TREATMENT OUTCOME ASSESSMENT OF FOUR IMPLANT-RETAINED PALATELESS MAXILLARY OVERDENTURES WITH BIOLOGICAL AND BIOMECHANICAL COMPLICATIONS: A ONE-YEAR OBSERVATIONAL STUDY

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A thesis submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfilment of the requirement for the degree of Master of Science in the School of Dentistry (Prosthodontics).

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ABSTRACT

Hector Saenz de Viteri Tejeda: Treatment outcome assessment of four-implant retained palateless maxillary overdentures with biological and biomechanical complications: a one-year observational study
(Under the direction of Ingeborg de Kok)

Objective: The purpose of this study was to assess the treatment outcome of four implant-retained palateless maxillary overdentures, their attachment systems, and the condition of surrounding hard and soft tissues after one year of use.

Methods: Patients who had received a four implant-retained maxillary overdenture one-year prior were evaluated. Follow up visits consisted of an examination of the tissues and the prostheses, implant parts, a series of periapical radiographs to evaluate the bone levels around the implants, and probing depths. Prosthetic maintenance service was completed, and complications that were encountered were recorded.

Results: Eleven patients received a final maxillary overdenture from a previous study. They wore a maxillary implant retained overdenture for one year. The follow up incidence was 78.6%. A total of 44 implants were evaluated for biomechanical and biological complications. There was 100% survival rate of the dental implants, a total of 30 mechanical complications, and a total of 16 implants presenting with bone loss. The two most common mechanical complications were the replacement of the nylon inserts due to loss of retention and denture tooth fracture.

Conclusions: Biologic complications may be prevented or reduced by avoiding short dental implants placed in bone of limited quantity and quality. Biomechanical complications may be prevented or reduced by providing palatal coverage and bilateral balanced occlusion.

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LIST OF ABBREVIATIONS

BOP	Bleeding on Probing
CBCT	Cone Beam Computed Tomography
CD	Complete Denture
HbA1C	Hemoglobin A1c
MBL	Marginal Bone Loss
IOD	Implant Retained Overdenture
ISFDP	Implant Supported Fixed Dental Prosthesis
OD	Overdenture
OHIP	Oral Health Impact Profile
OHIP-49	49 Item OHIP
OHRQOL	Oral Health-Related Quality of Life
OVD	Occlusal Vertical Dimension
P-11	Panoramic Radiograph
PE	Partially Edentulous
PRDP	Partial removable dental prosthesis
SD	Standard Deviation
QOL	Quality of Life
UNC	University of North Carolina

INTRODUCTION

1. Epidemiology

In many areas of the world, tooth loss is still seen by many as a natural consequence of the aging process. In developing countries, teeth causing pain or discomfort are often left untreated or are extracted due to limited access to oral health services. There has been a positive trend in many industrialized countries toward the reduction of tooth loss among the adult population. Unfortunately, however, the proportion of edentulous adults age 65 years of age or older continues to remain high in many counties. Figure 1 (below), created by Peterson in 2003, presents the prevalence of edentulism of the elderly population in several countries. [1]

WHO region / country	Percent Edentulous	Age group (year)
Africa		
Gambia	6	65+
Madagascar	25	65–74
The Americas		
Canada	58	65+
USA	26	65–69
Eastern Mediterranean		
Egypt	7	65+
Lebanon	20	64–75
Saudi Arabia	31–46	65+
Europe		
Albania	69	65+
Austria	15	65–74
Bosnia and Herzegovina	78	65+
Bulgaria	53	65+
Denmark	27	65–74
Finland	41	65+
Hungary	27	65–74
Iceland	15	65–74
Italy	19	65–74
Lithuania	14	65–74
Poland	25	65–74
Romania	26	65–74
Slovakia	44	65–74
Slovenia	16	65+
United Kingdom	46	65+

Figure 1: Prevalence of edentulism (%) of elderly reported for selected countries throughout the world

In the United States, it is estimated that edentulism has declined by 10% every decade for the last 30 years. This is based on a national epidemiologic survey reviewed by Douglass in 2002.[2] The National Health and Nutrition Examination Survey (NHANES III) from 1988-1991 estimated that 10.5% of the population 18 years of age and over were edentulous. In addition, this survey found that partial edentulism was more common in the maxillary arch than the mandibular arch. [3]

An NHANES survey from 2009-2010 found that 34% of older adults aged 65-74 who lived below the federal poverty level were edentulous, while only 13% of older adults living above the poverty level were edentulous. [4] Figure 2 summarizes the NHANES survey and reveals the prevalence of edentulism by age and race in the US in addition to poverty level.

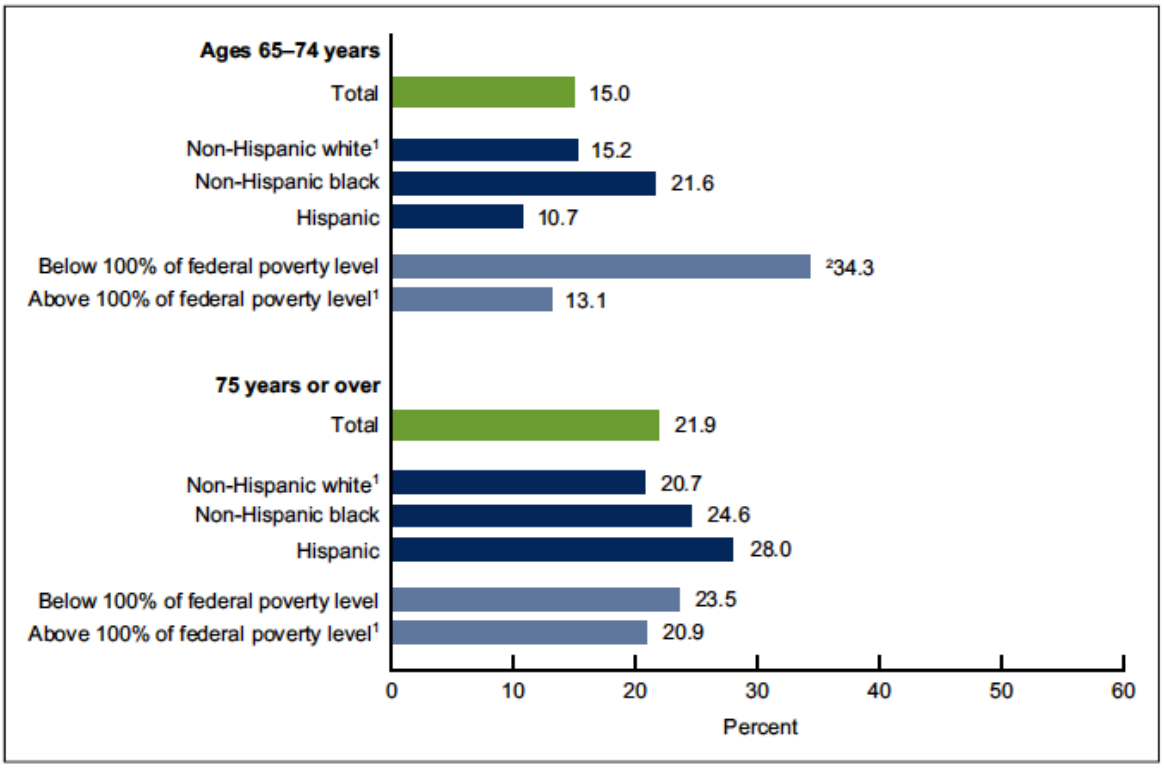

Figure 2: Prevalence of edentulism of older adults in the US by age, race & ethnicity, and poverty level

A study by Slade in 2014 found that edentulism was a rare condition in high-income households, and states with higher levels of poverty experienced higher levels of edentulism. [5] In addition to socioeconomic factors, additional studies show that edentulism is closely associated with age, education, access to dental care, dentist/population ratios, and insurance coverage. [6]

While the decrease in edentulism for the population as a whole is promising, this will be offset by an estimated 79% increase in the population of adults aged 55 years or older. [2,7] The need for one or two complete dentures will increase from 33.6 million in 1991 to approximately 37.9 million in 2020. Total edentulism is expected to increase slightly every decade. By 2020, there will be an increase in the overall need for complete denture therapy.[2]

2. Impact of Tooth Loss

Tooth loss and complete edentulism can have a profound effect on the overall health of an individual. An impaired dentition creates dietary restrictions and can affect the taste of food, food selection and preparation, as well as food eating patterns. A study by Locker revealed that 39% of elderly patients with edentulism were unable to eat food that they would like to eat, while 29% reported a reduction in their enjoyment of food. Also, 14% of these patients avoided eating with other people entirely.[8] Edentulous patients often have excess intake of highly processed and high-fat, high-carbohydrate foods. These foods contribute to obesity and obesity-related diseases, such as insulin resistance, cardiovascular disease, and hyperlipidemia. The onset of disability and mortality, therefore, is often found in edentulous patients. [6]

Felton has summarized a list of co-morbid conditions related to the edentulous patient. (see Figure 3) He reviews the complex oral-systemic disease paradigm and notes a relationship between tooth loss and other systemic comorbid conditions, making this a multifactorial disease. His review evaluated edentulism and its relationship to co-morbid conditions such as obesity, cardiovascular disease, diabetes, rheumatoid arthritis, respiratory diseases, cognitive disorders, cancer, and mortality. He concluded that the edentulous patient is at risk for reduced nutritional

intake and obesity, as tooth loss negatively affects patient's food choices and intake of vital nutrients. He further identified that edentulism was found to be an independent predictor of cardiovascular disease mortality. A reduced, but not replaced, dentition was associated with an increased risk for mortality. [7]

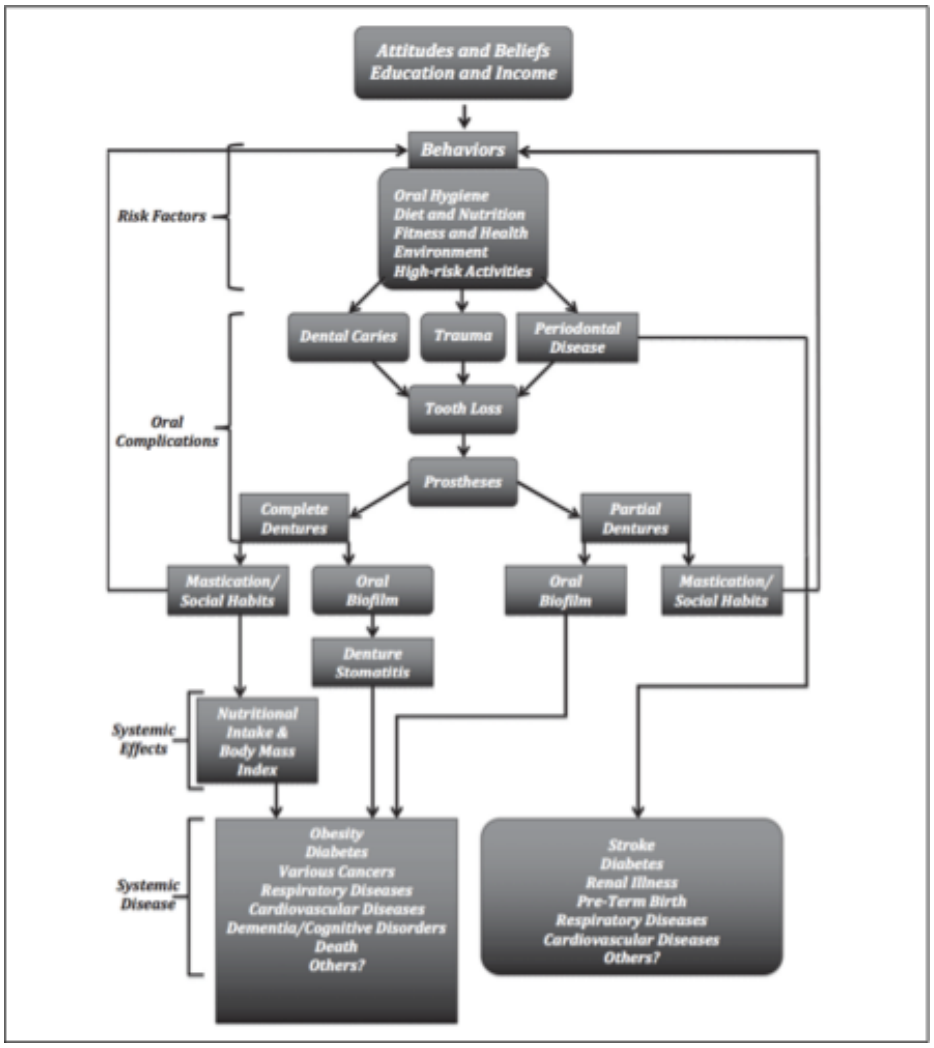

Figure 3: Felton. The complex oral-systemic disease paradigm

In addition to affecting general health, poor oral health can have a profound effect on the quality of life of an individual. The term "quality of life" is defined as an individual's perceptions of his or her condition and/or position in life and is based on the culture and value systems in which

they live; it is related to their expectations and concerns. [9] Perceptions of how oral conditions affect the daily function of a patient, as well as their well-being, are referred to as the "oral health-related quality of life." It is becoming increasingly recognized that patients' perceptions of their oral health are important in determining health care outcomes. [10]

Experiencing the pain and swelling of a dental abscess, dealing with problems with eating and chewing, and enduring embarrassment over the loss of teeth or shape and color of teeth has the potential to adversely affect a person's quality of life. In addition to poor oral health, excessive alcohol intake, smoking and/or tobacco use, and poor dietary choices can also impact a patient's oral condition. According to Peterson in 2003, an integrated approach to the promotion of oral and general heath should be adopted due to the correlation between these lifestyle behaviors and increased risk of oral conditions like dental caries, periodontal disease, oral infections, craniofacial defects, and oral cancer. [1]

Edentulous patients are unable to eat and speak effectively, and as such, are considered disabled.[11] It has been well documented that the orofacial region is crucial to a patient's functioning and has been described as critical to survival in (1) the need to eat and drink, (2) the detection of precancerous and eroding lesions which often accompany prosthetic application and change in oral environment, (3) social well-being for communication and self-esteem, and (4) the quality of life resulting from enjoyment of food, talking, music, and expressions of love. [12]

In addition to the social and functional loss that these patient's experience, other changes accompany edentulism as well. As alveolar bone exists solely to support the teeth, when the teeth are lost the result is a loss of bone. This bone loss occurs dramatically in the first 6 months following extraction and continues at a slower rate throughout the life of a patient. It has been shown that the mandible loses bone at a rate of four times that of the maxilla. With time, the bone loss in both arches has been shown to negatively affect denture bearing areas such that the intraoral and extraoral architecture is changed.

Prosthetic options have attempted to restore both function and esthetics for edentulous patients, however prosthetic rehabilitation becomes challenging with increasing loss of both bone and soft tissue support. Anatomic changes over time are unique to the individual and are related to factors such as age, gender, duration of edentulism, parafunctional habits, general health, and various diseases process. Nevertheless, multiple prosthetic options exist.

3. Treatment of the Edentulous Patient

3.1 Complete Denture Therapy

There are currently three treatment choices available to treat edentulism:

a) conventional complete dentures,

b) implant overdentures,

c) implant supported fixed dental prostheses

The most common treatment for the edentulous patient is a conventional complete denture.[13] A well-fitting, well-functioning complete denture that has acceptable esthetics and causes no pain or discomfort can significantly contribute to patient satisfaction. [14] Interestingly, the condition of the mouth may or may not have an influence on the patient's satisfaction with his or her dentures. The literature in the last few decades has concluded that predicting denture success is complex. Even patients with optimal anatomic conditions may have the same problems with their dentures as patients with atrophic ridges. [15]

The most frequently encountered complication from removable dentures is loss of retention, followed by ulcerations. Loss of retention causes dissatisfaction of patients related to their chewing ability. Ulcerations can also affect chewing ability, as well as affecting patient's speech. Another common finding includes fabrication of the denture at an incorrect vertical dimension of occlusion and/or centric relation. This also has a direct impact on decreased satisfaction in regard to chewing ability. [16]

It has been found that denture related mucosal lesions account for 8.4% of all oral mucosal lesions. They occur frequently and may be associated with pain and may be related to

other co-morbid conditions. [17] It is suggested that denture use, not edentulism itself, is associated with the prevalence of oral mucosal lesions.

In addition to ulcers, other commonly reported complete denture complications include denture stomatitis and angular chelitis. [18] A reduced vertical dimension of occlusion may be associated with angular chelitis. Other findings observed with faulty dentures include problems with both denture design and conditions of patients' mucosa. The most frequent design fault was denture border under-extension and incorrect jaw relationships. Less frequent were inadequate vertical dimension and incorrect post palatal seal placement. [19]

Maxillary complete dentures result in high patient satisfaction, with new maxillary denture construction resulting in improved patient benefits. Less pain and less movement are recorded for maxillary complete dentures when compared to conventional mandibular dentures. Common prosthetic complications of maxillary dentures are denture base fracture and denture tooth fracture. [20] The most common complaints of mandibular dentures are lack of retention and stability, due to unfavorable adaptation. [21,22]

3.2 Endosseous Dental Implant Therapy

A new era in the management of edentulous patients was first introduced by Branemark, who recognized the predictability of successfully osseointegrated implant rehabilitation of the edentulous jaw. [23] The introduction of dental implants into the field of dentistry had a significant impact on the quality of life of patients as it affords an increasing number of treatment modalities. For many years complete denture therapy was the only option available to the completely edentulous patient.

There are several advantages to utilizing dental implants in prosthodontic treatment, including increased stability and comfort. [24] In the maladaptive & psychosocially disabled denture wearing patient, dental implants offer improved comfort, function, speech, self-image, and overall dental health. [25] Biological advantages of dental implants include the preservation of bone levels, the induction of bone in the posterior mandible, increased stability and retention of

the prosthesis, as well as increased masticatory function [26-29] For maladaptive denture wearing patients, dental implant therapy offers a significant improvement in oral health related quality of life when compared to conventional dentures.[30]

Mandibular two implant overdentures have been shown to be superior to mandibular conventional complete dentures in both randomized and non-randomized clinical trials ranging from six months to nine years. In addition, patients are significantly more satisfied with the two-implant overdenture compared to new conventional dentures, independent of the attachment system used. This suggests that the two-implant overdenture should become the first choice of treatment for the edentulous mandible. [11]

3.3 Treatment Planning Considerations for the Edentulous Maxilla

Compared to mandibular reconstruction, restoration of the edentulous maxilla remains one of the most complex restorative challenges in dentistry. This is due to the number of variables that affect both the esthetic and functional aspects of the prosthesis.[31] Treatment considerations of the maxillary arch are numerous, and include: bone quality, degree of bone resorption, inter-arch space, previous implant failure, jaw classification, lip and facial support needs, discrepancy of the arches, and exposure on smile on the transition line between prosthesis and mucosa. [32] The number of implants, implant distribution, and economics also play an important role when it comes to treatment planning of the final prosthesis. [33] Finally, the long-term prognosis for implants in the maxilla is less secure than that of the edentulous mandible. [23]

When restoring the edentulous maxilla with dental implants, one of the most important decisions to make is whether the patient should be restored with either a fixed or removable prosthesis. Zitzmann and Marinello summarized treatment options for the edentulous maxilla. (see Figure 4 and 5) Implant overdentures can be classified as either implant-mucosa supported, or implant supported prosthesis. [34] Implant supported prostheses do not allow for movement and do not have a mucosal rest, compared to implant overdentures, which are both

implant and mucosa supported. [32] These removable prostheses can be secured by various methods including bar and clip, magnets, ball attachments, or with the use of precision milled or spark eroded components. [33]

Fixed partial denture design	Removable partial denture design		
–Screw-retained (detachable) or –Cemented	–Overdenture with reduced palatal coverage Flange considerations: Palatal extension is detemined by • Need for load distribution • Phonetic improvement Buccal extension is determined by • Lip line • Need for soft tissue support	or	–Overdenture with full palatal coverage
6-10 implants Meticulously in optimal implant position	*6-8 implants* Bar retained with precision superstructure • Prefabricated bar and clip • Individually milled bar		*4 (2) implants* Bar retained (or single studs)
7-10 mm distance from center to center ideally distributed over the arch or anterior of the maxillary sinus for premolar occlusion or optional sinus elevation/augmentation	10-14 mm distance from center to center ideally distributed over the arch or anterior of the maxillary sinus or optional sinus elevation/ augmentation		

Figure 4: Treatment Options for the Edentulous Maxilla
Table adapted from Zitzmann and Marinello 1999

	Limited alveolar resorption	Moderate-to-advanced alveolar resorption	
Prosthetic design	Metal ceramic design	Fixed complete denture	Overdenture
Intermaxillary space allowance	Ideally 7 mm	≥11–12 mm	Locator (≥8–9mm), Bar and clip (≥12 mm), Milled bar with overcasting (≥11 mm)
Local factors	Sufficient bone for implants congruent with crowns positioned for segmented prostheses, esthetic approval of smile design	No display of the prosthetic/tissue junction, facial esthetic approval without flange	Requires anterior flange, discrepant arches easier to reconcile, severe resorption may need adjunctive surgical augmentation or tilted/zygomatic implants
Patient-related factors	Financial acceptance	Preference for fixed, accepting of limited hygiene access	Accepting of a removable design although possibility of a latching device, hygiene access priority
Number of implants	6–8 implants	Five to six implants depending on bone quality/quantity, bruxism, heavy smoking, opposing natural dentition, previous failure with implants	Five to six implants depending on bone quality/quantity, bruxism, heavy smoking, opposing natural dentition, previous failure with implants
Anchorage design	Preferably screw-retained	4 × 4 mm framework with retentive features and tribochemical preparation	Solitary anchors may be indicated if limitations in financial resources, home care facility, or keratinized tissue. A rigid bar system is recommended if divergence of implants and/or high retention needs

Ultimately, clinical judgment and emerging evidence of sound scientific rigor will govern decision making.

Figure 5: Treatment Planning the Edentulous Maxilla
Table adapted from Zitzmann and Marinello 1999

3.3.1 Maxillary Implant Supported Overdenture

Maxillary prostheses require specific space requirements, and this can differ depending on the prosthetic being fabricated. These space requirements exist for both fixed or removable treatment options. For implant retained overdentures with Locator attachments, a reported minimum space requirement from the platform of the implant to the opposing occlusion is 8.5mm. [35] If a bar design is utilized, 13-14mm of interocclusal space should exist. Finally, for an implant retained overdenture with other free-standing attachments, at least 10-12mm should be available. [36]

To add further complexity when treatment planning, patients often present with reduced quantity and quality of bone in the maxilla, as well as increased esthetic demands. In the edentulous maxilla, type three or type four bone is often found. In his 2012 systematic review,

Roccuzzo et al found no studies that report an optimal number of implants for maxillary supported overdentures. [37] Higher implant survival rates are reported with the use of six implants compared to four. [38]

There appears to be a consensus in the literature that a minimum of four implants would be favorable for a prosthesis without palatal coverage, but the evidence is supported by only short-term retrospective studies. [36] Maxillary implant survival rates have been reported as low as 71% at five years, making the decision regarding number of implants placed even more pivotal. In a systematic review by Slot et al, maxillary overdentures supported by six dental implants connected with a bar were the most successful treatment regarding survival of both the implants and the overdentures. The second most successful treatment was the overdenture with four implants and a bar. The least successful treatment outcome included four or less implants and a ball attachment system. [39]

Another consideration for implant supported overdentures when treatment planning is the influence of splinted or unsplinted anchorage systems. A recent review found no significant differences on implant survival, prosthetic complications and patient satisfaction between the designs, except for the fact that the unsplinted designs required more prosthetic maintenance. [40]

3. 4 Maxillary Implant Overdenture Complications

There are two categories of complications that occur in patients with implant maxillary overdentures: mechanical complications and biologic complications.

3.4.1 Mechanical Complications

"Mechanical complications" serve as a collective term for mechanical damage to the implant and implant components and superstructures. A variety of complications can occur, including:

a. Implant fracture
b. Wear or erosion of the retentive elements
c. Fracture of the superstructure

d. Abutment fracture

e. Abutment screw loosening or fracture

f. Attachment screw loosening or fracture

g. Need for activation or changing of the clip

h. Matrix activation (change of rubber ring, or nylon patrix)

i. Replacement or change of the O-ring housing

j. Change of the magnet

k. Rebasing or relining of the overdenture

l. Overdenture fracture.

A review of the literature reveals there is a gap in the general understanding of both type and severity of prosthetic complications with specific retention systems and overdenture designs. [41] In addition, there is a need among prosthodontist to define what constitutes repair versus maintenance for implant overdentures.

There are many potential sources of the mechanical complications that are listed above. Several studies have demonstrated that failures in the maxilla are related to short implants, having a small number of implants, or having poor quality and/or quantity of bone.[42] Additionally, the amount of ridge resorption, the length and number of implants, opposing dentition, angulation of implants and/or parafunctional habits may also increase the susceptibility of these complications. [43]

One study found that maintenance of attachment systems and denture adjustments were the most frequently encountered postoperative maintenance procedures. Differences in maintenance requirements relate to the overdenture design. It appears that the number of required maintenance events peak during the first year of service and decrease over subsequent years to reach a balanced level. [44] In a systematic review, Berglundh observes that there was a four to ten times higher incidence of prosthetic complications with an implant supported or implant retained overdenture compared to implant fixed prostheses.[45]

3.4.2 Biological Complications

In addition to mechanical complications, maxillary implant supported overdentures can also have biologic complications. Mucosal enlargement has been associated with a maxillary splinted overdenture design. In a systematic review, the most common mucosal complications reported with maxillary implant overdentures were hyperplasia, irritations, and denture stomatitis, independent of the type of attachment system. Also, hyperplasia under bars has been reported with high incidence. [44]

A study by Attard and Zarb in 2004, reported a cumulative survival rates of implants in both the maxilla and mandible to be 96%, with a cumulative success rate of 93% after a period of at least 5 years.[46] A systematic review of implant-supported and implant-retained overdentures in the maxilla was completed by Andreiotelli in 2010. The author found that maxillary overdentures generally involve an implant-splinted bar on a maximum of four to six dental implants. The success rate for these prostheses ranged from 72.4% to 84%. The implant survival rate was reported to be 75.4% with at least 5 years of follow-up. [47]

The implant-retained overdenture treatment modality has proven to be an effective treatment option to rehabilitate edentulous patients. The aim of this study is to determine the treatment outcome of four implant-retained palateless maxillary overdentures and their attachment systems, as well as the condition of surrounding hard and soft tissues after one year of use.

MATERIALS AND METHODS

1. Study Design

This study was an observational study, designed to evaluate the treatment outcome of four implant-retained palateless maxillary overdentures after one year of use, and to measure quality of life changes with an OHIP-49 questionnaire. This will be compared to the results of the previous study. The research protocol was registered and approved by the University of North Carolina Institutional Review Board 16-0521. The study protocol, purpose and modifications were explained to the participants. Those who volunteered to participate provided a written informed consent.

2. Patient Selection: Inclusion and Exclusion Criteria

Inclusion criteria required that adults who participated in the prospective observational study IRB 16-0521, had already received the final palateless overdenture and had worn the prosthesis for one year. All the participants were recruited under specific criteria to allow participation in the first part of the study IRB 16-0521.

Inclusion	Exclusion
ASA Class I and II Maxillary edentulism and wearing a conventional prosthesis for at least 6 months Patients requesting implant placement due to dissatisfaction with conventional prostheses Adequate bone volume for placement of 4 implants Willing and able to undergo prosthetic and surgical treatments	ASA III History of IV bisphosphonate use Requiring bone augmentation for implant placement Uncontrolled diabetes (BbA1c >7) Smoke more than 10 cigarettes daily

Table 1: Recruitment Criteria

A review of the first part of the study is shown in Table 2: Treatment Protocol. This protocol included the treatment planning, dental implant placement, and fabrication of a four implant-overdenture.

Time (Weeks)	Prosthesis Evaluation	Visit	Procedure	Consent	Exam	Photos	Impression	CBCT	PO	OHIP-49 Forms	Radiograph
0		1	Treatment planning visit	X							
		2	General exam	X	X	X	X			X	
		3	Final Impressions for interim				X				
		4	Bite registration				X				
		5	Esthetic try-in			X					
1-2	X	6	Denture insertion and CBCT					X	X		X
2-3	|	7	1-week post insertion assessment		X				X		
3-4	10 weeks	8	Guided implant placement						X		
4-5		9	Post-surgical assessment		X				X		
11-12	X	10	Insert overdenture (locators attached to interim denture)			X			X	X	
	10 weeks	11	Impressions for PLOD						X		
21-22	X	12	Insertion of PLOD						X	X	
	10 weeks	13	2 weeks post insertion of POLD						X		
31-32	X	14	2 months post insertion PLOD							X	
		15-19	Yearly follow- up	X	X	X				X	X
Total= 31-32 weeks											

Table 2: Treatment protocol

According to the electronic patient record, a total of 14 participants received the final prosthesis. At the time of reporting, 11 were contacted and agreed to participate in a one-year follow-up examination. At the start of each appointment, modifications to the original protocol were reviewed, which included adding five yearly follow-up visits consisting of an examination of the tissues and overdentures, implant parts, a series of periapical radiographs to evaluate bone levels around the implants, and probing depth recording. In addition, prosthetic maintenance service was completed, and complications encountered were recorded. All of these procedures are part of a periodic exam and implant maintenance that are considered standard of care during annual visits to the dentist. A review of the patient's medical history was completed with the provider and updated in the electronic patient record.

A data collection form was created prior to participant visits to record all biological and biomechanical complications. In addition, a thorough review of the participants chart was performed at the University of North Carolina School of Dentistry to collect data regarding surgical procedures, implant characteristics from the beginning of the study and any appointments with complications.

3. Biological Parameters

An extraoral and intraoral clinical examination was completed on each participant. Soft tissues were evaluated. The presence of denture stomatitis, epuli fissuratum, and/or ulcerations was recorded.

Probing depths were recorded from six locations around each dental implant. A UNC 15 periodontal probe was used for all periodontal measurements.

The amount of keratinized tissue present, BOP, tissue biotype, and recession was recorded if present. In order to evaluate looseness or loss of torque of locator abutments, the abutments were torqued to 25 Ncm following manufacturer's recommendations. Each locator abutment was then removed, and the tissue height at four locations from the implant shoulder

were measured to the nearest millimeter (mesial, distal, buccal, and lingual). The locators were then re-inserted and torqued to 25 Ncm.

The modified plaque index was used to assess amount of plaque present at four locations around each dental implant. [48] The scoring is as follows:

Score 0, no detection of plaque;

Score 1, plaque only recognized by running a probe across the smooth marginal surface of the implant;

Score 2, plaque can be seen by the naked eye; and

Score 3, abundance of soft matter.

The modified sulcus bleeding index was measured at four locations around the implants as well. [48] The scoring is as follows:

Score 0, no bleeding when a periodontal probe is passed along the gingival margin adjacent to the implant;

Score 1, isolated bleeding spot visible;

Score 2, blood forms a confluent red line on margin; and

Score 3, heavy or profuse bleeding.

In order to assess mean crestal bone loss during the first year, standardized intra-oral periapical radiographs of the coronal and apical parts of the implants were taken using a parallel cone technique with Rinn XCP (Dentsply Friadent Schweiz, Nidau, Switzerland) film holders, a portable x-ray machine NOMAD Pro™ (ARIBEX, Charlotte, North Carolina, USA), and a placement jig made from vinyl polysiloxane bite registration material Regisil ® 2X™ (Dentspy Sirona, York, PA). Images that presented bone loss around implant shoulder (mesial and distal) were carefully measured to the first visible bone to implant contact utilizing MiPACS® (Medicor Imaging™, Charlotte, North Carolina, USA) software's measuring tool. Implant survival was defined as the percentage of implants loaded that did not produce symptoms such as pain, mobility and infection.

4. Mechanical Parameters

In addition to the evaluation and determination of biologic complications, a prosthetic and biomechanical evaluation was completed. The overdentures were inspected both intraorally and extraorally. The following prosthetic parameters were evaluated and recorded:

1. **Vertical dimension of occlusion**: correct or incorrect.
2. **Centric relation:** The participant's mandible was positioned into the centric relation position using the bimanual manipulation technique to verify a repeatable and accurate centric relation position had been achieved with the prosthesis. Occlusal contact points were identified using double-sided articulating film AccuFilm ® II (Parkell Prod Inc., Edgewood, New York, USA).
3. **Occlusal Scheme**: Centric and eccentric movements of the subjects' mandibular movements were evaluated and recorded to determine the occlusal scheme present. The occlusal schemes included: Canine Guidance, Group Function and Balanced Occlusion.
4. **Vestibular border extensions of the overdenture**: the mucogingival junction and movable tissues were identified and compared to the position of the border extension of the prosthesis. If the borders were 2 mm past the mucogingival junction it was considered high, if the border was 2 mm below the mucogingival junction it was recorded low and when the border was at the junction it was considered normal.
5. **Overjet**: the amount of overjet was measured when the patient was in centric occlusion. This was measured in millimeters, using the UNC 15 periodontal probe.
6. **Overbite**: the amount of overbite was measured when the patient was in centric occlusion. This was measured in millimeters, using the UNC 15 periodontal probe.
7. **Retention:** The retention of the maxillary overdenture was tested. This is a very subjective parameter, and the level of retention was identified by the patient's discretion and based on his/her experience.

In addition to the evaluation of the prosthesis, a visual assessment of the dental implant abutments and anchorage system was performed. Locator abutments were checked to determine if there were signs of wear. In addition, both the nylon inserts and the locator housings were evaluated inside of the overdentures. If signs of wear or looseness were present, these were replaced.

5. Patient reported outcomes

In addition to biologic and biomechanical treatment outcomes, and in accordance with the original protocol of the study, the OHIP-49 questionnaire (Figure 6) was administered to compare and evaluate potential change in quality of life since receiving the overdenture prosthesis on the same seven domains:

1. Functional limitation
2. Physical discomfort
3. Psychological discomfort
4. Physical disability
5. Psychological disability
6. Social disability
7. Handicap

Functional limitation

1. Have you had difficulty chewing any food because of problems with your teeth, mouth, or dentures?
2. Have you had trouble pronouncing any words because of problems with your teeth, mouth, or dentures?
3. Have you noticed a tooth which does not look right?
4. Have you felt that your appearance has been affected because of problems with your teeth, mouth, or dentures?
5. Have you felt that your breath has been stale because of problems with your teeth, mouth, or dentures?
6. Have you felt that your sense of taste has worsened because of problems with your teeth, mouth, or dentures?
7. Have you had food catching in your teeth or dentures?
8. Have you felt that your digestion has worsened because of problems with your teeth, mouth, or dentures?
9. Have you felt that your dentures have not been fitting properly?

Physical pain

10. Have you had painful aching in your mouth?
11. Have you had a sore jaw?
12. Have you had headaches because of problems with your teeth, mouth, or dentures?
13. Have you had sensitive teeth, for example, due to hot or cold foods or drinks?
14. Have you had toothache?
15. Have you had painful gums?
16. Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth, or dentures?
17. Have you had sore spots in your mouth?
18. Have you had uncomfortable dentures?

Psychologic discomfort

19. Have you been worried by dental problems?
20. Have you been self-conscious because of your teeth, mouth, or dentures?
21. Have dental problems made you miserable?
22. Have you felt uncomfortable about the appearance of your teeth, mouth, or dentures?
23. Have you felt tense because of problems with your teeth, mouth, or dentures?

Physical disability

24. Has your speech been unclear because of problems with of your teeth, mouth, or dentures?
25. Have people misunderstood some of your words because of problems with your teeth, mouth, or dentures?
26. Have you felt that there have been fewer flavors in your food because of problems with your teeth, mouth, or dentures?
27. Have you been unable to brush your teeth properly because of problems with your teeth, mouth, or dentures?
28. Have you had to avoid eating some foods because of problems with your teeth, mouth, or dentures?
29. Has your diet been unsatisfied because of problems with your teeth, mouth, or dentures?
30. Have you been unable to eat with your dentures because of problems with them?
31. Have you avoided smiling because of problems with your teeth, mouth, or dentures?
32. Have you had to interrupt meals because of problems with your teeth, mouth, or dentures?

Psychologic disability

33. Has your sleep been interrupted because of problems with your teeth, mouth, or dentures?
34. Have you been upset because of problems with your teeth, mouth, or dentures?
35. Have you found it difficult to relax because of problems with your teeth, mouth, or dentures?
36. Have you felt depressed because of problems with your teeth, mouth, or dentures?
37. Has your concentration been affected because of problems with your teeth, mouth, or dentures?
38. Have you been a bit embarrassed because of problems with your teeth, mouth, or dentures?

Social disability

39. Have you avoided going out because of problems with your teeth, mouth, or dentures?
40. Have you been less tolerant of your spouse or family because of problems with your teeth, mouth, or dentures?
41. Have you had trouble getting along with people because of problems with your teeth, mouth, or dentures?
42. Have you been a bit irritable with other people because of problems with your teeth, mouth, or dentures?
43. Have you had difficulty doing your usual jobs because of problems with your teeth, mouth, or dentures?

Handicap

44. Have you felt that your general heath has worsened because of problems with your teeth, mouth, or dentures?
45. Have you suffered any financial loss because of problems with your teeth, mouth, or dentures?
46. Have you been unable to enjoy other people's company as much because of problems with your teeth, mouth, or dentures?
47. Have you felt that life is generally less satisfying because of problems with your teeth, mouth, or dentures?
48. Have you been totally unable to function because of problems with your teeth, mouth, or dentures?
49. Have you been unable to work to your full capacity because of problems with your teeth, mouth, or dentures?

Figure 6: Quality of Life Questionnaire
Adapted from Erkapers Oral Health Impact Profile Questions

A timeline of the OHIP-49 questionnaires given to patients is represented in Figure 7. The OHIP-49 questionnaire was given to the 11 participants during the follow-up appointment to measure OHRQOL since the day of insertion of the final four-implant retained palateless overdenture.

The OHIP questionnaire consists of 49 statements that have been rephrased as questions. Respondents are asked to indicate on a five-point Likert scale how frequently they experienced each problem within a reference period. Response categories for the five-point

scale are: “Very often”, “Fairly often”, “Occasionally”, “Hardly ever” and “Never”. Respondents may also be offered a “Don’t know” option for each question.

For data entry, responses are coded 0 (never or not applicable), 1 (hardly ever), 2 (occasionally), 3 (fairly often) or 4 (very often). “Don’t know” responses and blank entries are entered as missing values, which subsequently are recorded with the mean value of all valid responses to the corresponding question. However, if more than nine responses are left blank or marked “don’t know” the questionnaire is discarded.

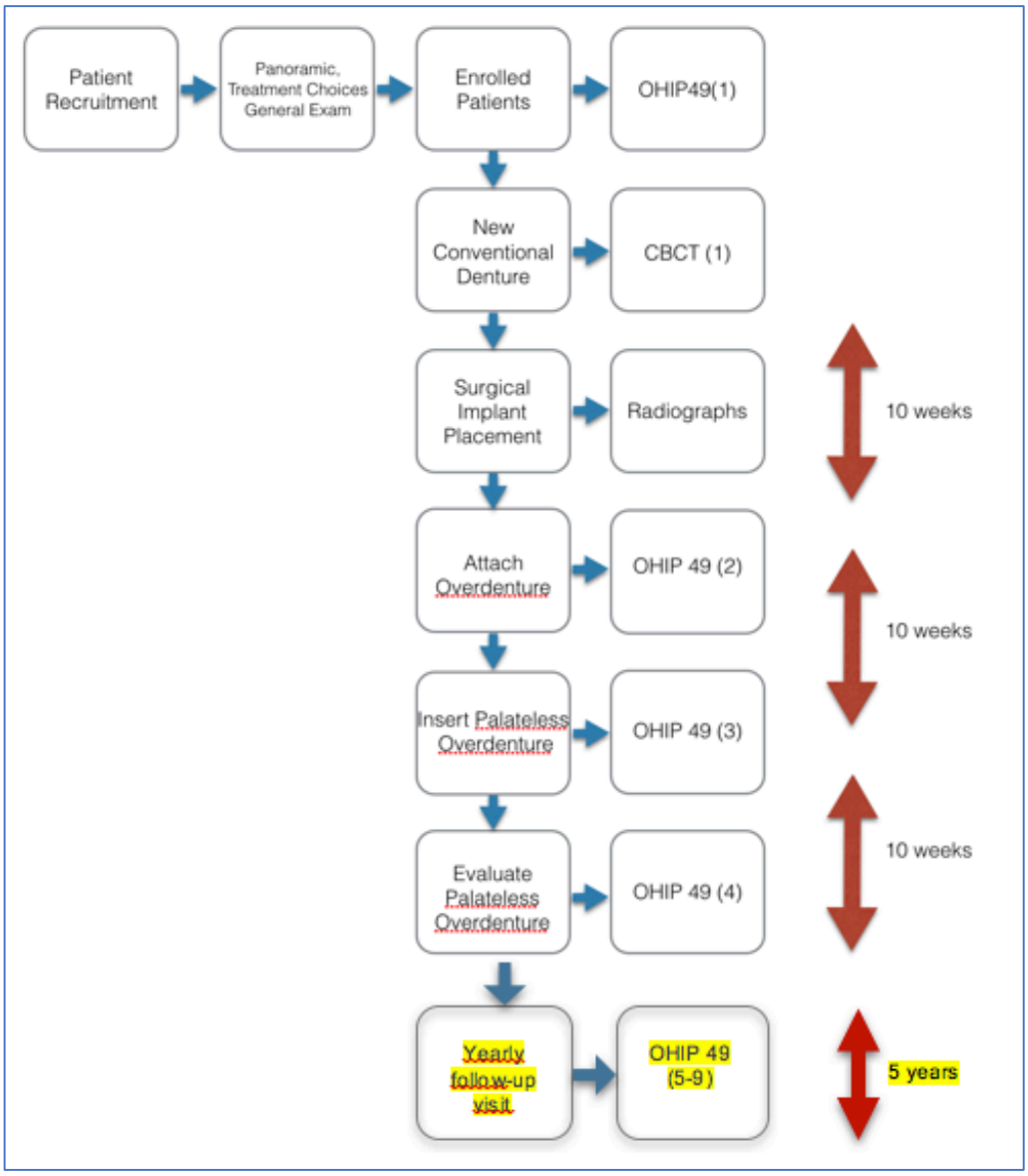

Figure 7: Oral Health Impact Profile (OHIP) Timeline

RESULTS

Eleven patients who had previously received the final maxillary overdenture volunteered to participate in this one-year follow up and written consent was obtained. This resulted in a follow up incidence of 78.57%.

The demographics of the patient population are presented in Table 3. A review of the medical histories revealed the following: one participant reported controlled type II diabetes, nine reported a previous history of smoking, one reported being a current smoker, and six had a history of periodontal disease.

Patient demographics	Patients with implant overdentures
Mean age, years (range)	65.7 (52-80)
Male, n (%)	6 (54.6 %)
Female, n (%)5	5 (45.5 %)
Medical history	
Diabetic, n (%)	1 (9.09 %)
Smoker, n (%)	1 (9.09 %)
Ex-smoker, n (%)	9 (81.8 %)
Never smoker, n (%)	1 (9.09 %)
History of periodontal disease, n (%)	6 (54.5 %)

Table 3: Patient Demographics

Implant Placement and Distribution

All maxillary overdentures were retained by a total of four implants. The total number of implants that were evaluated was 44. All implants were Astra Tech OsseoSpeed EV (DENTSPLY Implants, Mölndal, Sweden) and were placed with a fully guided approach utilizing SIMPLANT® Safe Guide by prosthodontic and oral surgery residents at the University of North Carolina Chapel Hill School of Dentistry. The implant sites, sizes, locator heights, and one versus two stage approach is listed in Table 4 (below) for all study participants.

Subject	Implant Site	Implant Diameter (mm)	Implant Length (mm)	Locator Height (mm)	One or Two Stage Approach
1	4	3.6 S	6	1	2
	7	3.6 S	9	3	2
	10	3.6 S	9	3	2
	13	3.6 S	9	1	2
3	4	4.2 C	11	3	1
	7	4.2 C	9	3	2
	10	4.2 C	9	4	1
	13	4.2 C	8	4	1
5	4	4.2 C	8	5	1
	7	4.2 S	9	5	1
	11	4.2 C	11	5	1
	13	4.2 C	9	5	1
6	5	4.2 S	11	5	1
	7	4.2 S	8	4	1
	10	4.2 C	9	5	1
	12	4.2 C	9	4	1
9	4	3.6 S	9	3	1
	7	3.6 S	8	5	2
	10	3.6 S	9	5	2
	13	3.6 S	8	3	1
11	5	3.6 S	6	4	2
	7	3.6 S	8	3	2
	10	3.6 S	8	4	2
	12	3.6 S	8	3	2
12	3	4.2 S	11	3	2
	6	3.6 S	8	4	2
	11	3.6 S	6	4	2
	14	4.2 C	11	3	2
13	5	3.6 S	8	3	1

	7	3.6 S	9	4	1
	11	3.6 S	8	3	1
	13	4.2 S	6	3	1
15	5	3.6 S	6	5	1
	7	3.6 S	8	5	1
	10	3.6 S	8	5	1
	12	3.6 S	8	5	1
16	4	4.2 S	9	4	1
	7	4.2 S	8	5	1
	10	4.2 S	8	5	1
	13	4.2 C	9	4	1
17	4	4.2 C	8	4	2
	6	4.2 C	9	5	2
	11	4.2 S	9	4	2
	13	4.2 S	6	3	2
Average/Total		3.91 mm	8.43 mm	3.88 mm	

Table 4: Dental implant information

The eleven participants presented with an average dental implant diameter of 3.91mm. The average dental implant length was 8.43mm. The average locator height was 3.88mm.

Implant survival

A total of 60 endosseous dental implants were placed in 15 patients. Fourteen patients received the final palateless overdenture, and eleven patients participated in the one-year follow up exam. Of the eleven subjects who participated in the follow-up examination, all of the dental implants were functioning normally without clinical mobility. One patient who did not participate in this study and was still in active treatment during the time of this study presented with an implant failure. This occurred one year after engaging the locator abutments and a few weeks

after making the final impression for the final prosthesis. The table below (Table 5) shows the cumulative survival rates of the dental implants that were included in the one year follow up study.

After placement (mo)	Overdentures (N)	Implants (N)	Failed implants (N)	CSR (%)
12-24	11	44	0	100

Table 5: Cumulative Survival Rates

Opposing Arch, Occlusal Scheme

The status of the opposing arch was also documented for each participant, as well as the occlusal scheme. In addition, the centric relation position was determined to be correct or incorrect for each subject. Table 6 shows the denture occlusion and opposing arch information by subject.

Subject	Opposing arch	Occlusal scheme	Centric relation
1	ISRPD	Group function	Correct
3	RPD	Canine guidance	Incorrect
5	2 IOD	Canine guidance / Group function	Correct
6	ISFD	Canine guidance	Correct
9	Natural dentition	Canine guidance	Incorrect
11	4 IOD	Canine guidance	Correct
12	2 IOD	Canine guidance / Group function	Correct
13	4 IOD	Bilateral balance	Incorrect
15	RPD	Group function	Correct
16	Natural dentition	Canine guidance / Group function	Correct
17	2 IOD	Canine guidance	Correct

Table 6: Denture occlusion and opposing arch

Biological Findings at Exam

A review of radiographs from the day of dental implant surgery until the one-year follow up was completed. A total of 16 implants showed bone loss. See Table 7 for peri-implant parameters. The average MBL of the 16 dental implants was 0.85 mm. The scores of the indices for plaque, and inflammation were very low. The mean probing depth was 2.03mm at the one-year evaluation for all implants. Bleeding on probing was present around 14 implants and the mean amount of keratinized tissue around implants was 4mm. Table 8 shows the modified plaque index scores for all participants. Table 9 shows the modified bleeding index. One patient presented with denture stomatitis at the one-year follow up exam. No were found to have ulcers or sores in their mouth due to the appliance.

Peri-implant parameters	
Total implants with bone loss (n)	n=16 9 patients
Mean MBL (mm)	0.85 mm (0.36-3.59 mm)
Mean PD (mm)	2.03 mm (1-6 mm)
Total implants with BOP (n)	n=14
Mean KT around implants (mm)	3.95 mm (0-6 mm)

Table 7: Peri-implant parameters

Average modified plaque index (individual score)	Clinical examination	Frequency n=	Percent %
0	No detection of plaque	n=24	54%
1	Plaque only recognized by running a probe across the smooth marginal surface of the implant	n=9	20.45%
2	Plaque can be seen by the naked eye	n=7	15.91%
3	Abundance of soft matter	n=4	9.09%

Table 8: Modified plaque index (mPI)

Average modified bleeding index (individual score)	Clinical examination	Frequency n=	Percent %
0	No bleeding when a periodontal probe is passed along the mucosal margin adjacent to implant	n=31	70.45%
1	Isolated bleeding spots visible	n=9	20.45%
2	Blood forms a confluent red line on mucosal margin	n=4	9.09%
3	Heavy or profuse bleeding	-	-

Table 9: Modified bleeding index (mBI)

Figure 8 shows the radiographic bone loss that was identified during the exam of one of the participants. The intraoral view of the locator can be seen, as well as the most coronal aspect of the dental implant.

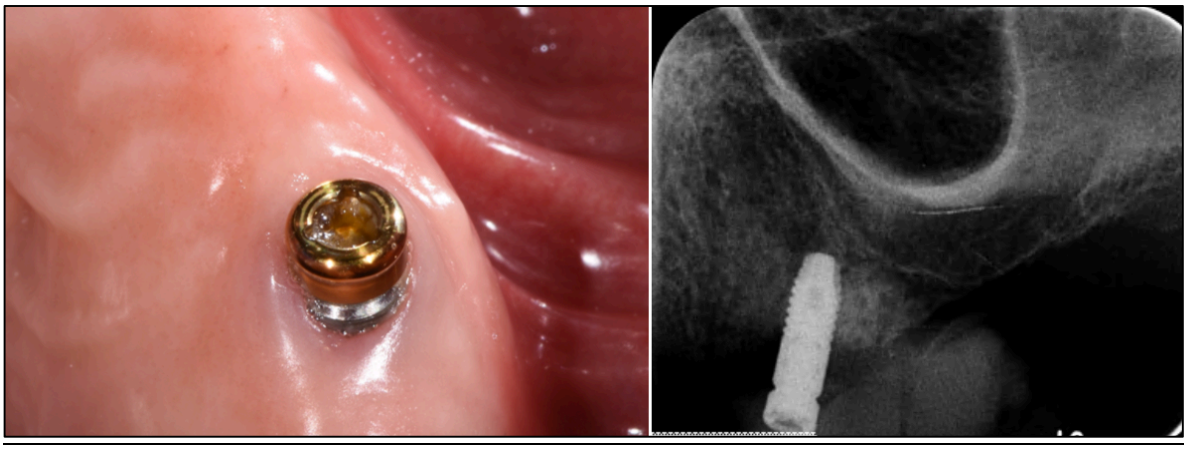

Figure 8: Radiographic bone loss

Figure 9 shows debris found on one of the locator abutments during the clinical examination. Debris was found on 45.45% of locators during the one-year examination. Inflammation was present in 30% of the implants evaluated. Patients were part of the hygiene

maintenance program offered in the Graduate Prosthodontics clinic and received at least one prophylaxis since the time of insertion of the final prosthesis.

Figure 9: Debris on locator

Mechanical Findings

A total of eleven overdentures were examined. The most common complication was the need for replacement of the nylon insert due to loss of retention. Seven (63%) participants required replacement of locator inserts one time during the one-year follow up. Four (36%) participants required replacement of locator inserts multiple times.

The second most common mechanical complication in this study was fracture of a prosthetic tooth. Two participants presented with this complication. Of those two participants, one of them had the same prosthetic tooth fracture three times within the one-year follow up. The other participant had the same prosthetic tooth fracture two times within the one-year follow up period. See Table 10 below for the number of events that occurred.

Category of Mechanical Complication	Number of Events
Replacement of Locator Insert	18
Artificial Tooth Fracture	5
Need for a Denture Reline	1
Resin Base Fracture	0
Loosening of Locator Abutments	3
De-bonding of Metal Housing	2
Wear of Locator Abutment	1
Total Events	30

Table 10: Prosthetic Complications

One patient required a denture reline. Although no participants presented with a complete resin base fracture, it was noted that two of the participants had denture bases that showed signs of cracking. Three patients presented with loose locator abutments that required re-torqueing them to the company's recommendations of 25 Ncm. Two patients presented with debonding of the metal housing within the prostheses. These were repaired chairside. Finally, one patient presented with wear of the locator abutment. This patient's prosthesis was opposing natural dentition.

Figure 10: Cracking of the Denture Base

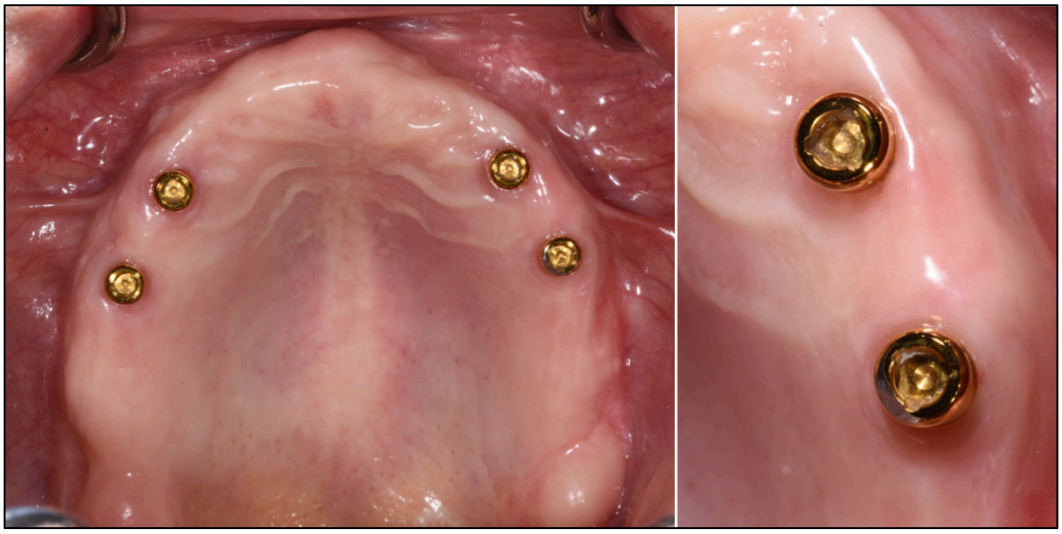

Figure 11: Wear of the locator abutment

Figure 12: Occlusion on locator abutments causing wear

Patient reported outcomes

The results from the responses on the OHIP-49 questionnaires were positive. The numbers remained stable from visit four to visit five. Visit four represents the day of insertion of the overdenture prosthesis. Visit five represents the one-year follow-up visit. Of the seven domains that were measured, “functional limitation” and “physical disability” declined but remained as the top-scoring domains. “Social disability” declined as well and remained as the top-scoring domain throughout the course of treatment and follow-up.

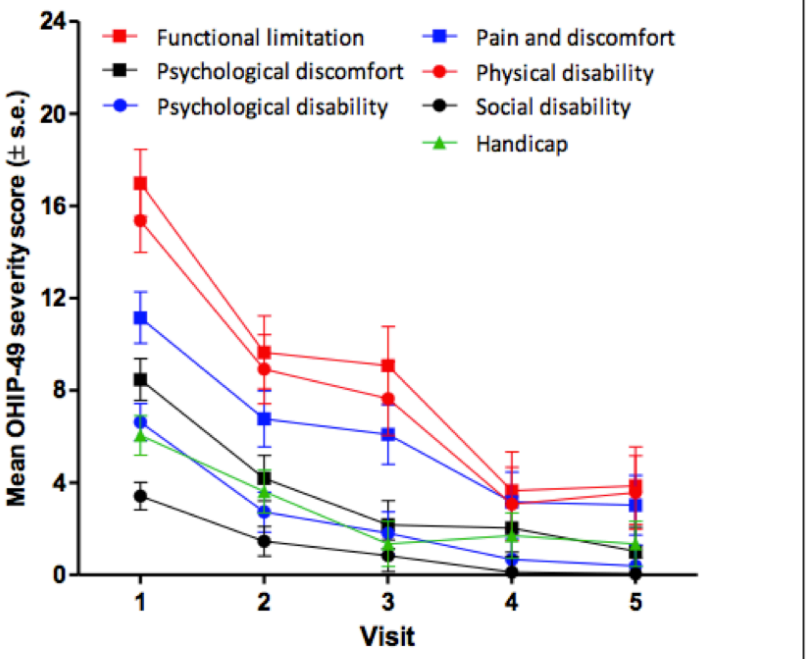

Figure x. Adverse impact of dental conditions measured at five visits with the 49-item Oral Health Impact Profile severity score.

Figure 13: Adverse impact of dental conditions measured with the 49-item OHIP severity score

Table x. Mean (standard error) OHIP-49 severity scores for each theoretical dimension of the scale at each of five visits

Visit	Functional limitation		Pain and discomfort		Psychological discomfort		Physical disability		Psychological disability		Social disability		Handicap	
1	17.0	1.5	11.2	1.1	8.5	0.9	15.4	1.4	6.6	0.8	3.4	0.6	6.1	0.9
2	9.7	1.6	6.8	1.2	4.2	1.0	8.9	1.5	2.7	0.9	1.5	0.6	3.6	0.9
3	9.1	1.7	6.1	1.3	2.2	1.0	7.6	1.6	1.8	0.9	0.8	0.7	1.3	1.0
4	3.7	1.7	3.2	1.3	2.0	1.0	3.1	1.6	0.7	0.9	0.1	0.7	1.7	1.0
5	3.9	1.7	3.0	1.3	1.0	1.0	3.6	1.6	0.4	0.9	0.0	0.7	1.3	1.0

Figure 14: Mean OHIP-49 severity scores

Statistical Analysis

At present, the sample size is too small to evaluate for statistical significance. Descriptive statistics were analyzed. The data analysis for this paper was generated using SAS software, Version 9.3 of the SAS System Copyright © SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

DISCUSSION

Implant-retained maxillary overdentures have become increasingly popular and can be considered a favorable treatment in case of insufficient bone volume. Indications for implant supported overdentures commonly include: high muscle attachments, sensitive mucosa, and/or mucosa that is easily irritated by the pressure of a denture. Patients who have knife-edge ridges or sharp mylohyoid projections can also benefit from overdentures.[50,51] On the other hand, a prosthesis that would require excessive cantilevers to obtain necessary occlusal contact would likely be better designed as an overdenture that uses tissue support.[52]

Two of the most commonly discussed benefits of maxillary implant overdentures, when compared to conventional maxillary dentures, are the increase in retention and the reduction of palatal coverage. [39] Maxillary bar-retained overdentures have been studied extensively and have a reported survival of 96.3% to 98.2%. [33] Compared to these splinted, bar-retained overdentures, however, there is a lack of treatment guidelines concerning implant-retained unsplinted overdentures. They are considered a favorable treatment option with easy maintenance and are less technique sensitive [36,39] The aim of the present study was to assess one-year treatment outcomes of four-implant retained palateless maxillary overdentures, both biologically and mechanically.

A total of 11 participants (5 women, 6 men; mean age 65.7; age range, 52-80 years) were seen for a follow up appointment in the Graduate Prosthodontics Clinic at the University of North Carolina, Chapel Hill approximately one year after prosthesis insertion.

Six of the total eleven participants in this study had a history of periodontal disease, and one was a current smoker with type II diabetes. While it is not an absolute contraindication to place implants in a smoker, smoking has been reported to cause bone loss around dental implants. It

has been shown that patients with periodontitis and a history of smoking can have higher implant survival rates if kept on a regular periodontal program. [53] In a review by Clementini et al. 2014, it was reported that smoking increases the annual rate of bone loss by 0.164 mm/year around dental implants.[54] In this study, the only patient that reported smoking had bone loss around three implants with an average of 2.09 mm (2.16mm-3.23mm).

In a 2003 prospective longitudinal cohort study, it was found that dental implants may be successfully placed and maintained in patients with and without a history of periodontal disease. Patients with a history of periodontitis, however, had lower implant survival rates, significantly higher biological complications, and lower success rates compared to those patients who had lost their teeth for reasons other than periodontal disease. [55] In this study, six participants reported a history of periodontal disease. All of the dental implants in these participants survived at the one-year follow up appointment.

Of the eleven participants, one reported a medical history significant for Type II diabetes mellitus which was also the only smoker in the study. The impact of diabetes and glycemia on osseointegration has been studied extensively. In two systematic reviews, it was found that there is no scientific evidence to confirm a negative association of diabetes mellitus with implant survival. [56,57]

Implant survival

Although the number of patients who reported for the one-year follow up examination was small, the recall rate was encouraging. Of the fourteen total patients who had received the final prosthesis, eleven were enrolled in this study, for a follow up recall rate of 78.57%. The cumulative implant survival rate of these eleven participants was 100%.

Generally, the cumulative survival rates of implants supporting overdentures is reported to be excellent. The long-term success rate of maxillary implants, however, has been reported to be lower than the success rate of mandibular implants. In a 2016 study, Wang reported an implant survival rate of 95.2% on 26 subjects (104 implants) who received a palateless four

implant-retained maxillary overdentures with locator abutments. The mean follow-up period was 46 months and reported that bone loss bone was 1.7mm (±1.1mm) during the first year and then stabilized in following years. [58]

Compared to the palateless overdenture design, Troeltzsch reports a survival rate of 98.8% for a four-implant maxillary overdenture with palatal coverage. The mean follow-up time was 32.9 months. A total of 24 maxillary arches with 84 dental implants were rehabilitated, using locator abutments as the attachment mechanism. One implant failed after 19 months of loading. Patients with periodontal disease did not exhibit a lower level of alveolar crest than periodontally health patients. [59] In our study, five out of the six subjects with a history of periodontal disease had bone loss on at least one implant. The average MBL for these subjects was 0.26 mm.

In contrast to unsplinted dental implant designs, bar anchorage has been a common treatment modality. In a 2010 systematic review, there was a 98.2% survival rate for six dental implants with bar anchorage. This is compared to 96.3% for four dental implants, also with bar anchorage. This systematic review included a total of 3,116 dental implants, with at least one year of functional loading. [39]

Albrektsson reported six parameters that need to be controlled for rigid implant fixation and proper osseointegration to occur. These parameters include:

1. biocompatibility
2. implant design
3. surface conditions of the implant
4. condition of the recipient bone bed
5. surgical technique and
6. loading conditions.

The clinician has little control over the bone quality. [60] The quality of the bone in the posterior maxilla is often poor, therefore, the anterior-posterior span of a prosthesis may be limited and/or

lead to an unfavorable implant failure rate. If enough bone is available in the anterior maxilla, however, bone augmentation procedures may be avoided, reducing treatment time, cost and morbidity. [61] The type of bone (Type I, II, III, or IV) was not reported in this study.

In order to increase the osseointegration of dental implants, it is often recommended to use a longer and/or wider implant in order to increase the bone to implant contact. In this study, the mean implant diameter and length was 3.91 mm (3.6mm-4.2mm) and 8.43 mm (6mm-11mm), respectively. This unsplinted palateless implant-retained design used relatively small implant sizes. Grafting was an exclusion criterion. While there are no studies that can be utilized to determine how many implants should support a maxillary overdenture, it is suggested that a minimum of four textured-surface implants with a length and width of at least 10mm and 3.75mm, respectively, may be sufficient to retain maxillary overdentures with locator attachments. [37,62]

For every case, the maximum implant length and diameter of the dental implant should be selected to increase the chance of long-term survival. [59] In regard to dental implant length, studies have shown that there is a dramatic increase in failures of implants shorter than 7mm. Both bone type and cortical bone engagement are mentioned to be more important factors than implant length. Conversely, a wide diameter implant leads to more bone to implant contact. Bi-cortical engagement may also be achieved. One of the main disadvantages of the narrow diameter dental implant is the reduction in resistance to occlusal loading. [63]

In addition to the dental implant size, the height of the locator abutment may also play a role in the success of a prosthesis and/or survival of a dental implant. Thicker masticatory mucosa is often seen in the maxilla, frequently requiring the use of longer implant abutments. This increases the lever arm length. [64] In this study, the majority of the participants had a thick masticatory mucosa. The average locator abutment height was 3.88mm (1mm-5mm).

Biologic Findings

It has been reported that compared to bar-retained overdentures, overdentures retained with locator attachments result in better soft tissues scores because the hygiene and maintenance was found to be more difficult around bars. The result of locator attachments has been a reduction in chronic inflammation around overdentures. [65] A study by Bergendal notes that hyperplasia is a common complication with overdentures. [66] Erythema and hyperplastic tissue was found specifically in bar supported overdentures in one study. [67] A review of the biologic findings in the present study reveal an absence of hyperplastic or erythematous tissue for all participants at their one year follow up examination.

Of the eleven participants in this study, none of them returned with ulcers or sores at the follow up examination. One patient presented with denture stomatitis. This patient reported not removing the prosthesis overnight. The patient was educated and changed his habits so that she no longer slept with the prosthesis in. The denture stomatitis was resolved quickly.

The plaque and bleeding indices were low in this patient population, as was the gingival index. In a five year follow up by Boven in 2017, it was reported that the plaque, gingiva and bleeding scores were significantly higher in the second, third, fourth and fifth years than during the first year follow up. [68] While the patient's in this study did have low scores, they were all encouraged to continue under a periodic hygiene maintenance program in the Graduate Prosthodontic program.

Keratinized tissue was measured at each implant location site for the participants in this study. The average amount of keratinized tissue was 4mm (0-4mm). Bouri found that an increased width of keratinized gingiva, over 2mm, was associated with increased soft tissue health and decreased bone loss. [68]

The most significant finding in regard to biologic complications for this patient population group was radiographic bone loss. The mean marginal bone loss (MBL) around the 16 implants

was 0.85 mm at the one-year examination. The bone loss was distributed on 9 patients. The mean probing depth was 2.03 mm.

According to criteria presented by Albrektsson, a 1mm change in bone height during the first year is allowed, after the abutment is connected to the dental implant, with 0.2mm/year afterwards. [70] Wang et al. reported that a total of 14 patients showed 2-3 mm of bone loss with higher levels on posterior areas of the maxilla. [58] An overall MBL of the implants cannot be provided due to the lack of standardization in the previous study. No radiographs were taken the day of implant loading or abutment connection.

Mechanical Findings

It has been reported that 76% of prosthetic complications occur during the first year of service of a maxillary overdenture. While these prostheses have a greater number of complications compared to mandibular overdentures, the Locator abutment and attachment system allows a simple and relatively inexpensive way to resolve these complications.[71] Previous studies have reported maintenance problems with fractures of retentive clips (22%), and acrylic fractures around retentive clips (14%). [72] Additionally, maxillary implant overdentures have been reported to have the highest incidence of implant loss compared to all other types of implant prosthesis, with survival rates as low as 71%.[41]

A study by Wang in 2016 reported that the most frequent complication was the loss of the denture caps (nylon inserts) and denture relining. The replacement of the nylon inserts presented mostly in the second and third year following overdenture insertion. [58] This finding is similar to other historical studies when ball attachments with used with O-ring inserts. [40,41] When compared to bar-clip, milled bar, and locator attachments, the O-ring and ball attachment system represented the highest failure rate. [73]

In this one-year observational study, a total of 30 maintenance of mechanical complications/events were recorded. The mechanical complications found in this study included, in order of decreasing frequency:

Replacement of the locator insert	18 events
Artificial tooth fracture	5 events
Loosening of the locator abutment	3 events
Debonding of the metal housing	2 events
Need for denture reline	1 event
Wear of the locator abutment	1 event

Although there were no fractures of the maxillary overdenture, two overdentures did show evidence of cracking. There was no indication for treatment at that time.

The most common mechanical complication, as shown above, was the need to replace the nylon inserts due to loss of retention. In this study, four patients required replacement of the nylon inserts multiple times. This finding is similar to the results of the Goodacre study mentioned above. [41] The nylon inserts have been shown to have a high initial retentive grip value that eventually diminishes over time. This has been confirmed by several authors in experimental studies. [74-77] Three studies with the same prosthesis design with four locator abutments reported that the most common complication or event was the replacement of nylon inserts. [58,59,79] When comparing the outcome between three different attachment systems, telescopic crown attachments, bar-clip attachment system and locator attachments during a three-year follow-up it was concluded that attachment system does not influence implant success rates. [79]

The second most common complication type in this study was fracture of the artificial teeth. One consideration when designing a four implant-supported palateless overdenture is the role occlusion and/or occlusal forces will play in the success of the prosthesis. A bilateral

balanced occlusal concept is used most often in overdenture construction. [78] In the present study, bilateral balanced occlusion was either poor or nonexistent. The occlusal schemes found in this study included:

Canine Guidance	5 participants
Canine Guidance/Group Function	3 participants
Group Function	2 participants
Bilateral balance	1 participant

Wang et al 2016 reported on common occlusal schemes, in regard to the opposing arch. Generally, when the opposing arch was a complete denture, the maxillary overdenture was positioned into a bilateral balanced occlusion. When natural teeth were in the opposing arch, prostheses were positioned without interference in lateral or protrusive excursive contacts.[58] In several studies, unfortunately, the type of opposing dentition was not described. It is hypothesized, however, that the opposing dentition may affect the survival of the dental implants due to differences in the bite force and adjustments to the occlusion. [59,62,79] For the most part, these occlusal schemes were not completed for the participants in this study, as noted at the follow up examination.

Occlusion and articulation may play an important role regarding the loading conditions on a dental implant. Lingualized occlusion was used in a majority of subjects to control eccentric forces, as noted in a retrospective study by Närhi in 2001.[80] In this study, when a maxillary overdenture was opposing a natural dentition, canine guidance was provided.

In review of several studies, the mean implant size and width was greater than the implants used in this study. All had at least a 95% survival and success rate. They all had biologic and prosthetic complications that did not affect the long-term outcome of the treatment.

A constant that was apparent in all studies, with and without palatal coverage, was an overall longer and wider implant selection than was used in this study.

Study Limitations

For this study, no statistical significance was found due to the small sample and lack of standardization in the previous study. A wide variety of implant sizes and widths was found, which makes it difficult to provide evidence-based recommendations. The lack of radiographic images at multiple stages in treatment limited us on providing an overall MBL number to understand the bone resorption pattern in this study from implant placement to one year of use. Six subjects opposed natural dentition and an implant supported fixed prosthesis making it challenging to achieve bilateral balance. Finally, without the ability to graft, implant sizes were dependent on the amount of bone available.

CONCLUSIONS

Treatment planning and overdenture design are critically important in the treatment of maxillary implant-supported overdentures, and can have a positive or negative impact on both the survival of the dental implants as well as the prosthesis. Bone grafting is recommended when needed, in order to decrease limitations to dental implant size and distribution. A fully guided surgical approach is also recommended to maximize retention with parallel implants. Both the quality and quantity of bone may dictate the number of implants placed, as well as the loading protocol.

An implant-retained overdenture is a mucosa supported prosthesis, and as such, it is vital that conventional complete denture principles are followed in order to achieve the greatest chance of success. Bilateral balanced occlusion is recommended, and palatal coverage should be considered when the number of implants or implant sizes are limited.

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