is best done at the try-in visit. Here the freeway space may be checked, the CR position may be confirmed, evaluation of the teeth may be done to confirm that they have been setup in the neutral zone and the fit assessed. The flanges need to be appraised, to ensure that they do not displace

the musculature of the lips as well as the cheeks, and that the lower has provided sufficient freedom of movement for the tongue.

In general, if it is perceived that the OVD is increased excessively, patients may have difficulty in speaking; complain of pain under the denture base and a feeling of tiredness. The oral mucosa will become sore and inflamed due to the excessive load caused by the continuous tooth contact. They may also complain of clicking of the teeth during speech and report of having to remove the lower denture to obtain some form of relief. With regards to appearance, the mouth may look strained due to the Orbicularis oris muscle group unable to effect proper closure of the lips. When the vertical dimension is excessively decreased, overclosure results. Patients are left with an unattractive appearance, because the musculature loses its efficiency, thus resulting in an aged appearance. In addition a protruded mandible and possible dribbling also occurs. They may also suffer from inflammation or fissuring of the corners of the mouth, commonly known as angular cheilitis/stomatitis.



Warren and co-workers (1991) reported that changes to the OVD do not cause disorders of the masticatory system as some authors claim. Their study reports that research has shown that slight increases in the OVD, where the appliance covers the occlusal surfaces, in other words – a diagnostic denture initially, shows good adaptation to change.

Concern should be addressed at this stage of construction if a patient presents with either an excessively decreased or increased OVD. Although the freeway space is an average value for most patients, it should not be assumed that for these patients the same rule applies. It should be borne in mind that, they may require a larger or smaller OVD in order to adjust to a new prosthesis. At this point, good clinical judgment and some experience are of utmost importance.

**VERTICAL AND HORIZONTAL DIMENSIONS**

It is widely acknowledged that our face is a unique feature of our bodies. It identifies us from each other more easily than any other part of our bodies. It allows us to recognise unique features of each other – and so if we change one part, we ultimately change the entire face. It enables us to highlight obvious differences separating us from those of our own species.

The teeth are another important aspect of the face which affects our appearance. While the bones of the facial skeleton support the cheeks, nose and forehead, so the teeth support out lips and determine to some extent the shape and form of the mouth. Unlike the facial bones which are hidden, the teeth are often visible when we speak, laugh or smile. It is these factors which determine the extent of the facial dimensions we speak of.



According to Watt and McGregor (1976), both the vertical and horizontal relationships are related, because the success or failure of the denture depends on the proper registration of both these dimensions. To assess a patient's vertical dimension for diagnostic and restorative reasons, LaBarre and co-workers, (2007) state that it is the amount of freeway space which is the concluding clinical criterion. It in turn is dependent on the resting facial height and the occlusal vertical dimension. These dimensions are shaped at the registration visit, when the CR is determined. Its extensions vary widely among individuals and between different areas of the mouth.

Formerly, the resting vertical dimension was thought to be constant throughout life (Harper and Misch, 2000; McCord and Grant, 2000; Weinberg, 1982). However, we now know that the rest position is altered by a number of postural positions, as well as intrinsic and extrinsic stimuli such as age, disease and human emotions (Watt and McGregor, 1976). Although this variation is present, the RVD still remains an initial, clinically useful reference point to help determine OVD

(Chou *et al*, 1994; Weinberg, 1982). The reason for this is due to the fact that it plays an important role in the appearance of the denture wearer. In addition McCord and Grant (2000) state, that it is an important factor when determining whether a patient will be able to tolerate wearing dentures without intra-oral damage occurring.

It was Niswonger (1934) who proposed that from the measurement of the resting vertical dimension, the average freeway space may be estimated at about 3 mm, and by the process of subtraction the occlusal vertical dimension can be calculated. (i.e.: RVD – FS = OVD)

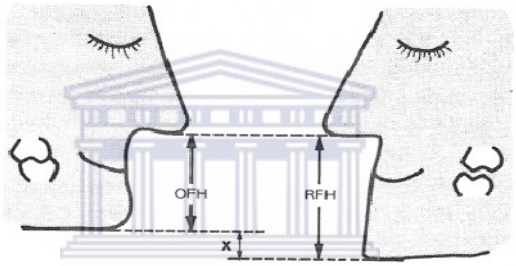



**Fig 8: The difference between resting facial height (RFH) and occlusal vertical dimension (OFH) is the freeway space (X) (Basker *et al*, 1976*)***



Watt and McGregor (1976) cited that the horizontal movements of the mandible have distinct limits. These limits are divided into border movements and intra-border movements. Both they say, are affected by the health of the facial muscles, nervous system as well as, joints and ligaments. They add that border movements are more easily reproducible than intra-border ones and are neither influenced by the presence or absence of teeth, nor by head posture.

Freeway space has been shown to range on average between 2-4mm, but some studies demonstrate patients adapting to interocclusal distances of 2-8mm without pathosis (Harper and Misch, 2000). This was confirmed by a study done in 2002 by Johnson and co-workers. In their study where they used 72 dentate

subjects to measure the average freeway space, they found that the majority of subjects showed a measurement of 2-4 mm, but 15% had a measurement outside of this range. The conclusion was that the range of freeway space realistically was between 2-7 mm.

The very fact that there is a range shows the lenient character of the dimension and the adaptable capacity of human beings. The establishment of the precise freeway space for a specific patient is therefore a matter of clinical judgment, experience and clinical trial. According to Laney and Gibilisco (1983), it is unacceptable to give all patients the same amount of freeway space. The physiologic methods discussed in the literature review should be used during the try-in visit to assess its correctness. They state that it is sensible to give the elderly patient and patients who have extremely resorbed ridges more freeway space (Laney and Gibilisco, 1983).



The manner in which people speak also needs to be considered. Some individuals have a small range of movement of the mandible and thus can be said to 'speak between closed lips' (Watt and McGregor, 1976). Conversely, there are others who have a wider range of movement of the mandible when speaking. Mutually, these characteristics to some degree, intrudes on the freeway space. Thus, individuals with a wider mandibular movement during speech require more freeway space than those with a smaller range. Watt and MacGregor (1976) further reported, that it's not the freeway space that is the critical factor here, but what Silverman (1953) described as the '*closest speaking distance*'. They both suggested that all complete dentures should have both a closest speaking space of 1mm as well as the freeway space, between the ranges of 2-7mm.

In addition, Watt and MacGregor (1976) states that it is difficult to determine with any measure of certainty that an edentulous person had competent lips before dental clearance occurred, except if pre-extraction photographs were

available. They state that dentate patients often exhibit competent lips, but complete denture wearers seldom do. They further report that the assessment of strained lips during denture construction should not be a deciding factor for VDO measurement.

As mentioned earlier, a number of methods were found to be used to establish the all important vertical and horizontal relationship of the mandible to the maxilla. Depending on what you were taught and the resources available to clinicians, the combination of methods varied between operators. When choosing a method, certain criteria have been suggested: precision and flexibility of the technique, consistency of the measurement, the nature and complexity of the equipment needed, cost, and the length of time required to make the measurement (Fayz and Eslami, 1988). The instruments commonly used at the University to date are the Willis gauge and the dividers. A new devise invented by a South African dental technician prompted the purpose of this thesis.



**RELIABILITY AND VALIDITY:**

An instrument is reliable to the point that whatever it measures, it measures it consistently (Siegle, 2008). In this study the test-retest method of reliability was used. The measurements were made twice on the same patients with all three devices mentioned in the study. The difficulty with test-retest reliability, is deciding how long to wait between measurements. As this study involved devices used to record millimetre measurements of facial landmarks, the decision was to wait four to seven days to retake the measurements.

An instrument will be valid, if its' scores allow suitable deductions to be made about a particular group, for a particular reason (Siegle, 2008). The FAD is valid as it is a device used to measure occlusal vertical dimension in people, whether dentate or edentulous.

# CHAPTER 3

# METHODOLOGY

## 3.1 AIM:

The aim of this study was to determine the reliability and validity of the newly developed FAD, and compare it to the instruments more commonly used today: the Willis gauge (standard) and Dividers.

## 3.2 OBJECTIVES:

- Using a Willis gauge, Dividers and FAD to measure the OVD of dentate patients.
- Using a Willis gauge, Dividers and FAD to measure the OVD of edentulous patients.
- Using the Willis gauge, Dividers and FAD to measure the OVD on the same patients (dentate and edentulous), one week later.
- Make recommendations about the use of FAD: its reliability, validity and feasibility as a mechanical device for measuring OVD.



## 3.3 NULL HYPOTHESIS

The Null Hypothesis states that there is no significant difference with regard to validity and reliability between the three instruments namely, the Willis gauge, dividers and the FAD.

## 3.4 STUDY DESIGN

This study used a Quantitative analysis design to compare three VDO measuring systems. These measurements were recorded in millimetres (mm).

## 3.5 SAMPLE SIZE

The study population were randomly selected. A pilot study was undertaken, which is discussed in a later chapter. The actual study sample size comprised: 35

dentate and 35 edentulous subjects. The pilot subjects were included in the actual study sample. Dentate and edentulous subjects were aged between 30-70 years. These were patients who presented for treatment. Both Dental hospitals (i.e. Mitchell's Plain and Tygerberg) were used to collect the sample of participants.

All subjects were screened to determine their suitability for this study. Dentate subjects were selected on their occlusal health. Only dentate subjects who had healthy bilateral molar support were considered. Edentulous subjects were randomly selected using the hospital's denture register, as well as, some were chosen during the delivery stage of student denture construction and then re-measured at the recall visit. Fully edentulous subjects, who displayed satisfactory or functionally sound removable upper and lower denture made within the last 2 years, were considered. Those who required moderate to large amounts of modifications to their dentures were not included.



**3.6 DATA COLLECTION**

The data was recorded on a record sheet. Edentulous subjects had a screening number from E01 to E35. Similarly, dentate subjects had numbers ascending from D01 to D35.

One examiner recorded all the measurements: using the FAD, Willis gauge and the Dividers to rule out any inter-examiner variability. The instruments were standardised before use. Only quality instruments were used. The devices' linear markings were blinded to the examiner, using exposed and disposed of x-radiation films. The measuring techniques were practised prior to recording of the facial height, to confirm that these supplementary additions did not interfere with the recording of the data. All three devices were consecutively applied, but not quantified until the examiner was absolutely certain. The measurements were made thrice and an average recorded as the final measurement. When

measuring these soft tissue landmarks, the hard edge of the instrument gently and firmly contacted the skin, but was not pressed against the skin surface. Another measurement for each instrument, taken in the same manner was recorded one week later on the same patient and the reliability of the instrument tested.

In each of the cases the subjects' posture was of utmost importance. For measurements, the subjects were seated in the dental chair with the head resting on the head support of the dental chair and their back up right. The examiner stood in front of the subject. The head of the examiner was at the level of the head of the subject. The subjects' were asked to look straight ahead and bite gently, so that their posterior teeth were in contact. Subjects were reminded not to clench, but only to hold in centric occlusion. This position was repeated after every measurement to preserve uniformity. Each measurement was read and written down on a separate blank sheet of paper, then transferred to the record sheet by the same examiner. The next patient was only measured thirty minutes later.



## 3.7 EXCLUSION CRITERIA

All patients with:

- Facial or nasal deformities,
- TMJ pathology,
- Mental disabilities.

Dentate:

- Patients who did not have a definite centric position.
- Patients with Occlusal pathology, eg: attrition, loss of vertical dimension, no posterior teeth.
- Patients with Periodontal problems.

Edentulous:

- Patients who have worn-down acrylic teeth or monoplane teeth.
- Patients with denture related problems, eg: epulis, stomatitis
- Patients with 'bite' problems (eg: reverse or open bites).

## 3.8 DATA MANAGEMENT

Data quality was maintained throughout the study by the same examiner who recorded the data. The data was checked for accuracy and logged. The transformations which were required to develop and document a database structure which integrated the study's various measures were implemented.

## 3.9 DATA ANALYSIS

Data was entered into a computer using Microsoft Excel for statistical computation. It was analysed using SPSS statistical package. Paired sample t-tests were done to determine significant differences ($P < 0.05$).



## 3.10 STUDY LIMITATIONS

Possible limitations of this study could include:

1. Improper identification of the landmarks
2. Faulty measuring equipment
3. Non-standardised equipment
4. Improper instrument usage

## CHAPTER 4

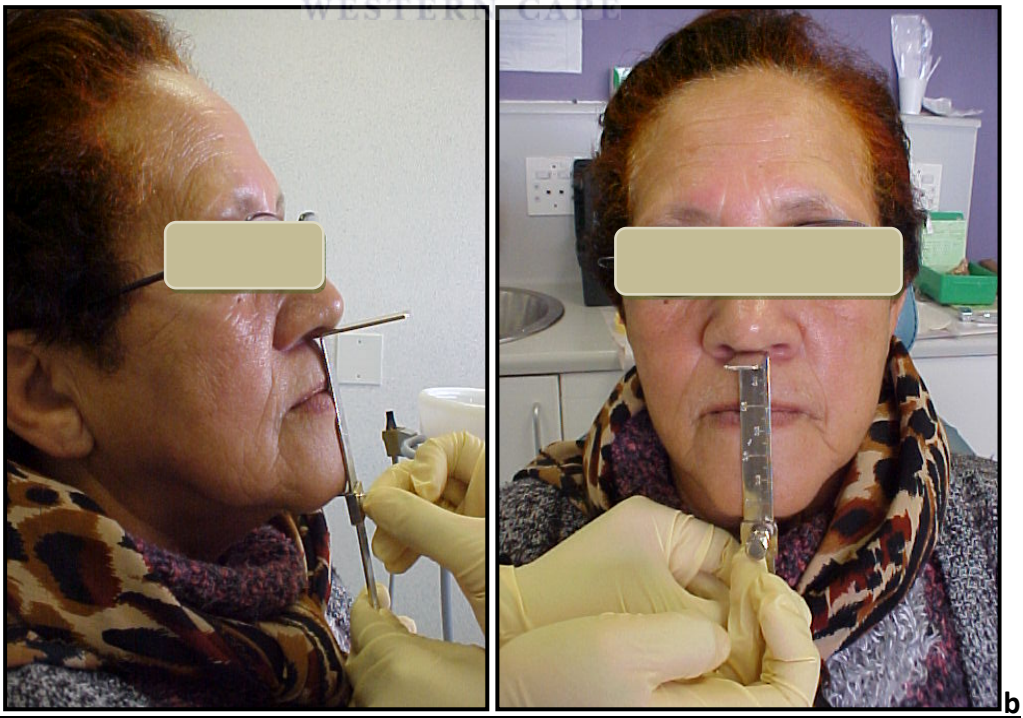
## DEVICES AND MEASURING METHODS

Instruments used and their landmarks:

### Willis Gauge:

**Fig 10: Willis gauge with an integrated scale, used to measure RVD and OVD**





**a** **b**

**Fig 11: Positioning and recording of the OVD using a Willis gauge**

The Willis gauge was used to measure the distance from the base of the nose - subnasale (sn), to the lower border of the chin in the midline - gnathion (gn)/menton (m). The fixed arm with the linear portion facing the operator was placed firmly against the anterior nasal spine as shown in Fig 6. The movable arm was then firmly placed on the under surface of the mandible and the patient asked to occlude gently. The reading was then recorded from the instrument.

## Dividers:

**Fig 12: Dividers used to measure RVD and OVD**



a b

**Fig 13: a. Indelible pencil markings depicting the arbitrary points and b. Positioning and recording of the OVD using a Dividers**

The dividers represent a linear measurement of 2 arbitrary points: one in the tip of the nose and the other on the chin. These points are made on sites which represent minimal muscular and skin movements. These sites should be chosen after careful observation of the patient when seated upright in the dental chair.

With their sharp points, dividers make it easy to pin-point markings and are most frequently used to measure between two points. The measurements are then easily and accurately read using a ruler.

## Facial Anthropological Device (FAD):

**a.**


**b.**

**Fig 14: (a) Facial Anthropological Device(b) illustration of its water-level**

## BACKGROUND OF THE FAD:

The FAD was developed in March 1999, by a South African dental technician. Initially it was named after the inventor, 'Z. Gordon-Fatagodien bite registration device' (fig 15 and 16), but the name was later changed to the FAD (Facial Anthropological Device). It was developed as a dental-facial measuring

instrument, in order to make bite registration during the construction of complete dentures easier for both the dentist and technician. Ultimately, it was the inventor's intention that the FAD's dimensions be integrated onto an articulator in order to make the recorded measurements more transferable and the setting-up of teeth easier.

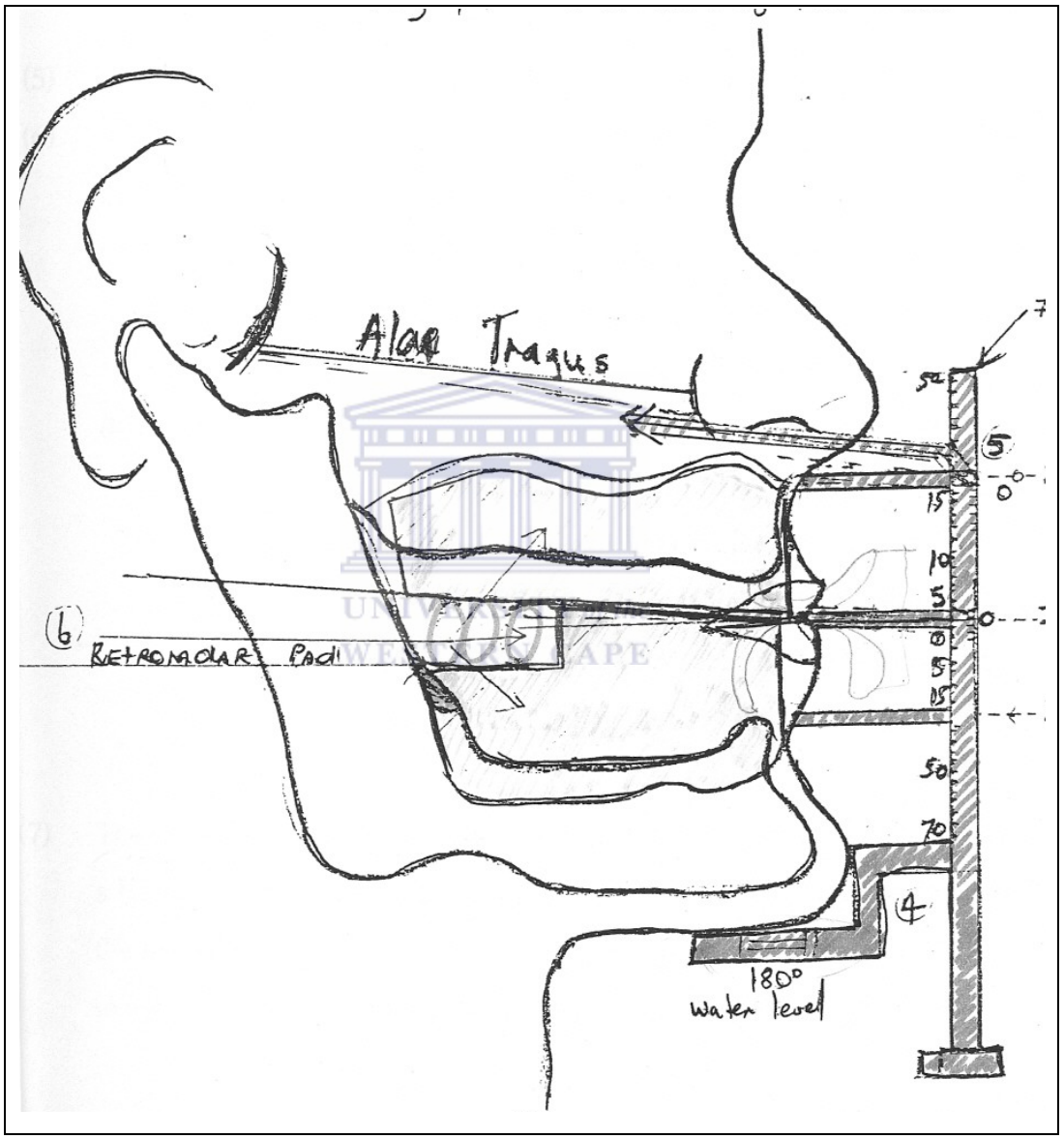



**Fig 15: Illustration of the Z. Gordon-Fatagodien device – original FAD**

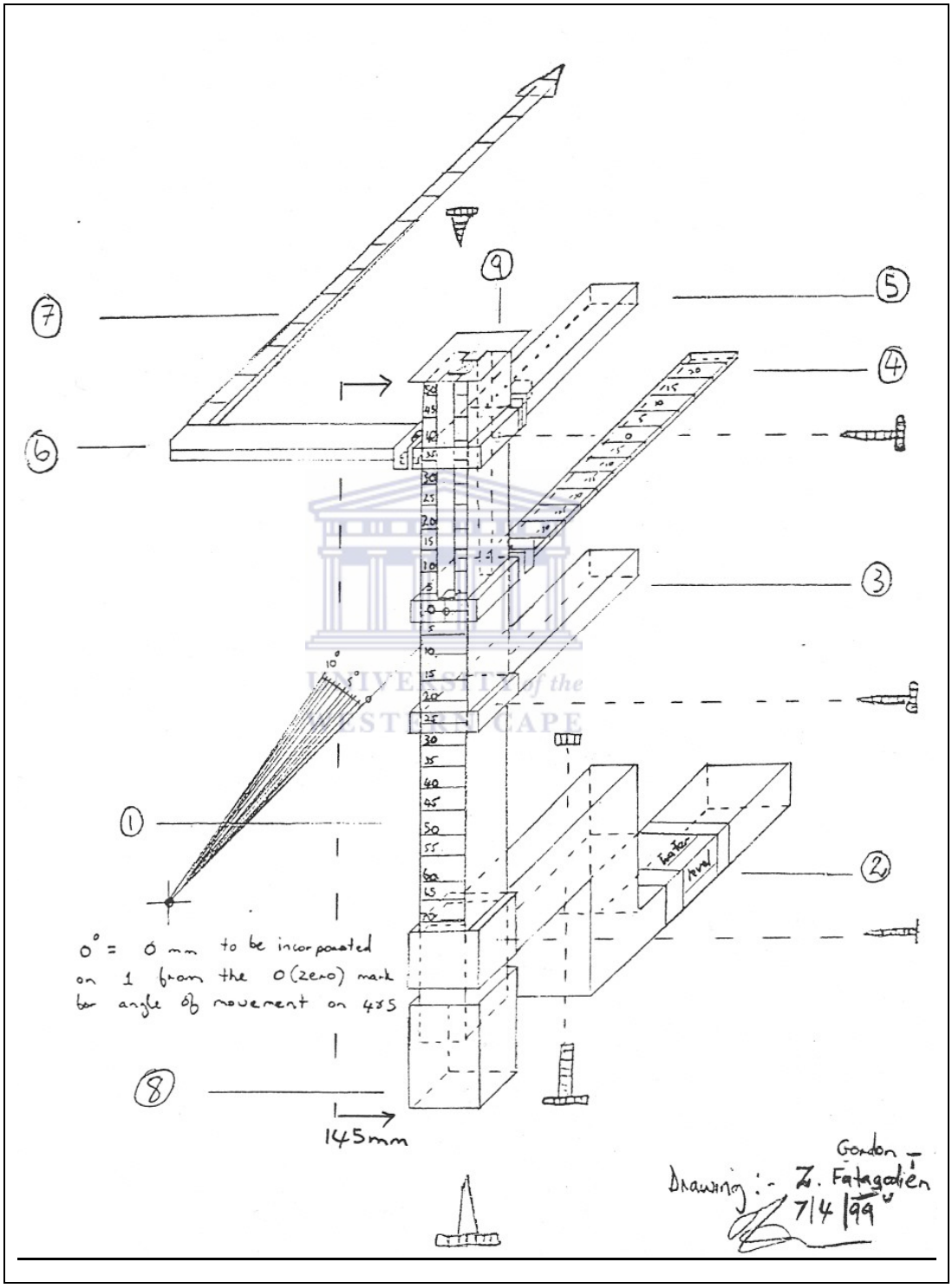



**Fig 16: Actual size and design of the Z. Gordon-Fatagodien device**

The FAD measures a linear measurement in the midline of 3 landmarks: nasion (n), subnasale and the gnathion(gn)/menton(m). It is a dental facial measuring instrument, which provides an opportunity to measure the height of the facial landmarks in the midline (fig 18).

The instrument is composed of:

One fixed horizontal metal arm placed at the bridge of the nose (nasion). This arm is fixed to a vertical support with a measuring scale.


**Fig 17: Positioning and recording of the OVD using the FAD**

The rest of the instrument is comprised of movable arms positioned at varying distances along the vertical bar Fig 11:

a) At a point below the nose with a screw to immobilise it (subnasale)

b) One between unstrained lips with a screw to immobilise it (stomion) – *not used in this study*

c) At the depression below the lower lip with a screw to immobilise it (sublabiale) – *not used in this study*

d) Lower border of the chin with a screw to immobilise it (gnathion) - which consists of a water-level attached, to maintain parallelism of the face.

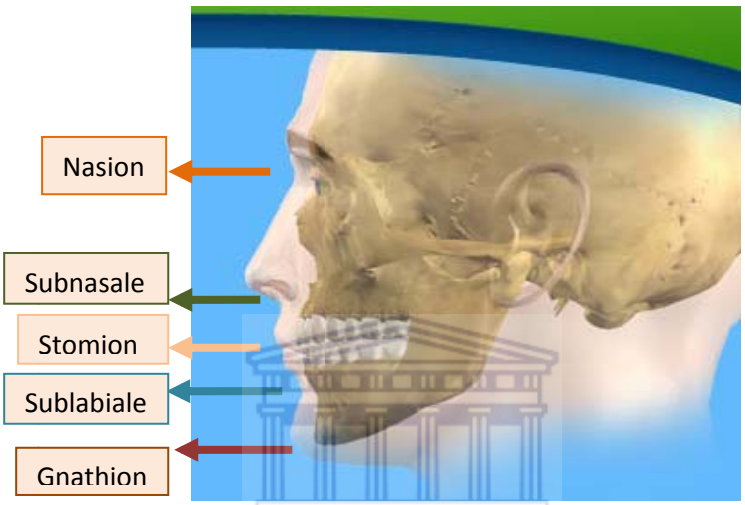



**Fig 18: Depiction of different anatomical points of the FAD**



The FAD used during the Pilot study was a prototype. It was made of plastic and less bulky than the original version as shown in figure 19.

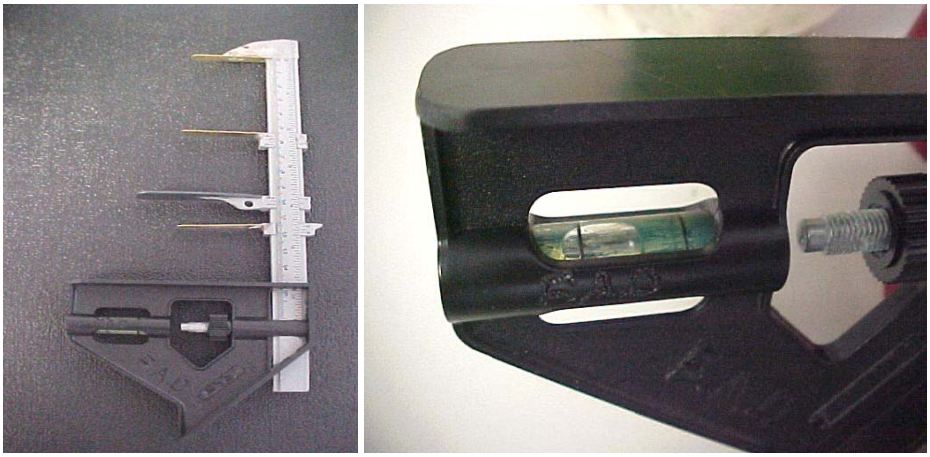


**Fig 19: Pictures showing the FAD prototype and its spirit-level**

The final result namely the FAD (fig 15) was modified somewhat through the actual design stages.

**CLINICAL USE OF THE FAD**

The FAD can be used for determining the vertical dimension of occlusion for edentulous individuals when fabricating complete dentures, as well as dentate individuals when measuring OVD. It may be used as an aid to facial measurements which may be stored for use in later years as pre-extraction data or in forensic studies.

# CHAPTER 5

# RESULTS

## 5.1 DEMOGRAPHICS

The study population consisted of 70 individuals, 35 dentate and 35 edentulous. The individuals were randomly selected from patients attending the University of the Western Cape, Faculty of Dentistry. 60% and 74% of the sample were female in the dentate and edentulous groups respectively (fig 1 & 2). Ages ranged from 30-70 years and the mean ages were 39 and 59 years for dentate and edentulous patients respectively (fig 3).

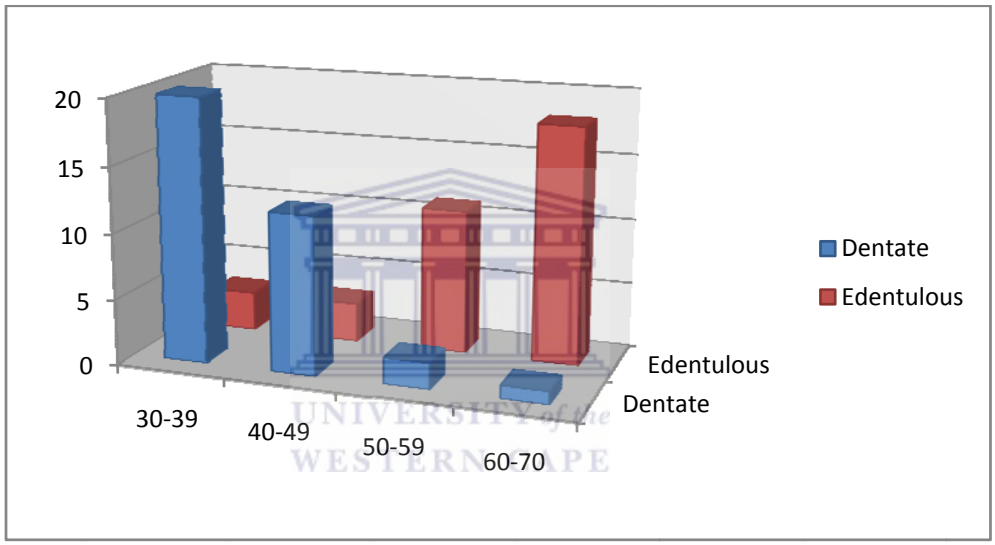



**Table 1: Age ranges of the population**

## 5.2 COMPARISONS BETWEEN INSTRUMENTS

The commonly used gauges, namely the Willis gauge and dividers allowed the operator to measure the distance between two points. For the Willis gauge it involved two reference points, one below the nose and the other on the lower border of the chin. For the dividers, the reference marks were chosen by the operator, to involve the least moveable points on the nose and chin. The newly developed FAD, involved reference points similar to the Willis gauge and in addition, included an arm directed at the nasion. Therefore, the measuring distances between reference marks were essentially different between the instruments.

The readings were analysed to determine if there were any differences between the values recorded by each instrument at baseline and at the subsequent visit.

5.2.1 **Dentate individuals**

No statistical significance difference ($P > 0.05$) was found in the readings of the FAD and the Willis gauge at the first or second visit ($P$-value= 0.12 and 0.76 respectively) (fig 4).

When comparing the dividers to both the FAD and Willis gauge, the results showed a statistically significant difference ($P < 0.05$) in measurements ($P$-values of 0.00 for all comparisons).

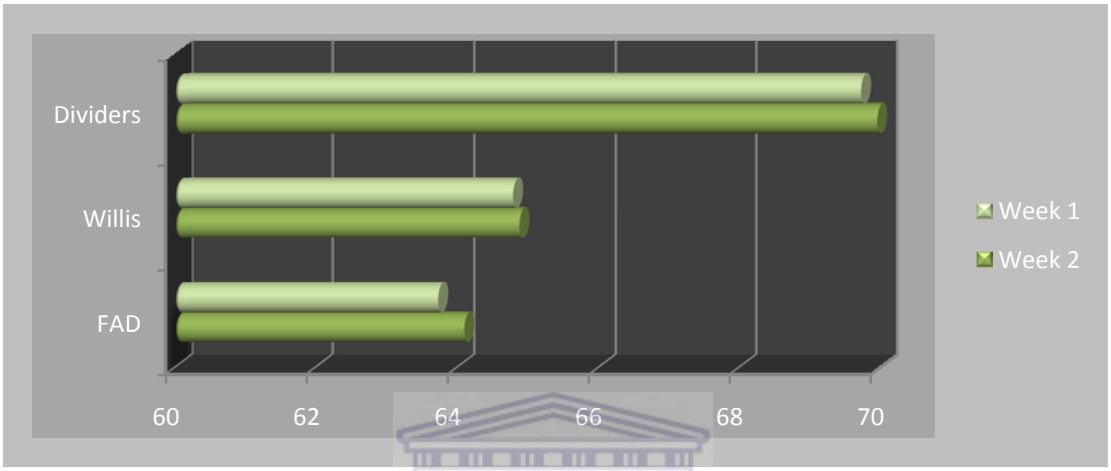



**Fig 20: Mean differences of the instruments at Week 1 and Week 2 for the dentate group**

5.2.2 **Edentulous individuals**

Similarly, no statistical significance difference ($P > 0.05$) was found in the readings of the FAD and the Willis gauge at the first or second visit ($P$-value= 0.27 and 0.207 respectively) (fig 5).

When comparing the Dividers to both the FAD and Willis gauge, the results showed a statistically significant difference ($P < 0.05$) in measurements ($P$-values of 0.00 for all comparisons).

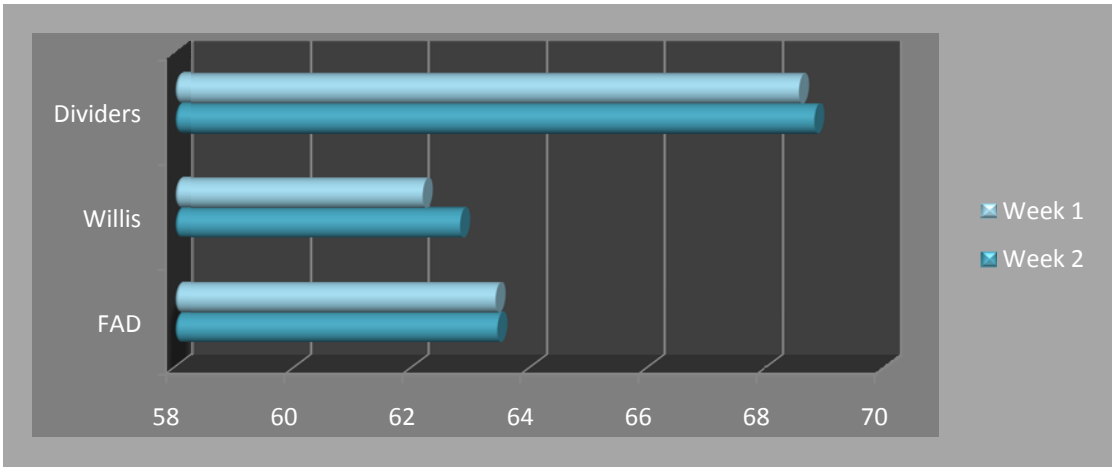



**Fig 21: Mean differences of the instruments at Week 1 and Week 2 for the edentulous group**

The FAD produced results most similar to the Willis gauge in both dentate and ede individuals at both the first and second visits. The dividers showed readings inco with the FAD and Willis. The readings were also higher for the dividers compared other two instruments (Fig 6).

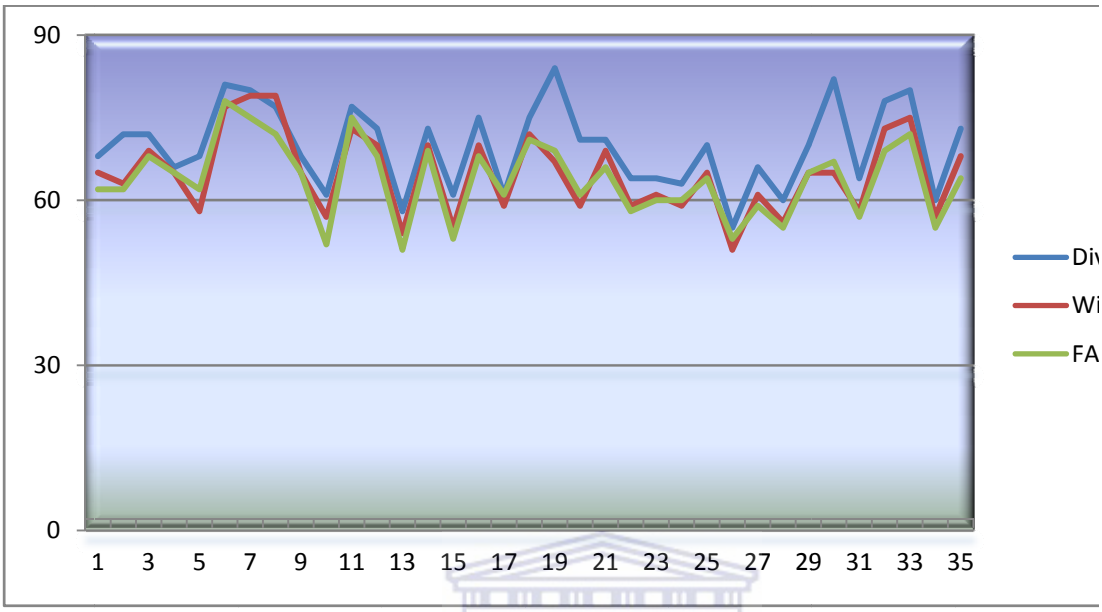



**Fig 22: Comparison of the three instruments at baseline of the dentate population**



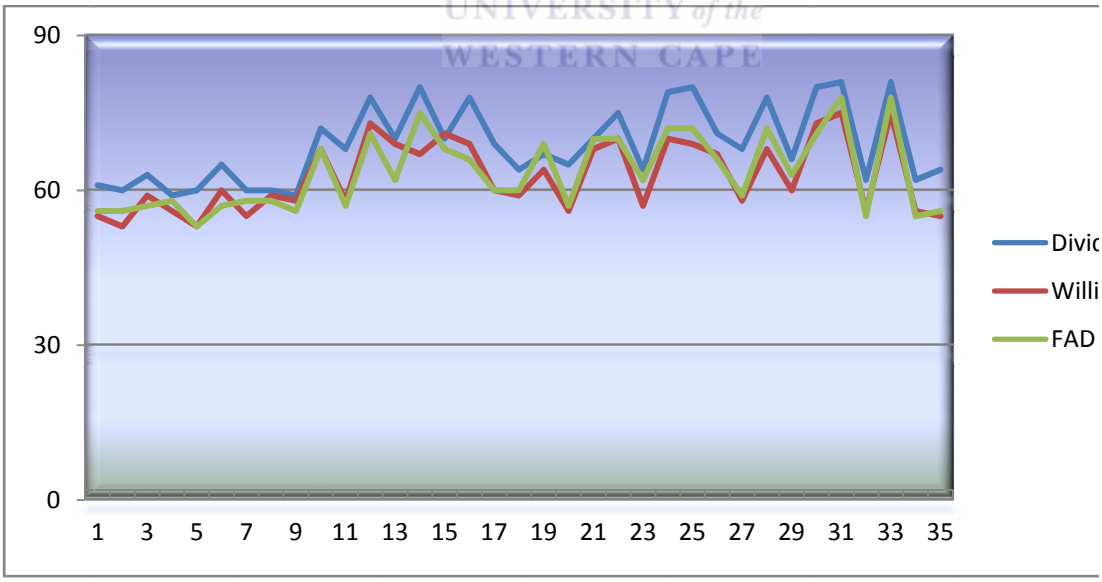



**Fig 23: Comparison of the three instruments at Week 2 for the dentate population**

# CHAPTER 6

## DISCUSSION

The design of this study was such that the samples of edentulous and dentate subjects were randomly selected from the Dental Faculty of the University of the Western Cape. In the pilot study subjects were only chosen from the Mitchell's Plain location, but due to the inadequate number of patients attending the clinic, the Tygerberg location was also included. Edentulous patients were measured at the delivery stage of complete denture fabrication and then re-measured 4-7 days later at their recall visit. The dentures were carefully scrutinised to ensure the basic criterion of good denture construction was adhered to, before the patient was invited to participate in the study.

Satisfactory dentate individuals were few and far between. Similarly, they were randomly selected from the attending students' patients requiring conservative treatment at both Dental sites of the University of the Western Cape. These patients were carefully selected as well, to ensure they conformed to the elected exclusion criteria chosen for this study mentioned in the methodology.



A pilot study was performed before the actual study to determine if the methodology was sound and worth pursuing with a greater number of individuals. A few changes were made after the pilot study as discussed.

The problems encountered in the pilot study were:

1. There were three examiners who recorded measurements. Each examiner had an instrument they were responsible for. The instrument needed to be quality checked and standardised every time it was used. Due to difficulties in time constraints, work commitments and patient availability, it was not possible to use three examiners with the actual sample size. The final decision was to use one, which would eliminate inter-examiner variability.

2. The linear measurement was not covered during the reading of the instrument, and thus allowed examiners with good memories the chance to incorporate bias into the measurements. This was overcome by using one examiner, where the linear portions were covered with darkened and exposed radiographic sheets. The second reading was taken 4-7 days after the first reading.
3. The measurement, once read off from the instrument and recorded on the record sheet was covered with a piece of paper, so that the following examiner was unable to see the results of the previous instruments. An easier and less prejudiced option eventually incorporated was to write down the measurement on a separate sheet of blank paper, and have an individual not involved in the research transfer the reading onto the record sheet.
4. Initially all 5 anatomical points of the FAD were recorded, but it was later decided that the additional anatomical readings made, would be disregarded as they were irrelevant for the purposes of this study.
5. The patients' posture was an important variable in recording the measurement. If the same position was not held for all instruments, the readings could be biased. This consistency could not be maintained, using 3 examiners. It was thus overcome by one examiner taking each reading in a routinely, methodical manner. Patients were reminded that their posterior teeth were to stay in contact; their head positioned upright and to look straight ahead at every reading.



The results of the actual study show that the FAD produced results most similar to the Willis gauge when comparing the three instruments. There were no statistically significant differences noted at the baseline or subsequent visit (*P* – value = 0.12 and 0.76, respectively) (fig 22-25). The measuring distances between the anatomical landmarks of all the instruments were comparatively different. The most pertinent difference about the FAD compared to the Willis gauge, is

that it uses an immovable arm directed at the Nasion or nasal suture, which has been described as being a stable landmark incorporated in its frame (Farkas, 1994). In addition, a water level has been integrated in its design, thus allowing for parallelism and increasing the duplication of its measurements. The Dividers on the other hand, measured two arbitrary points on the nose and chin and its reproducibility was shown to be second best to the FAD (fig 26 and 27).

The reliability of the occlusal vertical dimension was examined by a repeated measurement of all three mechanical devices over a specific period of time. The devices were the Willis gauge, also chosen as the 'gold standard' for this study, the dividers and the newly developed FAD. Morikawa and co-workers, (1988) stated that most of the mechanical devices described in the literature are composed of linear measuring gauges attached to two arms – one fixed and one often moveable. This is true for two out of the three instruments used in this study, namely the Willis gauge and FAD.



It is important to note, that when measuring occurs more than once on the same subject the relationship will in part, depend on the length of time that elapses between the measurements (Siegle, 2008). The less time elapsing, the higher the correlation will be, the more time that elapses the less the correlation. Siegle (2008) concurs, that the time lapsed should be sufficient enough, so the subject does not fully remember how they responded to the procedure, but not so long that their familiarity of the method has changed.

The reason for this is because the two measurements are related over time (Siegle, 2008). The shorter the time intervals, the more likely the features will be that contribute to error. This is a disadvantage of the test-retest method of reliability used in this study. One can often obtain considerably different amounts depending on the time interval. The waiting time chosen between the

measurements was 4-7 days after the first reading. A huge problem encountered, were patients not returning for their recall visits so that the measurement could be retaken. New patients were then chosen for the sample population.

In this study the FAD showed very reliable measurements from the baseline to the subsequent visit. For both dentate and edentulous subjects the mean readings for week 1 and week 2 were extremely similar (fig 30 and 31). This could be due to the fact that there was one examiner who knew how to position the instrument consistently and that it had a water-level to increase parallelism and reproduce its measurements. The measurements recorded for the Dividers were significantly higher than that of the Willis gauge and FAD. This is understandable as the Willis gauge and the FAD measure similar anatomical landmarks, whereas the Dividers measure arbitrary points which also cover a larger linear distance.



According to Siegle 2008, an instrument is said to be valid only if the information allows suitable deductions to be made about a *'specific group'* for a *'specific purpose'.* The FAD has proven to be a valid measure of OVD in edentulous as well as dentate individuals in this study. The two terms – reliability and validity – are inter-related. It should be noted that an instrument may be reliable, but not valid or vice versa. An example according to Siegle (2008) is a scale that consistently records 15 kg for someone being weighed. Although the scale may prove to be reliable, it is not a valid instrument for determining someone's changing weight in kilograms.

The physiological and mechanical methods used to determine OVD accurately, remains debatable. According to the literature, combination approaches are the most commonly used and repeatable methods in use today. Swallowing and pronouncing sibilant sounds during certain construction stages, have proven to

be valuable physiological techniques. Although mechanical methods may be varied, the Willis gauge and Dividers are commonly used instruments in determining OVD in both dentate and edentulous individuals. With a few changes to its design, the FAD may also prove to be a valuable mechanical aid when measuring facial occlusal vertical dimension.

Unfortunately, there is no practically accurate means available for teaching how to determine the vertical dimension of occlusion consistently. Instead, lessons must be learnt from undertaking a number of clinical practices in order to gain experience (LaBarre *et al*, 2007). Hence, during the technique of registration of the vertical dimension, the act still remains a matter of good clinical judgement. It has proven itself to be an art, rather than a science (Watt and McGregor, 1976).



The fabrication of dentures can be a rewarding and pleasurable experience if dentists allow patients to participate in the construction. They should have input on the final aspects involving aesthetics, function and speech. If this happens patients will be more optimistic about their dentures and enjoy their artificial replacements. One of the most taxing steps in denture fabrication is the determination of the OVD, and if reliable instruments are available to make the process easier, it would put dentists more at ease during its construction.

# CHAPTER 7

## CONCLUSION

Despite all the valuable information research has yielded on this widely studied subject, there is still no clinically reliable method available when determining the OVD in edentulous individuals (Laney and Gibilisco, 1983). The physiological and mechanical methods mentioned in the literature should be used in combination with one another, to increase the accuracy and reliability of the vertical dimensions being measured.

The instruments compared in this study were chosen as they are the common devices used at Universities to date. The FAD reproduced results most similar to the Willis, as they measured equivalent facial landmarks. The dividers however, measured comparable points but would vary with every individual. Its linear distance also proved to be longer than the FAD and Willis and therefore, had results less similar to the other two instruments but not necessarily flawed.



We can conclude that the FAD is a good invention, but still needs some modification of its design to be an efficient mechanical aid for measuring OVD. It has proven to be valid and reliable in its features. It is also extremely reproducible, despite some limitations mentioned in the discussion. It has useful characteristics which are unique in its design on a single instrument, namely one immoveable arm directed at the nasal suture deemed to be a stable landmark, and a water level which aids in its reproducibility. Several recommendations may prove useful when re-assessing its design; this includes its ability to be autoclaved as the water-level may pose a problem. In addition, the negative impact of the weight of the lower metal portion integrating the water level impairs the handling ability of the device; this may be overcome by using a lighter metal material.

Due to its ability to measure additional facial proportions, it is the authors' opinion that the FAD may be a useful aid in anthropological or forensic studies in the future, with further research required. However for its use as an aid in measuring OVD its bulkiness, cost and

difficulty of use make it an instrument less likely to be used in its original state, compared to the Willis and dividers commonly used today.

# CHAPTER 8

8.1

## ADDENDUM A

## DATA RECORD SHEET

*Record examination* *No: E/D……*

**Folder no:----------**

**Age:----------**

**Gender:----------**

### Clinical Information using the FAD: Measurement A

| **Measurements in mm** | **1** | **2** |
|---|---|---|
| Occlusal Vertical Dimension (sn-gn) | | |
| n-sn | | |



### Clinical Information using a Willis gauge: Measurement B

| **Measurements in mm** | **1** | **2** |
|---|---|---|
| Occlusal Vertical Dimension | | |

### Clinical Information using Dividers: Measurement C

| **Measurements in mm** | **1** | **2** |
|---|---|---|
| Occlusal Vertical Dimension | | |

8.2

# ADDENDUM B

## ETHICAL CONSIDERATION

The approval of the institutional ethical committee was sought - Faculty of Dentistry and WHO Oral Health Centre University of the Western Cape and organs of the other related institutes.

Informed Consent was obtained from each subject before any measurements were recorded. All information gathered from the study was strictly confidential. Anonymity of all subjects was maintained by careful storage of information. If any dental related problems were noticed, patients were informed and referred to the relevant clinics for necessary treatment.

8.3

# ADDENDUM C

## *Information and Informed Consent Document*

**TITLE:** The reliability of the Facial Anthropological Device.

**PRINCIPAL INVESTIGATOR:** Dr M. J. Rayner

**ADDRESS:** Department of Prosthetic Dentistry, Faculty of Dentistry, University of the Western Cape. Tel: 370 4000

**REFERENCE:** **NUMBER:**

……..

1.1 **AIM:** The aim of this study is to determine the reliability of the newly developed Facial Anthropological Device (FAD). An instrument used to measure lower facial height, and compare it to the instruments more commonly used today, namely the Willis gauge and Dividers.

1.2 **PROCEDURES:** Data will be recorded on a 'record sheet'.



One examiner will record all measurements: using the FAD, Willis gauge and the Dividers. Linear markings visible to the examiner will be covered with discarded radiographic sheets. All three measurements will be consecutively recorded, but not quantified. The measurement will be taken thrice and an average recorded as the final measurement. Only quality instruments will be used. When measuring occurs between the soft tissue landmarks, the hard edge of the instrument will firmly touch the skin surface. Another measurement for each instrument will be taken one week later on the same patient and the objectivity and reproducibility of the instrument tested.

In each of the cases the subjects' posture will be of utmost importance. For measurements, the subjects will be seated in the dental chair with the head resting on the head support and the back, up right. The examiner will stand in front of the subject. The head of the examiner must be at the level of the head of the subject. The subjects' will have to look straight ahead and bite gently, so that their posterior teeth contact. Subjects will be reminded not to clench, but only to hold in centric occlusion. This position will be repeated after every measurement to preserve uniformity.

2. **CONFIDENTIALITY:** The information is strictly confidential and although the findings will be reported at a scientific meeting or in a scientific publication you will not be identified.

3. **VOLUNTARY PARTICIPATION/REFUSAL/DISCONTINUATION:** You are completely free to take part in the study, in which case you need to sign the attached consent form. You also have the right to refuse or withdraw from the study at any time without it affecting your future treatment. If you decide against participating, it will not be held against you.

    1. The information above was explained to me/*the patient/*participant by **Monique Rayner** in Afrikaans/English/Xhosa/Other……..and I am/*the patient/* participant in command of this language/*it was satisfactorily translated to me/*him/*her by …… (Name of translator). I/*The patient/*participant was given the opportunity to ask questions and all these questions were answered satisfactorily.
    2. No pressure was exerted on me/*the patient/*participant to consent to participation and I/*the patient/*participant understand(s) that I/*the patient/*participant may withdraw at any stage without any penalization.

Participation in this study will not result in any additional costs to myself/*the patient/*participant nor will I be paid.

**DECLARATION BY OR ON BEHALF OF PATIENT/PARTICIPANT:**

**I, THE UNDERSIGNED:……**(name) **[ID No: ……] the patient/*participant ……**(address)



**A: HEREBY CONFIRM AS FOLLOWS:**

1. I/*The patient/*participant was invited to participate in the abovementioned research project which is being undertaken by the Department of Prosthetics Dentistry, Faculty of Dentistry, University of the Western Cape.
2. The following aspects have been explained to me/*the Patient/*participant:

**B. I HEREBY CONSENT VOLUNTARILY TO PARTICIPATE IN THE ABOVEMENTIONED PROJECT/*THAT THE PATIENT/*POTENTIAL PARTICIPANT MAY PARTICIPATE IN THE ABOVEMENTIONED STUDY.**

Signed/Confirmed at……on ……/……/2008,

at …….Mitchell's Plain/Tygerberg…… (circle)

Signature/Right thumb print of patient/*participant

……

Signature of witness

……

**STATEMENT BY OR ON BEHALF OF INVESTIGATOR(S):**

**I …….. declare that:**

1. **I explained the information given in this statement to ……. (Name of patient/*participant) and/*or his/*her representative …….. (Name of the representative).**
2. **He/*she was encouraged and given ample time to ask me questions.**
3. **This conversation was conducted in *Afrikaans/*English/*Xhosa/* Other …… and a/no translator was used/ this conversation was translated into …….. (Language) by …… (Name of translator).**

Signed at …… Mitchell's Plain /Tygerberg …….. On……../……/2008.



Signature of investigator/*representative of the investigator.

……

Signature of witness

……..

*Delete whichever is not applicable.

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