Impact of implant retained overdenture treatment and speech, oromyofunction, social participation and quality of life

Ester Fonteyne

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–Overal schoonheid, praten met jou–
Yevgueni

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List of Abbreviations

WHO	World Health Organization
ICF	International Classification of Functioning
e.g.	example giving
OHRQoL	oral health related quality of life
SIR	Single Implant Restauration
ND	Natural Dentition
CD	Complete removable Dentures
FID	Fixed implant Dentures
IOD	Implant retained Overdentures
MDI	Mini-dental Implants
N_0	Null Hypothesis
n	Number of patients
SLP	Speech language pathologist
VAS	Visual Analog Scale
OHIP	Oral Health Impact Profile
N	Neuroticism
C	Conscientiousness
OMF	Oromyofunctional behavior

CHAPTER 1

Introduction

Background

In 2005 the World Health Organization (WHO) encountered an important shift in priorities by introducing the International Classification of Functioning (ICF). The WHO traditionally focused on infection control and mortality reduction. Now it recognizes the importance of reducing burden or consequences associated with health conditions by enabling people to achieve and maintain optimal functioning despite their possible disability. This shift requires many disciplines to work together to allow the patient to thrive in the best possible environment [1]. Also in dentistry multidisciplinary practices are desirable. Now, the department of Periodontology and Oral Implantology of Ghent University has several ongoing clinical trials in relation to long-term implant survival, quality of life, speech, oromyofunctional behavior and technical aspects. Therefore a team of dentists (periodontists and prosthodontists) and speech language pathologists (SLPs) is assembled. The opportunity of evaluating and following the same patient groups, from different points of view is an important enrichment of the current knowledge.

The completely edentulous jaw

From the age of 17, most people have 32 teeth and ideally keep them until their final days. Most people, due to life events lose some teeth during life. The main causes of tooth loss are untreated tooth decay and periodontal disease, mainly caused by the absence of efficient preventive measures (e.g. control of sugar intake, oral hygiene) [2]. Worldwide the prevalence of edentulism, the loss of all natural teeth, is difficult to assess, because of questionable statistical information in developing countries [3]. The WHO report of 2010 by Petersen et al. stressed the lack of self-care and access to oral health facilities, due to physical and financial barriers, for older people (+65y) [3]. Figure 1 shows the percentage of people of 65–74 years old in low-, middle and high income countries with no natural teeth and the percentage of people having experienced problems with mouth/teeth during the past year. Edentulism has worldwide important effects on a person's life. Especially when it comes to food intake and aesthetics, affecting general health and social status, the need for dental rehabilitation is very high.

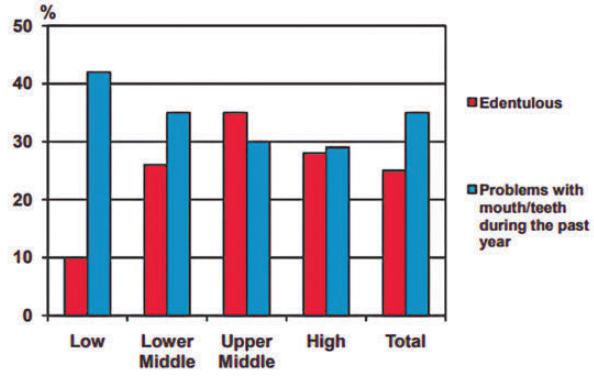

Fig 1. *Percentage of people 65–74 years old in low-, middle- and high income countries with no natural teeth and percentage of people having experienced problems with mouth/teeth during the past year – The World Health Survey* [3]

The number of patients suffering from complete tooth loss is declining due to better awareness about dental hygiene. Still, large proportions of patients are edentulous and patients are more demanding when receiving dental rehabilitation [4]. Johannsen et al (2012) stated that tooth loss leads to fear, shame and denial affecting patient's social activities [5]. According to the WHO, edentulism can be considered as a chronic disability, influencing mastication, speech and aesthetics [6]. This makes it important to evaluate the current practice in dental implant rehabilitation.

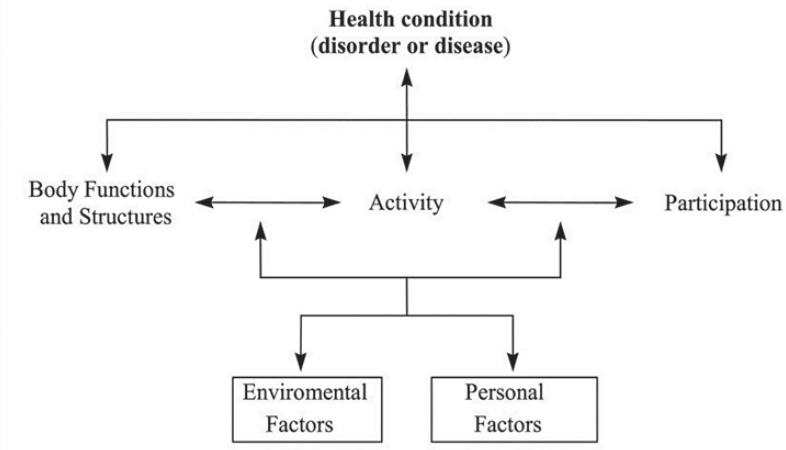

Fig 2. *International Classification of Functioning, WHO 2001* [1]

Edentulism, as a chronic disease, requests treatment according to the International Classification of Functioning, Disability and Health (ICF, fig. 2) [1,7]. In this framework, the outcome of a treatment is described in terms of three main components: Body functions and structures, activity and participation. These three components are in interaction with the health condition, personal factors, including personality, and environmental factors [1]. In the evaluation of any treatment it is important to keep these factors and interactions in mind. Edentulism is not only associated with less oral functionality ('body functions and structures' in the ICF–model), but also with loss of social status and less self–esteem ('personal factors' in the ICF–model). It is hence important and necessary to take all these impacts into account while evaluating the result of dental treatments [8]. The concept of oral health related quality of life (OHRQoL) is commonly used to evaluate treatment in dental practice [9].It refers to the impact of the dental status on a patients' life and can be situated in the ICF–model as 'health condition (=dental status)' that influences 'participation', 'activities' and 'functions'[8].

Dental rehabilitation

'Oral rehabilitation' refers to several levels of oral therapy, when only defective teeth are restored, the term 'dental rehabilitation' is used [10].There are different options in rehabilitation of the edentulous jaw. The most common option is treatment with complete removable dentures (CD). Other options are constructions connected to implants: either fixed (fixed implant dentures, FID) or removable (implant retained overdentures, IOD). In many cases rehabilitation with complete removable dentures is the first choice, predominantly dependent on the financial condition of the patient. A dental prosthesis aims to restore speech, chewing, bite and swallow functions, but also improves aesthetics and facilitates psychosocial functions [11,12]. Unfortunately denture wearing reduces functional comfort compared to natural teeth and affects OHRQoL [11,12]. Long time removable denture wearing increases resorption of the crestal bone of the jaw. As a result, a denture might no longer fit properly, losing its retention. Retention is the impossibility of the denture to move in vertical direction [11]. To solve this retention problem dental implant treatment can be useful. The most common way to anchor a dental prosthesis is a treatment with conventional dental implants of at least 3.5 mm diameter. Long–term implant survival for dentures is in the order of 93% to 97% [13,14]. To anchor the full denture on the

implants, there are in general two possibilities. Firstly the denture can be fixed to the implants (FID). Secondly the denture can be clicked over the implants (IOD). Implant-retained overdentures are anchored over a bar, firmly connecting the implants, or over non-connected implants via a ball or locator abutments (Fig. 3). The abutment is the transmucosal component that is screwed into the implant (in the bone) and makes it possible to have the connecting components in the oral cavity (outside). The advantage of using the latter is mainly the ability to remove the denture. This enables the patient to clean the denture himself and gives the possibility to release some of the pressure on the gum. The IOD treatment is getting more attention the past years. The review of Mishra and Chowdhary (2019) examined the literature concerning patient's OHRQoL and satisfaction with IOD's compared to CD's, reviewing 21 articles. Retention, stability, comfort, speech and chewing efficiency improved with IOD's with enhanced patient's satisfaction and a better OHRQoL, compared to CD's [15].

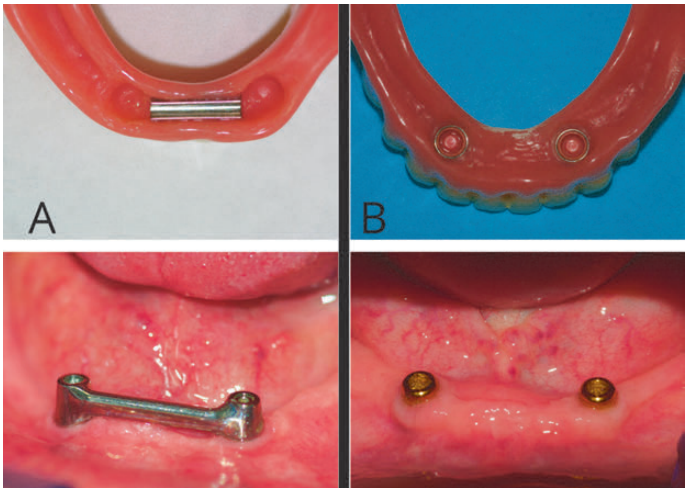

Fig 3. *Two implant rehabilitation in the maxilla connected with a bar (A) and non-connected on locators (B).*

However, some patients present with an advanced resorption of their jawbone, caused by longtime edentulism and rehabilitation with CD. Hereby regular dental implants cannot be placed due to limitations in bone morphology. In those cases often invasive reconstructive bone regenerative procedures are required with higher costs, increased morbidity and consequently higher barrier for treatment as compared to conventional implant placement [16,17]. Furthermore, elderly edentulous patients are often medically compromised

and benefit more from minimally invasive surgery. In light of this evolution, one piece mini-dental implants (MDI) with diameter less than or equal to 2.5mm should be considered as an alternative treatment solution for improved denture retention [18,19].

Treatment with MDI is introduced early 2000 and in general its outcome is promising although the clinical outcome defined by implant survival, bone stability or complications is often underreported, especially in the upper jaw [18,20].

Speech in rehabilitation of the edentulous jaw

Speech is the result of a complex interaction between the respiratory system (lungs), phonatory system (vocal folds), resonatory system (pharynx, nasal and oral cavity) and the articulatory system (the jaw, tongue, lips, soft palate, teeth, hard palate and the alveolar ridge) [21]. Air from the lungs passes through the pharynx, larynx and oronasal cavity during exhalation. The movable structures in the oral cavity (tongue, velopharyngeal mechanism, lips and jaw) are able to take specific positions, molding the air stream and causing sounds we know as speech sounds. This process is called articulation [21]. When changes are made to the oral structures, as is the case in rehabilitation with full dentures, it is possible that this complex interaction is disturbed and articulation in speech production is affected (Fig. 4). Table 1 gives an overview of the relevant literature concerning speech and oromyofunctional behavior in the rehabilitation of the edentulous jaw.

Traditionally, consonants are described according to *place* (where along the vocal tract the consonant is formed; e.g. bilabial, alveolar, velar, palatal,...), *manner* (how is it formed; e.g. nasa, glide, fricative,...) and *voicing* (whether the vocal folds are vibrating during production). Articulation disorders can be categorized into omissions (the sound is not produced), substitutions (the sound is replaced by another sound), additions (another sound is added to the target sound) or distortions (the sound is produced in an alternative way) [23]. There are two main causes of articulation problems. Firstly, functional problems caused by a wrong use of the articulatory muscles. Secondly, organic problems which appear due to changes of the structures responsible for articulation, which is the case in dental rehabilitation [21]. Studies on speech in dental rehabilitation in the maxilla report distortions in alveolar sounds (/s/, /z/, /t/, /d/,/n/, /l/ and

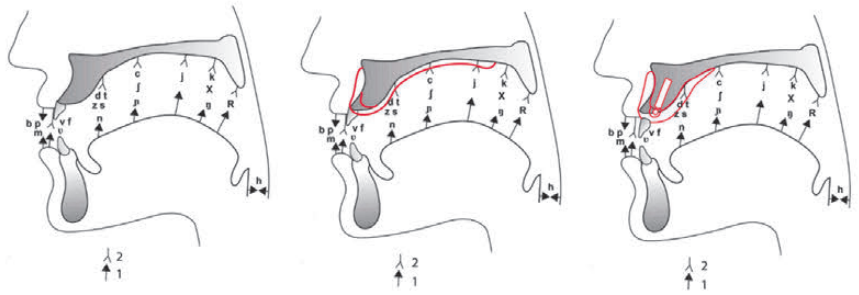

Fig 4. *Sagittal view on the oral cavity with contact spots of the tongue (1) to the palate (2) with normal dentition (left), conventional denture (middle) and overdenture on MDI (right)* [22].

/r/) and labiodental sounds (/v/ and /f/)[11,24–29]. Adaptation time is the time a patient needs to get used to their new oral situation. Because of the changes made in the oral environment during dental treatment the delicate interaction between the articulators, when producing speech sounds is being challenged. It is still unclear what the best adaptation period is for patients to get used to their new oral situation and what patient characteristics (e.g. age, gender, profession, language,...) may influence this adaptation. The adaptation time per study is displayed in table 1.

The most frequently heard complaint in dental rehabilitation is the occurrence of /s/ sound disorders [11,24,26,30,31]. The /s/ sound is produced by the formation of a channel between the tongue and the palate ending in a narrow point between the tongue and the alveolar ridge, through which air is forced. The tongue makes contact with the alveolar ridge of the upper jaw in the (pre)molar region, making the specific /s/ sound. There are two ways of placing the tongue when producing the /s/ sound. A speaker can lift the apex of the tongue in the direction of the upper frontal teeth (apical production) or position the apex of the tongue against the lower frontal teeth and the blade of the tongue in the direction of the upper frontal teeth (laminal production). Icht & Ben-David (2018) found the prevalence of apical and laminal production of the /s/ and /z/ sound in 242 Hebrew-speaking adults to be respectively 40% and 60%. They detected no acoustical differences between apical and laminal productions of these sounds [32]. The angle of the frontal teeth and the width of the prosthesis are especially important factors, influencing this sound [33–36]. In general, research focused on the influence of rehabilitation in the upper jaw on articulation [25–27,29], as most speech sounds are formed by making an upper movement with the

tongue against or close to the teeth, alveolar ridge, palate or uvula (fig. 4)[21]. However, alterations in the lower jaw, especially in fully edentulous people, may also cause articulation disorders.

Additionally, clinical experience shows that dental implants placed in a resorbed maxilla are often mispositioned due to resorption of the crest in palatal direction. This may result into wide bucco-lingual volumes, causing hinderance of the tongue during speech movement. Collaert (2015) examined the use of resin removal (removal of slices of the prosthesis) in patients suffering from speech problems due to treatment with fixed dentures on implants in the maxilla. A trained SLP examined the patients before treatment, one day after insertion of the prosthesis and after 21 days of adaptation (table 1). After reduction of the volume of the premolar region of the denture, all patients returned to baseline speech or improved speech [34]. Changes in thickness of the ridge and the palate of the prosthesis are also found to be an important factor in the occurrence of speech problems in patients treated with FID [34,35].

It is also possible that other problems present depending on which jaw is treated. As suggested in the research of Jacobs et al. (2001) there are especially problems with the apico-alveolar fricatives (/s/ and /z/) in fixed rehabilitation of the maxilla and fixed reconstruction in the mandibula seems to cause more problems with the plosives (/t/ and /d/) compared to the control group [25]. The reason mentioned in the paper is 'the difference in sound formation and the involvement of upper and lower teeth'. This study assessed speech function in 113 edentulous patients wearing fixed or removable dental prosthesis supported or not by oral implants. One SLP performed a standard speech and oromyofunctional examination (table 1). Although the mentioned fricatives and plosives both are alveolar sounds, there is a difference in formation. In case of the /s/ and /z/, a narrow channel is formed between the palate and the tongue to direct the air from the lungs against the upper or lower teeth to cause turbulence. The /t/ and /d/ is formed by a total block of the tongue against the maxilla to enable the airstream to escape all at once, making the typical 'explosive' sound.

When overviewing the studies displayed in table 1, it is clear that there is a lot of variation in the methods used to evaluate speech during dental rehabilitation. Two main strategies are used, sometimes combined. The first strategy was analysis of the spectral properties and energy distribution of the evaluated

sounds [28,33,35,37,38] and the second strategy was the use of perceptual analysis of a certain speech sample [24,25,27,28,34,37,39–41]. The speech samples used for the analysis are different in most studies and the use of one or more SLP's for (consensus) evaluation is not consistent.

This finding is also confirmed by the review of Meira et al. (2021) on speech in implant-supported and removable complete denture wearers. They reveal serious lacks in the research on the influence of complete denture treatment on speech. Out of 2586 studies, only 8 studies (4 paired clinical trials and cross-sectional studies) were considered appropriate for inclusion in the review according to the Joanna Briggs Institute checklists for quasi experimental and cross-sectional studies [42]. This checklists evaluate for instance the average interrater reliability coefficient between SLPs and risk of bias. The /s/ sound was the most distorted sound in the first six months of maxillary FID use compared to CD. Studies comparing CD to IOD revealed no significant differences in speech production. None of those studies could lead to a meta-analysis because of inconsistencies in the presentation of data on articulation disorders. Given this information, critical evaluation of the used methods for speech assessment in dental treatment of the existing literature and further research on speech disorders in prosthesis wearers is needed [43].

Oromyofunctional behavior in rehabilitation of the edentulous jaw

There is no consensus in literature about the influence of dental implant treatment on oromyofunctional behavior. Oromyofunctional problems are problems of muscles in the oral area, mostly tongue thrusting, deviate swallowing, mouth breathing and deviate mandibular movement [44].

These are the most important oromyofunctional disorders, underlying possible speech problems. The position of the articulators during these oromyofunctional disorders can be influenced by teeth position and denture placement [44]. On the other hand, it is stated that the position of the teeth and alterations in the oral cavity can influence the use of the oral muscles [11]. Research of Molly and coworkers (2008) examined in 10 patients with complete edentulous maxillae, rehabilitated with FID (immediate loading). Patients were tested by two groups of SLPs (one expert group and one non-expert group), before surgery, 1, 3, 6 and 12 months after surgery. The positioning of the lip and tongue at ease and the tongue during swallowing were evaluated. The positioning of the lip and the

tongue at ease were evaluated by the patient, indicating on schematic figures of the tongue what position resembled theirs the most. Hyperfunction of the musculus Mentalis during swallowing and the position and tonus of the lips were noted by the examiner. The results showed an increase of tongue thrust. Thrust is the frontal position of the tongue during rest and swallowing [27]. This could be affected by the conversion of a palate covering denture to an implant prosthesis without palatal coverage. Other research on oromyofunctional behavior does not report severe problems in implant treatment of any kind [29,31,40].

Quality of life and satisfaction with overdenture treatment

The impact of dental implant treatment on OHRQoL has been well documented in literature [9]. Compared to a natural dentition, denture wearing is associated with a reduction in functional comfort and OHRQoL. Lack of stability and retention as well as decreased chewing ability are the most prevalent patient complaints [11]. It is important to notice that OHRQoL is different from 'satisfaction' defined as the individuals positive evaluation of distinct dimensions of health care [45]. Satisfaction with the oral situation after implantation depends on the outcome in eating comfort, speech comfort and esthetics [46].

Overall, people are very satisfied and report minimal impact on OHRQoL after their treatment [9,28,29,34,46,47]. Nonetheless, there is a difference in impact on OHRQoL depending on the initial problem as well as the kind of prosthetic rehabilitation that has been performed. Patients are seemingly more satisfied and report less impact on OHRQoL with the treatment when rehabilitated with single crowns compared to fixed dentures or removable implant retained overdentures [31]. The effect of one missing tooth on OHRQoL is minimal whereas it is jeopardized in totally edentulous patients wearing removable prostheses. Compared to fixed dental prostheses on implants, OHRQoL improves proportionally more with overdentures on implants [47]. When adjustments are made to the orofacial and dental structures, the possible impact on different functions and quality of life can't be underestimated. On the other hand, people have higher demands and expectations regarding aesthetics, comfort and function [4].

Social participation and the role of personality traits

The outcome on OHRQoL, satisfaction and social participation is influenced by several other factors besides the pure technical treatment. Another large aspect, also provided in the ICF–model is 'personal factors'. Gender, age and

educational level of the patient are described as having an effect on patient related outcomes in dental treatment [48–50]. Dentists experience difficulties treating certain patients, always coming back with complaints or questions about their dental situation. When looking back to the ICF–model, one has to take into account an important factor influencing the functioning of patients, namely personality. Personality is the set of psychological traits and mechanisms within the individual that influences our interaction with and adaptation to intrapsychic, physical and social environments [51]. Personality may also affect the experiencing and reporting of health status and satisfaction with treatment. Despite a technically perfect treatment, some patients are still not satisfied with their oral situation [52,53] and personality traits may account for this differential experience [54–56].

Personality traits help to describe differences among people and contribute to our prediction of individuals' future behavior. Personality traits demonstrated not only to be important to understand quality of life and interpersonal behavior, but also to comprehend health behavior and health perceptions [57]. Umaki et al. (2012) suggested several reasons for non–compliance with oral hygiene measures, including the personality traits of neuroticism (N; emotional instability) and (low) conscientiousness (C; reliable, punctual and hardworking), but also stressful life events (e.g. death of a loved one, divorce, trauma,...) and health beliefs of the patient [58].

Research on the impact of prosthodontic treatment on quality of life and social relationships in patients almost exclusively relied on self–reports of experienced health status and interpersonal functioning. This type of evaluation is very important to understand the patients' point of view and the perceived impact on their quality of life. Although self–reports provide insightful information, there is a methodological problem of self–reporting bias. Especially when patients have undertaken efforts such as invested time, undergoing surgery, financial consequences, their reported treatment impact may be biased [51]. Costa and McCrae (1987) further argued that we cannot assume that people can rate their own health conditions accurately, because personality traits may bias the perception and reporting of medical symptoms. To overcome these biases, it is recommended to expand self–ratings with reports by an informed external observer who knows the daily functioning of the patient well. Including such

extra observer perspective in the evaluation of prosthodontic treatment would be a key innovation in this type of research [59,60]. The use of an multi-informant approach is a frequently used method in behavioral science [61]. It is important from a clinical view to stress that the suggestion about using multiple observers does not conflict with a patient centered approach. The extra information, gained from the extra observer, may give more insight in a patients' situation perceived both by the patient and the external observer. In some cases this insight may help patients to better understand and accept their situation.

Contemporary research on the impact of dental implants on quality of life and social participation paid only marginal attention to the role of personality in the experiencing of quality of life and social relationships and adaptation after surgery.

The literature overview in table 1 and the review of Meira et al. (2021) reveals that there are serious lacks in the research on overdenture treatment more specifically regarding the impact of overdenture wearing on speech, oromyofunctional behavior and social participation [43]. The available literature focusses mostly on fixed denture treatment or conventional dentures and fails to provide an objective assessment by professional speech language pathologists nor includes spectral analysis for an objective evaluation of speech sounds. Also longitudinal research on this topic is not available at the moment. The latter is important because clinicians are tempted to believe speech issues will resolve over time. In most cases patients adept well, but others get confronted with persistent complaints about their speech. In search for tools in dealing with those patients, there is a serious knowledge gap and a need for translational multidisciplinary research leading to clinical guidelines. The current PhD project is a start in exploring opportunities for a multidisciplinary approach of the overdenture patient.

Aims and Hypotheses

The main aim of this PhD study is to describe the multidisciplinary outcome of three different overdenture treatments on patients related outcomes (Specific information about the clinical outcomes of the treatments is provided in appendix).

The main aim of this thesis was specified in four sub aims and null hypotheses:

1. To assess prospectively the influence of changes made to the oral environment during mandibulary and maxillary overdenture treatment on speech. **Papers 1,2,3**
   $N_0 1_A$: Articulation distortions will occur but these are expected to disappear once the denture is implant retained.
   $N_0 1_B$: The /s/ sound will be the most affected sound in all stages of the treatment.
2. To assess prospectively the influence of changes made to the oral environment during mandibulary and maxillary overdenture treatment on oromyofunctional behavior. **Papers 1 & 3**
   $N_0 2$: Oromyofunctional behavior will not be affected by overdenture treatment.
3. To assess prospectively the influence of changes made to the oral environment during mandibulary and maxillary overdenture treatment on Oral Health Related Quality of Life and satisfaction. **Papers 1,2,3 & 4**
   $N_0 3_A$: The impact on OHRQoL will improve once the denture is implant retained.
   $N_0 3_B$: There will be higher patients' satisfaction with speech and overall health once the denture is implant retained.
4. To evaluate the impact of personality on social participation after implant treatment with a multi-informant approach. **Paper 4**
   $N_0 4_A$: There is an association between the five personality traits and OHRQoL and social participation before and after dental rehabilitation.
   $N_0 4_B$: The use of multi-informants in evaluating dental treatment is adds more insight in the patients' situation.

Study design

Papers 1–3 were designed similarly as a prospective case series. We recruited edentulous patients, suited for overdenture treatment. These patients were evaluated at several timepoints before, during and after treatment. Besides clinical and dental parameters [62–64] (not in this thesis), speech, oromyofuncional behavior, satisfaction and OHRQoL was examined at each timepoint. The comparison between the timepoints was performed pairwise (within patient comparison).

Paper 4 was designed as a multi-informant prospective study. We recruited patients, suited for complete denture treatment (conventional denture, overdenture and fixed denture) or single tooth replacement. All patients were asked to select an extra observer, close to their life. Patients were evaluated before and after full completion of the treatment. A self-rating and an observer rating was performed on following topics: OHRQoL, Personality and social participation. The comparison between the two timepoints was performed pairwise (within patient comparison), comparison between self- and observer rating was also performed pairwise (matched observer) and comparison between the single unit and complete denture group was performed on a group level.

Research papers

Paper 1

Fonteyne, E, Matthys, C, Bruneel, L, Becue, L, De Bruyn, H, Van Lierde, K. Articulation, oral function, and quality of life in patients treated with implant overdentures in the mandible: A prospective study. *Clin Implant Dent Relat Res*. 2021; 1– 12. https://doi.org/10.1111/cid.12989

Impact factor: 3.932
Quartile 1

Paper 2

Fonteyne, E, Burms, E, Matthys, C, Van Lierde, K, De Bruyn, H. Four–implant supported overdenture treatment in the maxilla. Part II: Speech and oral health related quality of life in patients with implant–supported overdentures in the maxilla: a prospective 3–years follow–up. *Clin Implant Dent Relat Res*. 2021. doi.org/10.1111/cid.13034

Impact factor: 3.932
Quartile 1

Paper 3

Fonteyne, E, Van Doorne, L, Becue, L, Matthys, C, Bronckhorst, E, De Bruyn, H. Speech evaluation during maxillary mini–dental implant overdenture treatment: A prospective study. *J Oral Rehabil*. 2019; 46: 1151– 1160. https://doi.org/10.1111/joor.12852

Impact factor: 3.837
Quartile 1

Paper 4

Ester Fonteyne, Hugo De Bruyn, Filip De Fruyt, Quality of life and social participation in dental rehabilitation: A personality and multi–informant perspective, Journal of Dentistry: X, Volume 4, 2020, https://doi.org/10.1016/j.jjodo.2020.100021.

Impact factor: 4.379
Quartile 1

Table 1. *Literature speech and complete dentures: Fixed Implant supported Denture =FID, Overdenture = IOD, Conventional Denture = CD (palatal coverage), Single Implant Restauration =SIR, Natural Dentition =ND.*

Authors	Purpose the study	Subjects and methods	Results
Petrovic (1985)	Evaluation of speech problems caused by changes in morphology of the upper CD.	n: 125 Morphological changes - Thickness of the palate (0,7mm; 1,2mm; 2mm) - Anterior vs. posterior position of the upper incisors Timing - with old CD - without CD - with CD with different changes in morphology Adaptation time: - 7 days - 1 month - 8 months	Effect of changes in thickness of the palate to spectral features of speech - Changes in resonance cavity, influencing the sounds' energy in the higher frequency region. - Distortion of the sounds in the word 'ivica' - Thickness above 1,2 mm causes faster distortion of sounds. - Energy ratio of the highest and lowest frequency in the /i/ sound changed significant. Changes in position of the upper incisors - 2 mm in labial direction caused in 80% of the subjects distortion of speech.

Table 1. *continued*

Authors	Purpose the study	Subjects and methods	Results
Lundqvist et al. (1992)	Assessment of difference in articulation between upper CD (with palatal coverage) and upper FID and the correlation with inter-dental space in the same subjects.	n: 17 ♀ : 12 ♂ : 5 Analysis of the prosthesis - Inter-dental space-difference - Height. - Width Timing/ adaptation time: - Pre-implant: CD - Post-implant: 3-6 months with FID. - Post- implant: 3 years	Perceptual analysis of /t/ and /s/ sound (using 4 SLPs and a non-expert group) - Pre-implant: 30% had slightly distorted /s/ and 5% slightly distorted /t/ - Post-implant (3-6 months): 45% had slightly distorted /s/, 10% had heavily distorted /s/ and 30% had slightly distorted /t/, 5% had heavily distorted /t/ - Post-implant (3 years): same level as CD (pre-implant) Spectral analysis - Energy of /s/ in post-implant condition was spread over the whole frequency band in the 3-6 months post-implant situation. Questionnaire satisfaction - Pre-implant: 29% considered their speech worsened by the prosthesis - Post-implant (3-6 months): 24% reported speech problems - Post-implant (3 years): 6% reported speech problems Analysis of the prosthesis - Inter-dental space had no significant influence on speech. - Little influence of height and width on distortion of the /s/ sound.
Ichikawa et al. (1995)	Influence of changes made in the oral cavity on speech.	n: 7 ♀ : 0 ♂ : 7 Subjects had a normal dentition Changes to the oral cavity - 1 mm augmentation of the palate. - 8 mm enlargement of the vertical distance in occlusion. Adaptation time: not provided	Spectral analysis of speech - The changes in augmentation had no influence on the /k/-sound - Aspiration time and the VOT (Voice Onset Time) of the /c/ prolonged significantly. - The vertical occlusion had no significant influence on speech.

Table 1. *continued*

Authors	Purpose the study	Subjects and methods	Results
Jacobs et al. (2001)	Evaluation of influence of CD, FID and OD on speech.	n: 138 ♀ : 89 ♂ :49 Experimental group: n1: (CD/FID): 22 n2: (FID/ND): 27 n3: (CD/IOD): 49 n4: (FID/FID): 15 Control group n5: (ND/ND): 25 *(Maxillar/Mandibular) Adaptation time: – Range: 5.2 – 15.2 years	Perceptual analysis of speech (using rating by one SLP) – More speech problems in the experimental group compared with the control group. Especially with the /s/–/z/ and /t/–/d/. Analysis of oromyofunction No differences between the two groups. Questionnaire satisfaction – No change of satisfaction with speech before and after treatment. – No difference between the control group and the experimental group.
Runte et al. (2001)	Evaluation of influence of the position of the upper incisives on the /s/ sound.	n: 20 12♀ 8♂ Situations 1. normal position 2. 30° palatal direction 3. 30° labial direction Adaptation time: not provided	Spectral analysis of speech – There was less energy in the /s/sound in the situations 2 and 3. – A labial direction evoked a lower frequency, a palatal direction evoked higher frequency. – Palatal situation had a smaller frequency band. – The duration of the /s/ sound in situation 2 and was shorter.

Table 1. *continued*

Authors	Purpose the study	Subjects and methods	Results
Heydecke et al. (2004)	Assessment of the influence of different prosthetic designs on speech.	n: 30 Trial 1: patients wore both IOD and FID on 6 implants in the maxilla (crossover). - n1: 15 ♀ : 8 ♂ : 7 *mandibula:* IOD *maxilla:* - IOD - FID Trial 2: patients wore both IOD with and without palate on 4 implants in the maxilla (crossover). - n2: 15 ♀ : 7 ♂ : 8 *mandibula:* FID *maxilla:* - IOD without palate - IOD with palate Within-subject crossover design Adaptation time: 2 months	Perceptual analysis of speech (two nonprofessional raters evaluated speech samples) Trial 1: - More correctly pronounced consonants with OD compared to FID in maxilla - More problems in fricatives compared to stops. - No difference in pronunciation of vocals. Trial 2 : - Mandibular restauration had no influence on speech. - Addition of palate had no influence on speech. Questionnaire satisfaction - IOD had a higher score compared to FID.
Sansone et al. (2006)	Evaluation of oromyofunctional behavior and speech after treatment with FID in the mandibula.	n: 14 ♀ : 8 ♂ : 6 (41j-78j) Timing/ adaptation time: - Pre-surgery - 1 month after surgery - 4 months after surgery	Perceptual analysis of speech (examinator not specified) - 7,1% (1/14) had /s/ sigmatism in all phases of the treatment

Table 1. *continued*

Authors	Purpose the study	Subjects and methods	Results
Molly et al. (2008)	The influence of immediate loading of a FID in maxilla or mandibula on speech adaptation.	n: 10 ♀ : 6 ♂ : 4 Timing/ adaptation time: - pre-surgery - 1 month after surgery - 3 months after surgery - 6 months after surgery - 12 months after surgery	Perceptual analysis of speech (blinded consensus evaluation by two groups of SLPs, expert and non-expert group) - After one year of speech-adaptation there were less interdental and strident pronunciations of /s/ and /z/. - After one year of speech-adaptation there were less interdental pronunciations of /t/ and /d/. - Improvement of speech between 1 month and 3 month adaptation. - Improvement of diadochokinesis and reading of sentences between 1 month and 6 months adaptation. - Subjects thought their speech was better before surgery. - More addental positions of the tongue in /s/ and /z/-sounds after surgery. - After 1 year adaptation, the speech was comparable with speech before surgery. Spectral analysis - There were no differences found in energy level in the /s/ sound over time. Analysis of oromyofunctional behavior - Amount of addental position of the tongue in rest increased after surgery. - Addental position of the tongue during swallow was seen in most subjects after one year adaptation. Questionnaire satisfaction - Subjects who were more satisfied with surgery, had les speech problems.

Table 1. *continued*

Authors	Purpose the study	Subjects and methods	Results
Rodrigues et al. (2010)	Detection of the influence of different prosthetic treatments on speech in elderly people.	n: 36 3 groups: 1. ND n:13 2. CD in maxilla and mandibula. n: 13 3. CD in maxilla and FID in mandibula. n:10 Adaptation time: - Range: 1 month – 22 years	Perceptual analysis of speech (using five SLPs for evaluation) - High frequency of speech-problems in group 3 - Closed articulation was observed in all groups. - Reduction of lip movements was observed in group 1 and 2. - Exaggerated articulation and lack of salivary control were observed in group 3. - There were no statistically significant differences between groups. - In group 2 and 3 there were more interdental productions of the /s/.
Van Lierde et al. (2012)	Comparison of speech intelligibility, articulation and oromyofunctional behavior in subjects with SIR, FID and CD.	n: 53 SIR: n: 14 ♀ : 7 ♂ : 7 Adaptation time: - Range 0.11–2.1 years FID in mandibula or maxilla n:15 ♀ : 9 ♂ : 6 Adaptation time: - Range 6–8 months CD in mandibula or maxilla n:15 ♀ : 3 ♂ : 12 Adaptation time: - Range 0.11–1.2 years Control group: n=9	Perceptual analysis of speech (using consensus evaluation by two blinded SLPs) - Consonant distortions: SIR: 57% (8/14) FID: 87% (13/15) CD: 60% (9/15) Control-group: no distortions In all groups: most detected distortion was sigmatismus simplex and stridens. Spectral analyses - No significant differences were found Analysis of oromyofunctional behavior - Oromyofunctional behavior was normal in all groups. Questionnaire satisfaction - SIR: 80%–100% (mean: 95%) - FID: 50% – 100% (mean: 87%) - CD: 20%–100% (mean: 68%) - Control-group: 100% - SIR more satisfied than CD. - Speech problems post-placement: SIR: 0%;FID: 53%; CD: 33%; - Changes between pre-treatment and post-treatment in FID and CD group

Table 1. *continued*

Authors	Purpose the study	Subjects and methods	Results
Collaert et al. (2015)	The influence of FID after immediate loading in edentulous maxilla on speech.	n: 10 ♀ : 7 ♂ : 3 Timing - Pre-operation - One day post- op - 21 days post-adaptation - 21 days post-intervention Changes to the oral cavity - If speech problems occurred after 21 days adaptation, the palate was adjusted to allow natural tongue movements. Adaptation time: 21 days	Perceptual analysis of speech (using evaluation by one SLP) - After 21 days adaptation 7 subjects had deteriorated speech. - After adjusting the prosthesis 5/7 subjects speech returned to baseline levels. - 21 days after adjusting the prosthesis, 2 subjects had improved speech and 8 had returned to baseline level. The palatal borders in the premolar region had to be reduced up to 3mm to achieve better speech or solve speech-problems.
Langlois et al. (2019)	The influence of oral health status on speech in elderly patients.	n: 30 ♀ : 20 ♂ : 10 CD mandibula or maxilla: 9 FD mandibula or maxilla: 2 Adaptation time: not provided	Perceptual analysis of speech (using blinded consensus evaluation by 2 SLPs) Association between the severity of articulation disorders and the state of the prosthodontic device (NS).

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CHAPTER 2

Articulation, oral function, and quality of life in patients treated with implant overdentures in the mandible: A prospective study.

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Abstract

Background: Modifications of facial and oral structures affect aesthetic appearance, orofacial functions and have impact on quality of life.

Purpose: This study determined alterations of articulation, oromyofunctional behavior and Oral Health Related Quality of Life (OHRQoL) in patients replacing complete removable dentures by implant retained overdentures in the mandible.

Materials and Methods: Twenty-one fully edentulous patients received mandibular overdenture retained on a bar connecting 2 titanium dental implants. Patients were evaluated after receiving a new set of fully removable dentures (stage 1), after surgery during provisionalisation on healing abutments (stage 2) and after final connection to the bar (stage 3). Assessments were taken by speech therapists and included evaluation of: articulation (picture naming and reading); oromyofunctional behavior; OHRQoL (OHIP-14 questionnaire) and overall satisfaction and speech (VAS). To measure changes over time, Wilcoxon matched-pairs signed-rank-test and McNemar test was used.

Results: There was no significant impact of the treatment on speech nor on the results of oromyofunction. In stage 1 patients had different kinds of articulation errors (mean:1.21) which evolved to 0.71 and 0.67. In stage 3 especially problems with the /s/ sound are seen in 37% (7/19) of the participants. Results of OHRQoL and satisfaction reveal that the average of satisfaction with oral health evolved from 67%, to 63% and finally 78%. OHIP-14 total score was 17.4/56 in stage 1, remained unchanged in stage 2 and evolved in stage 3 to 9.8/56 (p:0.010). This indicates improvement. Satisfaction with speech evolved significantly from 68% pretreatment to 82% in stage 3 (p:0.013).

Conclusion: Despite existing articulation and oromyofunctional disorders after treatment, people are very satisfied with their OHRQoL and their speech. Impact of mandibular denture wearing on OHRQoL declines once connected. It's important to inform patients that speech and oromyofunctional disorders may occur during treatment where especially the /s/ sound is vulnerable.

Introduction

When adjustments are made to the orofacial and dental structures, the possible impact on different functions and quality of life can't be underestimated. Despite more attention for oral health care, a substantial part of the population is still confronted with loss of all teeth, in most instances because life expectancy is rising.[1] On the other hand, people have higher demands and expectations regarding aesthetics, comfort and function.[2] In many cases removable appliances are the first choice predominantly dependent of the financial condition of the patient. Unfortunately denture wearing reduces functional comfort when compared to natural teeth and affects oral health related quality of life (OHRQoL). [3,4]

In fully edentulous patients, the first choice of rehabilitation is by means of a conventional removable denture. Over time, the wearing of a conventional denture worsens bone resorption and consequently decreases functionality.[3] Lack of stability and retention of the conventional denture is the most prevalent patient complaint and causes reduced chewing ability and reduced comfort during articulation.[5] To improve denture retention, dental implants are useful and overdentures on two implants in the lower jaw are considered the minimal standard of care.[6,7] For the majority of the edentulous patients, a 2–4 mandibular implant overdenture delivers a sufficient treatment solution with 95% implant survival after 10 years.[8] The most common way to anchor a dental prosthesis is a treatment with conventional dental implants of at least 3.5 mm diameter. Eating comfort, speech and aesthetics are known to be the most important factors in determining oral health related quality of life after dental rehabilitation.[9,10]

Speech is the result of a complex interaction between the respiratory system (lungs), phonatory system (vocal folds), resonatory system (pharynx, nasal and oral cavity) and the articulatory system (the jaw, tongue, lips, soft palate, teeth, hard palate and the alveolar ridge).[11] Air from the lungs passes through the pharynx, larynx and oronasal cavity during exhalation. The movable structures in the oral cavity (tongue, uvula, lips and jaw) are able to take specific positions, molding the air stream and causing sounds we know as speech sounds. The latter is called articulation.[11] When changes are made to those structures, as is the case in rehabilitation with full dentures, it is possible that this complex

interaction is disturbed and articulation in speech production is affected. The most frequently heard complaint in dental rehabilitation is the occurrence of /s/ sound disorders.[3,12–18] The /s/ sound is produced by forcing air through a narrow tunnel between the tongue and the palate where the airflow becomes turbulent and generates the /s/ sound at the anterior end of this constriction.[19] The tongue makes contact with the alveolar ridge of the upper jaw in the (pre) molar region, making the specific /s/ sound. Most people lift the apex of the tongue in the direction of the upper frontal teeth but others position their tongue against the lower frontal teeth. The angle of the frontal teeth and the width of the prosthesis are especially important factors, influencing this sound.[20–23] Overall, the slightest alteration in the oral cavity can affect articulation, especially directly after treatment. In general, research focused on the influence of rehabilitation in the upper jaw on articulation [12–16], as most speech sounds are formed by making an upper movement with the tongue against or close to the teeth, alveolar ridge, palate or uvula.[11] However, alterations in the lower jaw, especially in fully edentulous people, may also cause articulation disorders and problems with oromyofunctional behavior. Previous studies encountered distortions of the /s/, /t/ and /d/, others encountered no speech distortions in this population.[12,17,24]

In order to make functional movements, the oral and facial muscles need to move together in a harmonious way.[11] Due to organic reasons such as dental rehabilitation, this balance can be disturbed. This can result in problems pronouncing speech sounds and oromyofunctional behavior. Until now there are no studies reporting difficulties in oromyofunctional behavior in mandibular rehabilitation.[12,24]

The impact of dental treatment on OHRQoL has been well documented in literature.[25] Overall, people are very satisfied and report minimal impact on OHRQoL after their treatment. [9,15,16,18,21,25,26] Nonetheless, there is a difference in impact on OHRQoL depending on the initial problem as well as with the kind of prosthetic rehabilitation that has been performed. Patients are seemingly more satisfied with the treatment of a dental implant when rehabilitated with single crowns compared to fixed dentures or removable implant retained overdentures.[15] On the other hand, the effect of one missing tooth on OHRQoL is minimal whereas it is overwhelming jeopardized in totally edentulous patients wearing removable prostheses. Compared to fixed dental prostheses

on implants, OHRQoL improves proportionally more with overdentures on implants.[26]

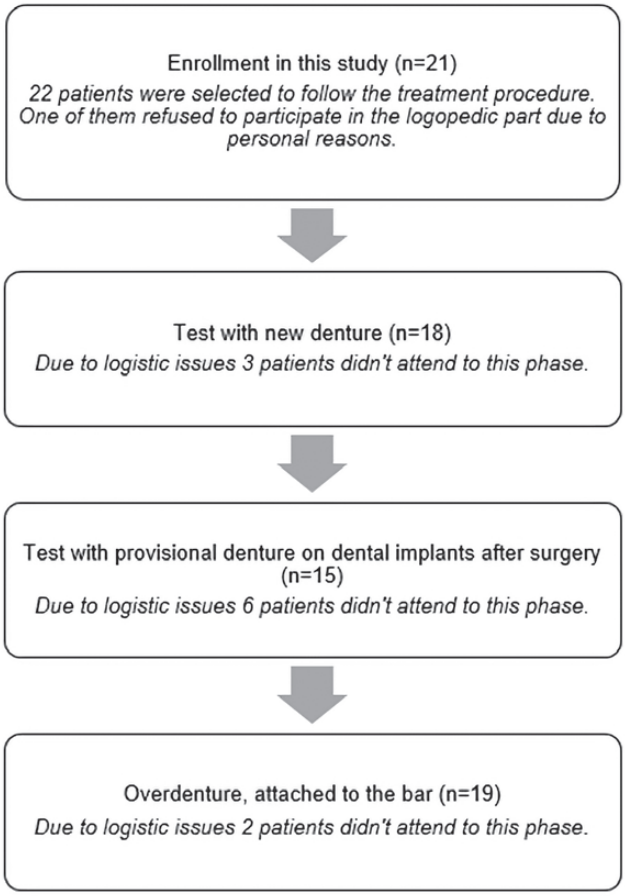

Fig 1. *Flowchart of the study population.*

In summary, research on articulation and oromyofunction in overdentures in the mandible is scarce, whilst the treatment is commonly used. Therefore, the aim of this study was to determine the impact on articulation, oromyofunctional behavior and Oral Health Related Quality of life (OHRQoL) in patients converting from a new removable denture and afterwards to a 2- implant retained overdenture. Based on the results of research on fixed prostheses and overdentures in the maxilla and mandibula, it is hypothesized that articulation distortions will occur but these are expected to disappear once the denture is implant-retained. Especially distortions of the /s/ sound are likely to occur in

all stages of the treatment because this sound seems very vulnerable when changes are made to the oral environment. We expect no significant impact of the treatment on oromyofunctional behavior. Based on previous literature on patient-related outcomes in overdentures, it is to expect that the impact on OHRQoL will improve after full treatment and the satisfaction with oral health will rise.

Methods and materials

Patient selection and clinical treatment procedure

This study was part of a project assessing clinical outcome of 2 different dental implants inserted in 22 mandibles. The implants were placed in the crest at two different depth positions. At the supracrestal and mucosal levels both implants received identically shaped abutments. The overdenture bar was screw-retained in a similar way on both abutments. Hence, the implant aspects are not affecting the outcome reported in this paper. All patients were edentulous in both jaws at intake. We may refer to Glibert et al. 2018 [27] for detailed description of the protocol and the implant-related outcome.

The participants of this prospective case series signed up for treatment at the dental clinic of the Ghent University Hospital, searching for a stable alternative for their conventional denture in the mandibula. Only patients with a fully edentulous maxilla and mandible for at least 4 months, that didn't suffer from systemic diseases and were non-smokers were included. As they could possibly affect articulation, the following criteria were assessed at intake: hearing disorders according to the patient, neurological disorders and a history of speech therapy.

One of the 22 patients preferred not to participate in the part of speech and oromyofunctional examination for personal reasons. Twenty-one patients (11 females and 10 males) participated in the speech and oromyofunctional assessment. During the intake examination, six patients reported hearing disorders. This group was analyzed post hoc on possible differences in outcome. There was no significant difference between the 'hearing disorders group' and the 'normal hearing group' for speech in all stages (1-3) of the treatment (resp.: p=0.085; p=0.251; p=0.401). Hence it was concluded that both groups could be

included in the results. Table 1 displays detailed patient information. 18 patients where tested on average 85.95 days (SD: 48.23) after receiving their new conventional denture. On average 86.60 days (SD: 56.54) after insertion of the two mandibular implants, 15 subjects were tested with a provisional connection of the overdenture to the implants. Finally, on average 87.95 days (SD: 62.34) after the overdenture was actively connected to the implants, 19 subjects were evaluated (Figure 1). Dropout, was related to time and logistic issues. The statistical analyses only includes the records of the patients of whom there were data in both measurements, pairwise.

Table 1. *Subject information at intake.*

Subject n°	Gender	Age	Hearing status by questioning	Adaptation to the dental situation Phase 1 (days)	Adaptation to the dental situation Phase 2 (days)	Adaptation to the dental situation Phase 3 (days)
1	F	44	Normal	48	90	140
2	F	56	Normal	40	81	162
3	F	71	Normal	172	193	–
4	F	62	Normal	55	49	141
5	M	57	Normal	48	–	130
6	F	56	Normal	56	–	42
7	M	55	Normal	–	8	–
8	M	61	Disturbed	88	137	41
9	M	51	Normal	36	41	20
10	M	64	Normal	40	–	94
11	M	72	Normal	98	130	112
12	M	62	Disturbed	115	96	47
13	M	56	Normal	76	34	46
14	F	60	Disturbed	–	56	221
15	F	79	Disturbed	–	83	54
16	F	73	Normal	185	–	208
17	M	61	Disturbed	103	198	43
18	M	63	Normal	69	69	41
19	F	66	Normal	179	–	49
20	F	85	Normal	70	–	57
21	F	76	Disturbed	69	34	23
Difference between 'normal hearing' and 'disturbed hearing' group				Z:–1.725 p:0.085	Z: –1.148 p:0.251	Z: –0.839 p:0.401

The denture treatment was performed by two experienced and calibrated faculty members. To prosthetically be able to make an ideal overdenture, an ideal presurgical condition, in terms of facial height, aesthetics and maximal fit of the denture was necessary. A new prosthesis was made to have this ideal situation and be able to convert this prosthesis to the final overdenture.

A cone beam computed tomography (CBCT) scan including gutta percha markers provided the correct implant positioning. The markers were placed 18 to 22 mm apart and as parallel to the hinge axis in the canine positions of the mandibular denture. Before placement of the two implants, the CBCT scan with the marked mandibular prosthesis provided information about the bone quantity in the interforaminal region of the mandible. Furthermore it allowed correct angulation of the implants in the bone as to guarantee an axial loading of the denture as well as a perfect location of the future bar within the normal dimensions of the denture. The two implants were placed under local anaesthesia by an experienced surgeon in a one-stage surgical procedure, with appropriate initial stability and clinically parallel in frontal view. Immediately after surgery, healing abutments were placed slightly above mucosal level and the internal surface of the mandibular denture was relieved to provide space for a resilient liner (COE SOFT; GC America Inc.; Illinois, U.S.A.). Antibiotics and analgesics were administrated immediately after surgery. After one week, sutures were removed and the denture base was adjusted whenever required for pain relief or pressure points. The participants were checked after one and two months. Intermediate check-ups were possible on request by the patient in case of discomfort. After a 3-month healing period, a pick-up impression technique in maximal occlusion with a light-body polyether impression material (Permadyne Polyether Impression Material; 3M ESPE; Saint Paul MN, U.S.A.) and the appropriate impression posts (Southern Implants Inc, Irene, South Africa) was made with the existing mandibular denture. CAD-CAM technique was used to fabricate the bar attachment. The mandibular denture was rebased, and the retentive clip was processed by the indirect technique at the dental laboratory (Figure 2). No internal metal reinforcement was inserted in the mandibular dentures. All prosthetic connections and recall procedures were performed by the same faculty members (C.M., E.F.).

The study protocol was designed according to the principles of the Helsinki Declaration on clinical research (1975, revised in 2002). All patients signed a written consent statement before being included in the study. Before this consent they received detailed oral and written information about the study protocol, treatment plan, financial costs, follow-up period, and potential risks and complications. The study was approved by the Ethical Committee of the Ghent University Hospital (2014/1231) on clinical research involving human beings.

Fig. 2 *Implant retained bar (a) and overdenture attachment in the mandible (b)*

Methods

The evaluation of the subjects took place in a clinical examination room with as minimal background noise as possible. Patients were evaluated with their new conventional denture; secondly with the provisional relined denture on average 3 months after surgery and finally with the implant–retained overdenture after 3 months. This adaptation period was also used in previous studies and was required for healing of the implants.[14] The subjects were invited to participate by the speech–language pathologist (SLP) (E.F.), who worked independent from the dentists. The test protocol (camera position, test items and score form) was identical for each testing. The adaptation time to the new oral situation is displayed in table 1. The whole test took approximately 20 minutes.

Articulation

To evaluate different speech sounds patients were asked to name a series of 135 full color pictures on white background, based on the protocol used in Van Borsel et al. 1995.[28] This test contains all Dutch speech sounds in all possible syllable positions and the most frequently occurring consonant clusters. Next, they were asked to read words and sentences aloud especially containing the /s/, /z/, /ʃ/ (as in **sh**ow), /ʒ/ (as in gara**g**e), /t/, /d/, /n/, /l/, /r/ and /f/ sounds, based on the protocol of Jacobs et al. 2001.[12] Both naming and reading are evaluated because the way of presenting the target words can possibly affect

the pronunciation. A sound was considered present in the inventory (both the correct production and the disturbed production) when at least two instances of the production were found. The whole protocol was video-recorded and evaluated independently by two speech-language pathologists (E.F. and L.B.). One SLP (L.B.) was blinded for the stage of the treatment. Inter-rater reliability was evaluated according to Landis and Koch and is displayed in table 1.[29]

Additionally we performed a spectral analysis on the /s/ sound in word-initial, word-medial and word-final position. The signals were sampled at 44 100 Hz. A Samson CO1U-USB microphone was used to record the samples. Each sample was visualized by means of Praat software.[30] By average a 0.1 s section was manually extracted from each /s/ token using a Hamming window. A Praat script, developed by Corthals (2008) was used to derive the four spectral moments (i.e., mean, standard deviation, skewness, kurtosis) and the peak frequency value of the Fast Fourier spectrum. We compared all spectral moments between the stages of the treatment, using Wilcoxon matched-pairs signed-rank-test.

Oromyofunctional behavior

To assess difficulties in muscle movement of the face and oral cavity, patients were asked to follow a series of instructions given by the SLP (E.F.) and perform certain movements with the facial and oral muscles. No visual modelling was performed by the SLP and there was no mirror provided to help the patients with the positioning of their muscles. The evaluation included jaw movement (in rest, open, horizontal movement of the jaw), tongue movement (tongue protrusion, tongue retrieval, tongue lift against the upper lip, tongue against the lower lip, tongue against the lip angles (left and right) and clicking the tongue against the palate), lip movement (in rest, lip closure, spread of the angles of the lips and lip protrusion) and integrated movements (coughing, blowing, spontaneous movement of the facial muscles, whistling, filling the cheeks with air, and swallowing water). The protocol of Lembrechts et al. 1999 [31] was adjusted to evaluate the functions, relevant to this study population (e.g. the evaluation of the velopharyngeal function was omitted). The whole protocol was video-recorded and evaluated independently by two SLPs (E.F. and L.Br). One SLP (L.Br.) was blinded for the stage of the treatment. A task was classified to be normal or disturbed. Interrater reliability is displayed in table 4.

Satisfaction and quality of life

Prior to each examination, patients filled in the validated Dutch version of the shortened Oral Health Impact Profile (OHIP-14, Slade and Spencer 1994 [32], van der Meulen et al. 2008 [33]). The OHIP-14 consists of 14 items divided in 7 domains: 1. functional limitation; 2. physical pain; 3. psychological discomfort; 4. physical disability; 5. psychological disability; 6. social disability and 7. handicap. We used the first question (Have you had trouble pronouncing any words because of problems with your teeth, mouth, dentures or jaw?) to determine the impact of the treatment on articulation and the total OHIP-14 score to measure the Oral Health related Quality of life. The items were rated by a Likert-scale ranging from 0 (no discomfort) to 4 (high discomfort). A total OHIP-14 score was assessed by counting the scores of the 14 individuals questions. A score of 56/56 is indicative for maximal negative appreciation and 0/56 indicates that there are no issues at all. Additionally, two visual analog scales (VAS, 10 cm) were used to rate the patient's satisfaction with speech and general oral health at each experimental interval. In the visual analog scales, the end of the line reflects 100% maximal satisfaction and the other end of the line corresponds 0% to complete dissatisfaction.

Statistical Analysis

To compare the changes in the variables of at least interval scale (number of errors per person, spectral characteristics and scores for satisfaction and OHRQoL) between the different stages of the treatment a Wilcoxon matched-pairs signed-rank-test was used. To compare the changes over time in the variables of a nominal scale (type of articulation and oromyofunctional errors) a McNemar test was used. The difference in speech outcomes between the 'disturbed hearing' group and the 'normal hearing' group (results based on a questionnaire) was assessed using a Mann-Whitney-U test. We estimated interrater reliability using Cohen's Kappa. Interpretation of these levels happened according to Landis and Koch.[29] All levels of significance were set at $\alpha=0.05/3$ (=0.01667), according to the Bonferroni correction for multiple testing. For analysis of the data SPSS statistics 25 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp) was used.

Results

Articulation

Table 3 and table 2 show the results of the perceptual speech evaluation based on the picture naming and reading test. When the patients received a new denture, and after a certain adaptation period, they presented with distortions of the following sounds: /s/ (PNT: 9/18 and reading: 11/18), /z/ (PNT: 3/18 and reading: 2/18), /ʃ/ (PNT: 1/18 and reading: 2/18), /t/ (PNT: 8/18 and reading: 4/18), /d/ (reading: 1/18), /n/ (PNT: 2/18 and reading: 2/18) and /l/ (PNT: 5/18 and reading: 4/18). After surgery, the denture is adjusted to provisionally fit over the implant abutments. Here the following sounds were distorted: /s/ (PNT: 6/15 and reading: 8/15), /z/ (PNT: 1/15 and reading: 3/15), /t/ (PNT: 5/15 and reading: 2/15), /n/ (reading: 3/15) and /l/ (PNT: 3/15 and reading: 3/15). Finally, when the osseointegration of the implants was satisfactory, the overdenture is manufactured and placed over the bridge on implants. After adaptation to the final situation, the sounds /s/ (PNT: 7/19 and reading: 7/19), /z/ (reading: 2/19), /t/ (PNT: 3/19 and reading: 1/19), /n/ (PNT: 1/19 and reading: 1/19) and /l/ (PNT: 3/19 and reading: 4/19) were found to be distorted. These articulation errors consisted of sigmatismus stridens (disorder of the /s/ sound accompanied with a whistle sound), sigmatismus simplex (disorder of the /s/ sound with insufficient frication), disturbed /ʃ/ and an addental (sound production with the tongue tip against the central incisors) and interdental (sound production with the tongue tip between de central incisors) production of the /t/, /d/, /n/ and /l/ (table 2). The most important clinical change in number of articulation errors was shown when comparing the measurement with the new conventional denture to the stage with final connection of the overdenture to the implants. The number of articulation disorders per person declined clinically, however not statistically over time.

Spectral evaluation of the /s/ sound compared over the different stages of the treatment revealed no significant results ($\alpha<0.05/3$) in all examined speech samples. Figure 3 shows the sample outcomes of the spectral moments (mean frequency, standard deviation, skewness and kurtosis) and the peak frequency value of the /s/ sound of one subject pronouncing sample word ‘set’ in the three different stages of the treatment.

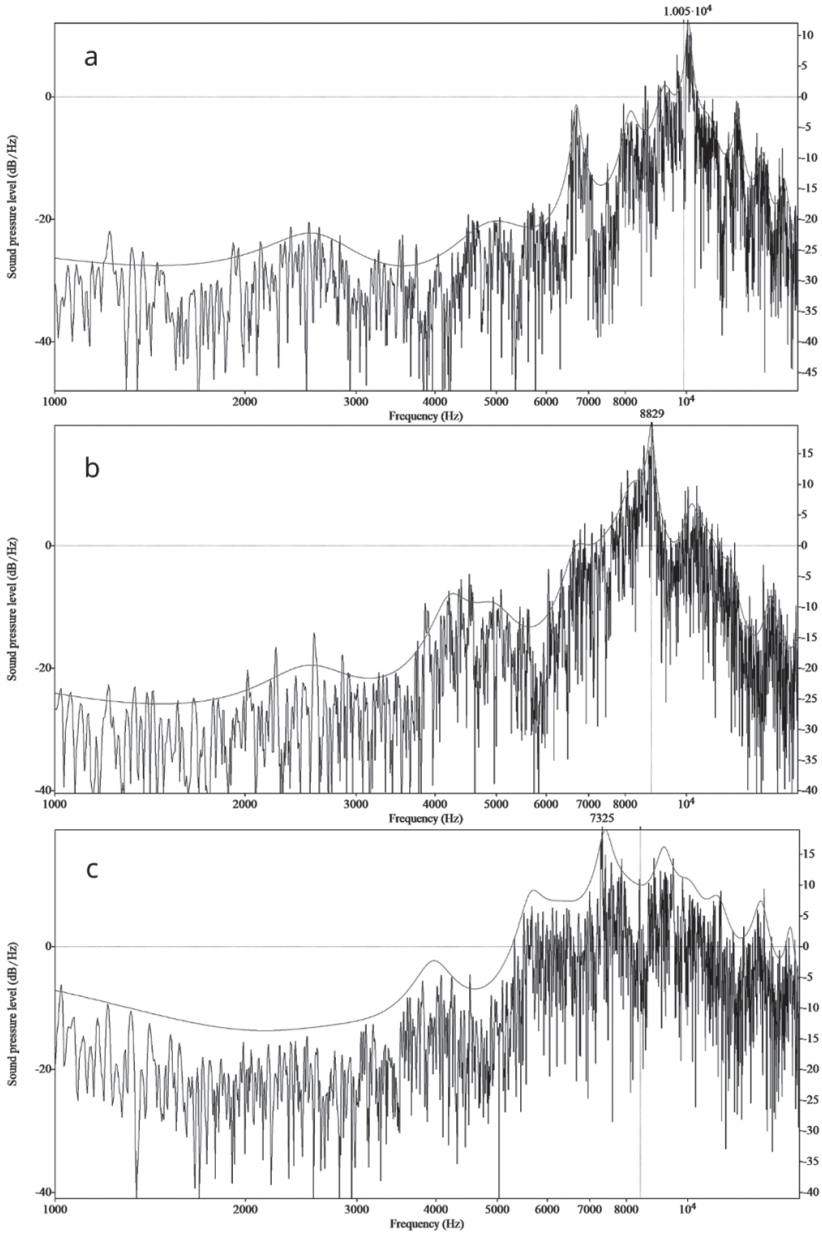

Fig 3. *Sample outcomes of the spectral analyses in subject 1. The spectral moments of the /s/ sound in 'set' with the new denture (a): mean freq. 9888 Hz; SD 1344 Hz; skewness –2.165; kurtosis 18.83 and peak freq. value 10046 Hz. The spectral moments of the /s/ sound with the provisional denture (b): mean freq. 8800 Hz; SD 1123 Hz; skewness –1.396; kurtosis 19.68 and peak freq. value 8829 Hz. The spectral moments with the overdenture (c): mean freq. 8416 Hz; SD 2567 Hz; skewness –0.748; kurtosis 3.29 and peak freq. value 7325 Hz.*

Table 2. *Articulation during the reading test: Articulation problems assessed during the stages of the mandibular overdenture treatment (preoperative, provisional loading and final connection) measured by the reading test. The level of significance after Bonferroni correction was set at α=0.05/3.*

	Inter examiner Reliability	New denture (n)	Provisional denture (n)	Overdenture (n)	New- provisional *p*-value	Provisional- overdenture *p*-value	New-overdenture *p*-value
Phonetic error of the /s/	0.71	11/18	8/15	7/19	0.625	0.500	0.453
stridens		9/18	8/15	6/19			
simplex		2/18	0/15	1/19			
Phonetic error of the /z/	0.90	2/18	3/15	2/19	0.500	1	1
stridens		1/18	3/15	2/19			
simplex		1/18	0/15	0/19			
Phonetic error of the /ʃ/	1	2/18	0/15	0/19	1	1	0.500
stridens		1/18	0/15	0/19			
simplex		1/18	0/15	0/19			
Phonetic error of the /t/	0.84	4/18	2/15	1/19	1	1	1
interdental		1/18	0/15	0/19			
addental		3/18	2/15	1/19			
Phonetic error of the /d/ addental	0.94	1/18	1/15	0/19			
Phonetic error of the /n/	0.83	2/18	3/15	1/19	1	1	1
interdental		2/18	3/15	0/19			
addental		0/18	0/15	1/19			
Phonetic error of the /l/	0.82	4/18	3/15	4/19	1	1	1
interdental		3/18	3/15	3/19			
addental		1/18	0/15	1/19			
Number of speech errors per person		Mean 1.13 [0–4] SD 1.39	Mean 0.87 [0–4] SD 1.29	Mean 0.65 [0–2] SD 0.83	Z: −0.852 p=0.394	Z: −0.589 p=0.556	Z: −1.721 p=0.085

Table 3. *Articulation during the picture naming test: Articulation problems assessed during the stages of the mandibular overdenture treatment (preoperative, provisional loading and final connection) measured by the picture naming test. The level of significance after Bonferroni correction was set at α=0.05/3.*

	Inter examiner Reliability	New denture (n)	Provisional denture (n)	Overdenture (n)	New- provisional *p*-value	Provisional-overdenture *p*-value	New-overdenture *p*-value
Phonetic error of the /s/	0.80	9/18	6/15	7/19	1	1	0.625
stridens		8/18	6/15	7/19			
simplex		1/18	0/15	0/19			
Phonetic error of the /z/ stridens	0.95	3/18	1/15	0/19	1	1	0.500
Phonetic error of the /ʃ/ stridens	1	1/18	0/15	0/19	1	1	1
Phonetic error of the /t/	0.85	8/18	5/15	3/19	1	0.500	0.180
interdental		3/18	2/15	1/19			
addental		5/18	3/15	2/19			
Phonetic error of the /n/	0.83	2/18	1/15	1/19	1	1	1
interdental		0/18	1/15	1/19			
addental		2/18	0/15	0/19			
Phonetic error of the /l/	0.64	5/18	3/15	3/19	1	1	0.625
interdental		4/18	3/15	3/19			
addental		1/18	0/15	0/19			
Number of speech errors per person		Mean 1.21 [0–5] SD 1.47	Mean 0.71 [0–3] SD 0.96	Mean 0.67 [0–2] SD 0.76	Z: -1.446 p=0.148	Z: -0.330 p=0.741	Z: -1.663 p=0.096

Table 4. *Type of articulation errors and their definitions (Pena-Brooks and Hegde, 2000).*

Type of articulation error	Definition
Stridens	The sound accompanied with a whistle sound
Simplex	The sound with insufficient frication
Interdental	The sound formed with the tongue tip between the central incisors
Addental	The sound formed with the tongue tip against the central incisors

Oromyofunctional behavior

Table 5 displays the results of the oromyofunctional evaluation during treatment. Of the 25 test items, 6 items where affected at some point during treatment in 6 or less patients. The statistical analyses showed no significant results. When participants received their new denture, 1/18 presented with immobility of the jaw, 2/18 patients showed insufficient closing of the lips, 4/18 presented with problems while whistling, 4/18 presented with tongue thrust during swallowing and 3/18 showed difficulties clicking one's tongue against the palate. After provisionalisation of the denture 1/15 presented with immobility of the jaw, 2/15 patients showed insufficient closing of the lips, 4/15 presented with problems with whistling, 1/15 presented with tongue thrust during swallowing, 1/15 showed tongue lift problems and 2/15 showed difficulties clicking one's tongue against the palate. Finally with the overdenture 1/19 presented with immobility of the jaw, 2/19 patients showed insufficient closing of the lips, 6/19 presented with problems with whistling, 1/19 presented with tongue thrust during swallowing, 2/19 showed tongue lift problems and 1/19 showed difficulties clicking one's tongue against the palate.

The average number of problems with oromyofunctional behavior evolved from the stage with the new denture (0.96) to the stage with the provisional denture (0.79). In the last stage, the average of problems was again higher (0.96). No significant differences between de stages were found.

Table 5. *Oromyofunctional evaluation: Problems with oromyofunctional behavior assessed during the stages of the mandibular overdenture treatment (preoperative, provisional loading and final connection). The level of significance after Bonferroni correction was set at α=0.05/3.*

	Inter examiner Reliability	New denture (n)	Provisional loading (n)	Overdenture (n)	New–Provisional *p*–value	Provisional – Overdenture *p*–value	New – Overdenture *p*–value
Immobility of the jaw	0.42	1/18	1/15	1/19	1	1	1
Insufficient closing of the lips	0.71	2/18	2/15	2/19	1	1	1
Whistling problems	0.40	4/18	4/15	6/19	1	1	1
Tongue thrust during swallowing	1	4/18	1/15	1/19	1	1	1
Tongue lift problems	0.75	0/18	1/15	2/19	1	1	1
Problems with clicking of the tongue	0.72	3/18	2/15	1/19	0.500	1	0.625
Number of errors per person		Mean 0.96 [0–4] SD 1.23	Mean 0.79 [0–3] SD 0.88	Mean 0.96 [0–6] SD 1.36	Z: −0.356 p=0.722	Z: −0.528 p=0.597	Z: −0.049 p=0.961

Oral health related quality of life

In table 6 and figure 4, the results of the examination of satisfaction and OHRQoL are displayed. An average of satisfaction with oral health (measured by the VAS) evolved from 67% with the new denture, 63% with the provisional and 78% with the overdenture in place. The OHIP–14 total score changed from 17.2/56 to 17.67/56 and finally 9.16/56. This improvement in impact on quality of life was statistically significant comparing the results of patients with provisional dentures to the overdentures on implants (Z: –2.585, p:0.010).

The satisfaction with speech (measured by the VAS) evolved from 72% to 75% and finally 82%. This was statistically significant in comparing the results of the new denture and the results with the overdenture connected to the implants (Z: –2.497, p:0.013). The fact that people are more satisfied with their speech is reflected in the answers on the first question of the OHIP–14, evaluating the impact of the denture on speech.

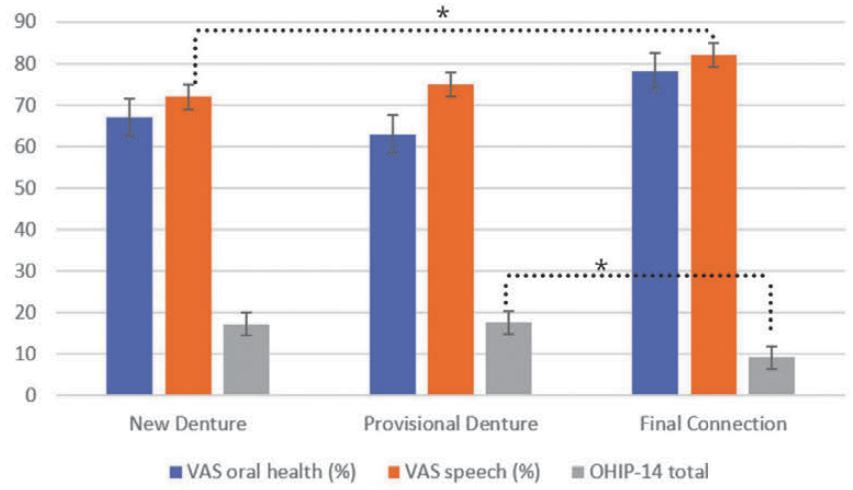

Fig. 4 *Satisfaction with overall status and speech (scale 100) and OHIP–14 total (scale 56) for the treatment over time. Bars indicating standard error are included. * Indicates p<0.05/3*

Table 6. *Oral Health related Quality of Life and Satisfaction: Total OHIP-14 (scale 0-56), VAS satisfaction with general oral health (%), VAS satisfaction with speech (%) and OHIP question 1 (n) reported during the stages of the mandibular overdenture treatment (preoperative, provisional loading and final connection of the overdenture). The level of significance after Bonferroni correction was set at α=0.05/3.*

		New denture (n)	Provisional loading (n)	Overdenture (n)	New–Provisional *p*-value	Provisional – Overdenture *p*-value	New – Overdenture *p*-value
Satisfaction oral health (VAS) (%)		Mean 67 [0–100] SD 23	Mean 63 [25–91] SD 18	Mean 78 [24–97] SD 18	Z: -0.353 p=0.724	Z: -1.958 p=0.050	Z: -1.775 p=0.075
OHIP-14 total score (0–56)		Mean 17.2 [0–38] SD 11.6	Mean 17.67 [0–46] SD 13.3	Mean 9.16 [0–33] SD 10.9	Z: -0.118 p=0.906	Z: -2.585 p=0.010	Z: -1.59 p=0.063
Satisfaction speech (VAS) (%)		Mean 72 [50–100] SD 18	Mean 75 [55–100] SD 14	Mean 82 [62–100] SD 10	Z: -1.067 p=0.286	Z: -1.434 p=0.152	Z: -2.497 p=0.013
OHIP Question 1 (n) *'Have you had trouble pronouncing any words because of problems with your teeth, mouth, dentures, or jaw'*	Never	2/18	5/15	8/19			
	Hardly ever	9/18	4/15	7/19			
	Occasionally	6/18	3/15	3/19			
	Fairly often	1/18	3/15	1/19			
	Very often	0/18	0/15	0/19			

Discussion

The use of dental implant treatment to solve retention problems in conventional rehabilitation is now common in dental practice. In the present study, we examined the possible impact of this treatment on articulation, oromyofunctional behavior and OHRQoL. More specifically, the effect of modifications of the denture during the conversion from a conventional removable denture, a provisional retained denture and finally a fully connected implant–retained overdenture in the mandible. The difference between rehabilitation with fixed dentures and overdentures is that in overdentures the anchoring of the overdenture is placed in the denture to fit over the bar (on implants) (Figure 2). When patients present with atrophy of the jaw, the bucco–lingual width of the denture can be too small to fit the supracrestal anchoring device. The technically required minimum dimensions of the bar, as well as the dimensions of the attachment system inside the overdenture, forces the dental technician to modify the shape of the overdenture. In most instances the overdenture is wider than the existing prosthesis. Therefore, the shape of the overdenture can be slightly different to the shape of the initial removable denture. This may, despite the improved retention of the denture, affect the way the tongue is positioned in the mouth to produce the speech sounds. This possible influence can be both positive (improved retention) and negative (difficulties in tongue movement and positioning to shape the airstream into speech sounds). Articulation errors occurred in all stages of the treatment but there were no significant differences between the stages. This finding is confirmed by the evaluation of the spectral characteristics of the /s/ sound between the stages. We found no significant differences of the spectral moments. This is not completely in line with previous findings of spectral analysis in dental patients. However, it is important to notice that previous studies compared different groups of patients (e.g. control group and study group) and in our study we observed the possible changes within the patient.[15,18,34] It is important to notice that the /s/ sound is the most vulnerable sound in all stages of the treatment. Besides problems pronouncing the /s/ sound, the /t/ and /l/ were affected in at least one patient during the whole treatment. This is not completely in line with previous research on fixed dentures and overdentures on implants in the mandible.[12] Research by Jacobs et al. found that patients mostly presented with problems pronouncing the /s/ sound when treated in the maxilla and problems

with the /t/ sound when treated in the mandible. Research by Sansone et al. and Heydecke et al. reported no influence of the treatment in the mandible on articulation.[17,24] The fact that we assessed no significant changes and previous studies reported no problems, indicate no impact of mandibular overdenture treatment on articulation in speech. This needs to be assessed in a bigger study population to be able to generalize this statement.

The second domain we examined was oromyofunctional behavior. There was no significant difference between de stages of the treatment. Still there were several patients presenting problems with oromyofunction. This is not in line with the few previous articles on fixed dentures in the mandible.[12,15] The study of Van Lierde et al. and the study of Jacobs et al. revealed no oromyofunctional disorders in patients with fixed dentures, overdentures and conventional dentures. Six of the 25 items tested were detected as distorted at some point during treatment. It is important to notice that the percentage of all disorders decreased during treatment. Only difficulties in whistling increased clinically in the last stage. It is important to know that in 5 of the 6 patients presenting whistling problems, this was the only oromyofunctional problem. Given this information, one can question the relevance of being able to whistle.

The third domain was satisfaction and OHRQoL. The results of the OHIP and the VAS scales revealed an improvement of satisfaction with oral health and satisfaction with speech. This is in line with previous research on fixed dentures and overdentures in the mandible.[35] Despite the considerably high percentage of patients with speech problems in the final stage of the treatment, the satisfaction with speech is high. It is possible that when patients rate their speech on the VAS and the OHIP-14 form, they consider both their production of the sounds and their comfort of speaking in the evaluation. The latter is an aspect of speech, speech-language pathologists cannot observe and cannot rate. Therefore, it is very important to ask the patients opinion about the outcome of the treatment before giving a professional evaluation of their functioning. Besides the general improvement of satisfaction with oral health and OHRQoL during treatment, the results after provisionalisation of the denture slightly drop. Hypothetically one can assume that patients expect the biggest improvement after surgery, and when this improvement is not what

they hoped for, patients may be disappointed. This underlines the importance of providing good information to the patient before treatment.

It is worth noticing that the strength of this study lies in the evaluation of articulation and oromyofunction by two independent professional speech–language pathologists and the extensive protocol used to evaluate the patients. Moreover, this is the first study in the Flemish language (Dutch spoken in the northern part of Belgium) assessing the impact of implant–retained overdentures in the mandible on articulation. This method is reliable but can be improved, especially because the /s/ sound turned out to be our primary affected sound and the interrater reliability of the two SLPs was acceptable but not excellent. The longitudinal, prospective design of this study is of great value but also caused drop–out due to organizational and logistic issues. Due to this drop out the post hoc power of the statistical results doesn't meet the ideal 0.80. Future research should focus on larger samples to generate robust statistical results. Still it is for this kind of research with a specific kind of treatment in this kind of population (higher age) a great challenge to organize this. Collaboration of different institutes or enrollment of patients in the study for several consecutive years would be needed. Finally, it is also possible that patients already had some articulation errors during their lifetime. This is impossible to assess because our participants came to the clinic with an existing denture, already influencing articulation and oromyofunctional behavior.

How the remaining articulation errors and oromyofunctional problems can be solved is another research question. It might be needed to adjust the width of the denture to allow the tongue to move properly in the oral cavity to produce correct sounds. This was already suggested by Collaert et al. in fixed dentures in the maxilla. [21] Besides that, articulation therapy could be a solution worth investigating.

Conclusion

In patients, treated with mandibular bar retained overdenture on two implants, oromyofunctional and articulation disorders were assessed in all stages of the treatment. The results of this study reveal no statistically significant changes

when converting from a conventional full denture to an implant retained overdenture, for speech articulation and oromyofunctional behavior. The overall impact on quality of life and the satisfaction with speech improved after the overdenture was connected to the implants. It is important for dentists to inform their patients about the possible articulation and oromyofunctional disorders that can occur during treatment with complete dentures. This will be especially important when treating elite performers and professional speakers.

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CHAPTER 3

Four-implant supported overdenture treatment in the maxilla. Part II: Speech and oral health related quality of life in patients with implant-supported overdentures in the maxilla: a prospective 3-years follow-up

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Abstract

Background: Implant-supported overdentures (IOD) are becoming a more common used treatment in the dental practice and it risks causing speech problems.

Purpose: The aim of this study was investigating the changes in speech, satisfaction with speech and overall oral health and the Oral Health Related Quality of Life (OHRQoL) in edentulous patients during and after treatment with maxillary IODs.

Materials and methods: 21 patients receiving an IOD participated in speech assessment. They were examined pre-operatively with their conventional denture (CD) with full palatal coverage, after connection of the implant-bar connected denture, without palatal coverage, and 3 years thereafter. The examination included assessment of articulation in speech, OHRQoL based on total OHIP-14, and satisfaction with overall oral health and speech (Visual Analogue Scale).

Results: There was a reduction in mean number of articulation disorders from 1.00 at baseline to 0.55 at connection, although statistically insignificant ($p = 0.059$). Especially the /s/ sound is vulnerable. At 3 years follow-up, still 6/16 (37.5%) of the patients suffered from this speech problem. Overall satisfaction improved from 64.05/100 at baseline to 82.95/100 at connection ($p:0.008$) and remained unchanged with 81.69/100 after 3 years follow-up. Patients' satisfaction with speech increased from 70.62/100 with CD to 82.63/100, 3 years follow-up ($p:0.009$). Total OHIP-14 decreased from 21.45/56 with CD to 8.00/56 ($p<0.001$) with IOD and 6.13/56 three years after connection ($p:0.001$). Significant improvement of all 7 domains in OHRQoL was observed with IOD compared to CD.

Conclusions: Patients treated with maxillary IODs show improved OHRQoL 3 years after connection of the IOD compared to the CD. Even though patients reported improvement of satisfaction and OHRQoL, articulation disorders were still present, suggesting that patients should be informed about possible speech issues.

Introduction

The elderly population is growing worldwide and edentulism increased with 27% between 2006 and 2016.[2] Edentulism is closely related to socioeconomic factors and has a negative impact on both oral and general health.[3] Large proportions of edentulous patients wear conventional removable dentures (CD), which imply some negative side-effects. These include residual ridge resorption yielding limited mastication and unhealthy food selection as well as negative effects on day-to-day activities. Hence, edentulous patients report poorer oral health-related quality of life (OHRQoL) related to dysfunctional mastication, lower self-esteem and aesthetic concerns.[3,4] The use of dental implants can prevent bone loss of the ridge.[5] But studies indicate improved quality of life and masticatory function when treated with an IOD and therefore this is a more cost-effective treatment than CD.[6]

For edentulous mandibles, treatment with IODs on two implants is the standard of care according to the McGill consensus statement.[7] For the edentulous maxilla, there is currently no consensus on what is the best treatment option. However, it is well established that treatment with a four or six implant IOD yields good clinical results in patients with denture retention issues in the maxilla.[8,9] The review of Di Francesco and co-workers (2019) describes a survival ranging from 73.5% to 100% for maxillary implants and 87.5% to 100% for the maxillary denture connecting to the implants. They found a correlation between the number of installed implants and the survival rate. A minimum of four implants, whether or not connected with a bar, effects the outcome positively.[10]

Besides the technical demands to establish whether an implant treatment is successful, the impact of oral health on quality of life is important. Poor oral health has a negative influence on the quality of life and is an important part of public health.[11] OHRQoL includes the functional, social and psychological effects of oral diseases on the individual.[12] OHRQoL can be measured by means of the validated Oral Health Impact Profile (OHIP).[13] The shortened version of the Oral Health Impact Profile, the OHIP-14,[14] is currently one of the most used standardized questionnaires in the dental practice.[8] Besides the OHIP-14 to measure OHRQoL, questions using a visual analogue scale (VAS), are preferred to assess patients' satisfaction.[15] Michaud et al. (2012) concluded that there is a positive correlation

between denture satisfaction and OHRQoL, specially satisfaction with the oral condition and chewing ability are key parameters.[12] The OHRQoL in maxillary CD is broadly described in literature. The review of Thalji et al. (2016) concluded that the expectations of patients regarding aesthetic and phonetic rehabilitation are high and can be met using CDs in the maxilla. Although when patients are dissatisfied an alternative implant treatment can be the solution.[16]

There is plenty of evidence for improved OHRQoL with IODs in the mandible but for the maxillary IOD literature is scarce.[17] Various studies reported a higher satisfaction[8,17] and an improved OHRQoL[18,19] in patients treated with maxillary IODs compared to CD. Maxillary Fixed implant Dentures (FID) and IODs were compared within-patient by Heydecke and co-workers (2003). They demonstrate that patients' general satisfaction, their ability to speak and the easiness for cleaning the prosthesis is higher when treated with removable long-bar IODs.[20] Studies show a significant increase of OHRQoL in patients treated with IOD compared to CD,[19] especially in the psychological and handicap domains.[17] And one study showed improvement in all domains except physical pain.[17]

Patients who were previously satisfied with their maxillary CD, did not report an increase of overall satisfaction, denture stability or better comfort despite implant treatment.[8,17,21] However, patients treated with a maxillary IOD without palatal coverage reported higher satisfaction, better speech, and more effective hygiene measures compared to patients treated with a FID.[8,21] The latter does not necessarily lead to higher patients' satisfaction, although some studies indicate improved OHRQoL, compared to an IOD.[8] For aesthetic reasons, a maxillary IOD can be preferred over a FID especially when more lip support is needed.[21] Compared with a CD, both the mandibular and maxillary IOD reduce pain, enhance denture stability, comfort, and function.[8]

An important part of people's quality of life is determined by the ability to communicate with others.[22] One major way of communication is through speech. Regarding satisfaction with speech, 33% of CD wearers and 53% of patients treated with a FID state having problems related to the dental treatment.[23] Treatment with mini-dental implants, placed in compromised bone in order to stabilize an IOD in the maxilla, improved satisfaction with speech[18] as well as OHRQoL when converting the CD to an IOD in all 7 domains of the OHIP-14.[19]

The characteristics of speech sounds depend on the vibration of the vocal cords, the position of the articulators, and the airflow passing through the mouth along the alveolar ridge, teeth and the hard palate.[24] There are two groups of speech sounds: vowels and consonants. The vowels originate as air, coming from the lungs, that starts vibrating while it passes the vocal cords that are opening and closing. In order to produce the vowels, the airflow in the mouth should be unobstructed by the articulators.[24] In contrast to vowels, when producing consonants, there is an obstruction somewhere in the oral cavity. It has been demonstrated that changes in the oral environment affect articulation and speech intelligibility.[25] The teeth are involved in the production of fricatives (e.g. /f/, /v/ and /s/) and plosives (e.g. /t/ and /d/) with respectively a partial or full obstruction of the airstream. The plosives /t/ and /d/ are produced with the tongue against the upper alveolar ridge.[24] Langlois and co-workers (2019) concluded that a significant correlation exists between site of the missing tooth/teeth and articulation distortions.[25] More speech disorders are observed when patients are treated with IODs[26] and FID,[23,27] compared to subjects with natural teeth,[23,26] single implant restorations,[23] and CDs.[23,27] In literature, problems with fricatives: /s/, /z/, /ʃ/ (**sh**ow), /ʒ/ (gara**g**e); plosives: /t/, /d/; and other alveolar sounds: /l/, /n/, and /r/ are reported during and after treatment with dental rehabilitation.[18,23,26,28] Sigmatism stridens (production of the /s/ with a whistle sound) and sigmatism simplex (production of the /s/ sound with insufficient frication) were the most common distortions observed in patients treated with mini-dental implant overdentures in the maxilla,[18] FID in maxilla or mandible,[23,26–29] single (anterior) implants,[23,30] and CDs.[23]

In severely resorbed edentulous maxillae implants are positioned more palatal due to bone resorption and this may cause changes in speech.[31,32] In patients treated with maxillary FIDs, who encountered speech problems, a reduction of the palatal volume of (pre)molars resulted in improvement of speech.[33] Besides the palatal thickness of the denture, the palatal, and especially labial inclination of the maxillary central incisors influences speech and can result in direct changes of the production of the /s/ sound.[34]

The aim of the current clinical study was to determine the impact on and changes in speech disorders, satisfaction with speech and OHRQoL in patients treated with maxillary IODs after a follow-up period of 3 years. Based on the

previous literature we expect problems pronouncing /s/, /z/, /ʃ/, /ʒ/, /t/, /d/, /l/ /n/, and /r/ sounds and especially the /s/ sound is most likely to be distorted in all stages of treatment. We expect no disorders of vowels. We expect higher patients' satisfaction with speech and overall health, and improved OHRQoL.

Materials and methods

Patient selection

The current clinical logopaedic study was part of a prospective clinical cohort study aimed at evaluating implants with different design and connection type. Patients dissatisfied with their CD in the maxilla, in terms of stability or comfort, were offered inclusion in a clinical study previously described.[35] The study protocol was designed according to the principle of the Helsinki Declaration on clinical research (1975, revised in 2002). Before signing a written informed consent, every patient was informed about the study protocol, financial costs, treatment plan, follow-up period, and possible complications and risks. The study received approval from the ethical committee of the Ghent University Hospital (EC/2015/0338) on clinical research involving human beings. Subjects were included when they were at least 4 months edentulous in the maxilla, had sufficient bone volume for 4 implants of 4 mm diameter and 9–11 mm length, with absence of neurological disorders and having Dutch as their native language. In the northern part of Belgium the main language is Dutch. It is important to include people who speak the same (native) language because over languages there are other standards of speech evaluation. Subjects were excluded when they were younger than 18 years, smoking more than 10 cigarettes per day, and if general contraindications for implant placement were present like full-dose radiation in head and neck area, intravenous bisphosphonates and ongoing chemotherapy. Secondary exclusion occurred when the prosthetic space, defined as the distance between the maxillary crest and the mandible, was less than 12 mm because this space is required for the bar and prosthesis. In addition, the bone height, measured on Cone Beam CT (Planmeca, Helsinki, Finland) images, was to be sufficient. The implant-related results are not reported in the current paper.

Table 1. *Subject information at intake with 'adaptation after new denture' and 'adaptation after connection' indicating how many days patients could get used to their dental situation after receiving a new complete denture or after final connection of the overdenture to the implants.*

Subject	Gender	Age	Dental status mandible	Hearing status	Adaptation to the baseline situation in case of new dentures (days)	Adaptation after connection (days)
1	M	66	Natural dentition	Normal	–	99
2	M	62	Natural dentition	Reduced	84	177
3	M	67	Conventional Denture	Reduced	395	142
4	M	55	Natural dentition	Normal	–	144
5	F	68	Natural dentition	Normal	69	241
6	M	71	Conventional Denture	Reduced	–	156
7	M	83	Overdenture	Reduced	357	181
8	M	56	Natural dentition	Normal	–	191
9	F	42	Natural dentition	Normal	–	172
10	M	66	Fixed denture	Normal	131	45
11	F	56	Conventional denture	Normal	111	112
12	F	80	Overdenture	Normal	–	93
13	F	81	Natural dentition	Reduced	489	175
14	F	45	Natural dentition	Normal	131	232
15	M	64	Natural dentition	Normal	378	169
16	M	57	Conventional denture	Reduced	36	28
17	F	55	Natural dentition	Normal	37	88
18	F	63	Natural dentition	Normal	50	59
19	M	48	Natural dentition	Reduced	78	–
20	M	77	Natural dentition	Reduced	33	84
21	M	61	Natural dentition	Normal	124	9

Subjects

22 out of 25 subjects, originally included in the clinical study, participated in the speech evaluation. Patient information is shown in table 1 and a detailed flowchart of the different evaluation moments is represented in figure 1. One

subject was excluded because she missed several assessments and she was considered a dropout (4.5%). The 21 remaining participants, 8 female (38.1%) and 13 male (61.9%) had a mean age of 63.44 (range 42.5–83.8; SD: 11.37). During the intake examination, patients were asked if they had currently hearing problems. This group was analyzed post hoc on possible differences in outcome. There was no significant difference between the subjects classified as 'normal hearing' and 'disturbed hearing' on all outcomes of speech, OHRQoL and satisfaction.

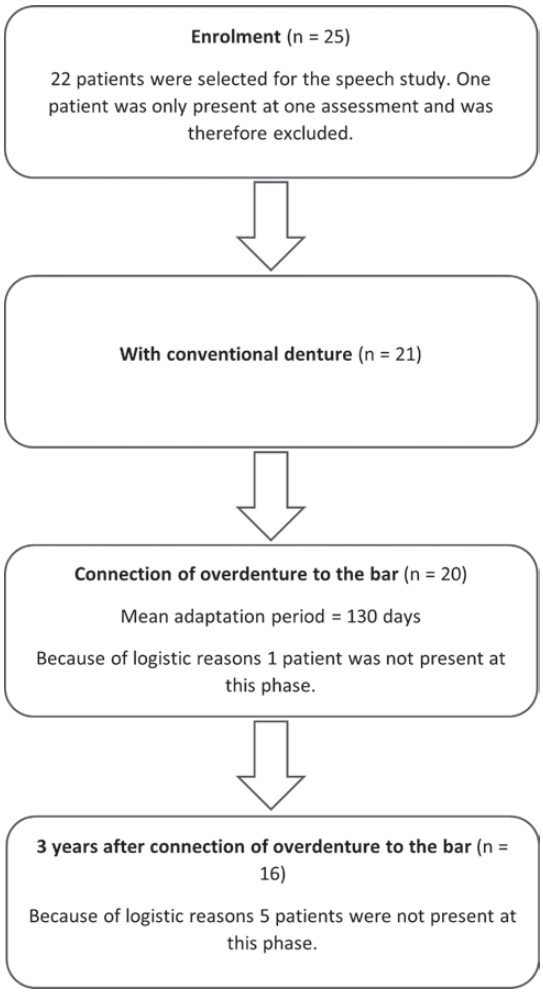

Fig. 1: *Flowchart of the study population.*

Surgical and prosthetic procedure

When subjects met all the criteria mentioned above, the original denture was relined or a new CD was manufactured. The purpose was to establish a correct vertical dimension, correct occlusion and aesthetics, more precisely position and length of the teeth and smile line. In the mandible the patients had their natural teeth, fixed restorative prosthetics or existing removable prosthetics on implants. If the existing maxillary complete denture fulfilled the above mentioned criteria it was relined (n=6). In the other case a new maxillary complete denture was fabricated (n=15). Patients received this new CD or the relining of their existing denture before implant placement.

After a muco-periosteal flap was raised, four Deep Conical Cylindric implants (DCC; Southern implants, Irene, South Africa), were placed in a one-stage surgery, preferably at the position of the canine and first molar, or alternatively at the second premolar site. Healing caps were placed on the abutments, torqued to 20 Ncm, with a standardized height of 4 mm, to respect the biological width. After implant placement, the maxillary denture was adjusted and relined with a soft liner (Coe Soft, GC Europe, Leuven, Belgium). The healing caps perforating the soft tissue improved denture stability and the denture was regularly checked and relined with the soft liner to prevent implant overload. A healing period of minimum four months was respected before the abutments were torqued to 30 Ncm and the final IOD was installed on a titanium milled bar connecting the four implants (figure 2). The surgical and prosthetic procedures as well as implant-related outcome have been described previously.[35]

Articulation

The logopaedic examination took place in a testing room, separated from other clinical activities, ensuring as little disturbing noise as possible. The subjects were tested during the different stages of maxillary IOD treatment. The speech was evaluated pre-operatively with the CD with full palatal coverage, and after connection of the denture to the bar (the palatal coverage was removed at this moment). Speech after connection was evaluated after an adaptation period of minimum four weeks. One examination took place after 9 days of adaptation because the patient went abroad and could not attend the planned research session. Besides these two assessments, a follow-up evaluation of articulation characteristics was performed three years after connection. The position of the

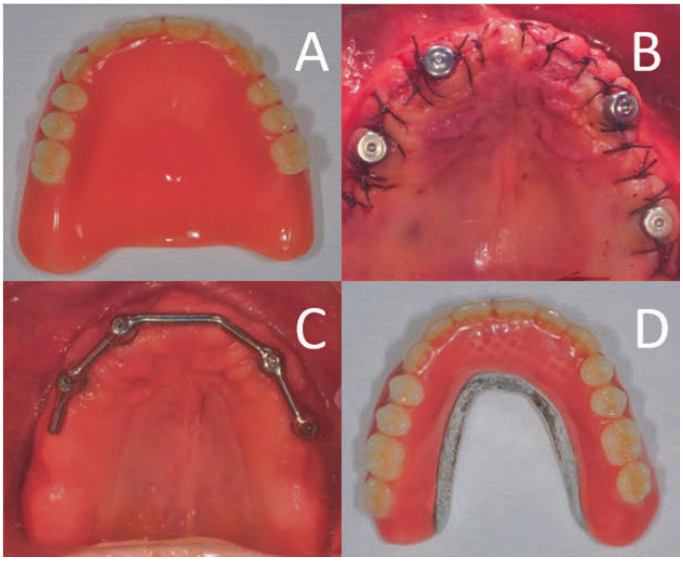

Fig 2. *Pre-operative stage with conventional denture with full palatal coverage (A); Immediately after one-stage implant surgery with abutments and healing caps perforating the soft tissues (B); Connection of the implants with a titanium milled bar after a 4 months healing period (C); Top view of the final overdenture without palatal coverage (D). © 2018 Wiley Periodicals, Inc.*

test setup (camera, evaluation form, subject and test items) was identical during each evaluation moment. The evaluation method used for this study is based on Van Lierde et al. (2011).[30] The assessment consisted of a perceptual evaluation of articulation, patient's satisfaction with oral health and satisfaction with speech, and OHRQoL. The assessment took approximately 20 minutes and was recorded with a digital video camera recorder (Sony Corporation, DCR-SR75E).

The assessment of articulation characteristics was performed by using a picture naming test (PNT) based on the protocol used in Van Borsel (1996).[36] The subject was asked to name 135 different pictures of ordinary objects and actions presented in colour on a white background. The speech sample is designed so that all Dutch single sounds and most of the consonant clusters are present. The consonants and consonant clusters were placed in all possible syllable positions in the words. The evaluation included a phonetic inventory and phonetic analysis. A sound was considered to be present in the inventory when at least two instances of the production were found. This means that if a sound was produced at least two times in a disordered way the disordered sound was present in the inventory. The recording was evaluated independently by two speech-language pathologists (EF and EB). One SLP was blinded for the

stage of the treatment. Interrater reliability is displayed in table 2. The average number of unique articulation disorders was calculated and changes were calculated statistically by using a Wilcoxon matched–pairs signed rank test.

Satisfaction and quality of life

To narrow possible bias, subjects rated their satisfaction levels before the speech assessment. Patients were asked to score the satisfaction with their speech and the overall satisfaction with their oral health on a Visual Analogue Scale (VAS) of 100 mm (on the left end 0% (dissatisfaction) and on the right 100% (maximal satisfaction)). The oral health–related quality of life was measured using the Dutch shortened version of the Oral Health Impact Profile (OHIP–14) (Appendix 1).[13,37] Subjects were asked to answer 14 questions in seven different domains: functional limitation, physical pain, psychological discomfort, physical, psychological and social disability, and handicap. The responses were rated by a 5–point Likert–type scale ranging from 0 to 4 (0 = never, 1 = almost never, 2 = sometimes, 3 = often, 4 = very often). The sum of the 14 individual questions yielded the OHIP–14 total score. A score of 56/56 represents a maximal negative OHRQoL and 0/56 indicates that the person experiences no impact of the treatment on the OHRQoL.

Statistical analysis

The Wilcoxon matched–pairs signed rank test was used to compare intra–patient changes in number of articulation disorders, oral health–related quality of life, and satisfaction with their speech and their overall oral health, between the different phases of the treatment. To compare the type of articulation disorders, the McNemar's test was performed. The Cohen's kappa coefficient was used to rate the inter–rater reliability. The Bonferroni correction for multiple comparisons was applied and all significance levels were set at $\alpha = 0.05/3$ (= 0.0167). SPSS Statistics 27 (IBM SPSS statistics for Windows, version 27.0. Armonk, NY: IBM Corp) was used to analyse the data. A post hoc power analysis indicated 72% to 100% power for the speech related variables.
The authors state compliance with the STROBE checklist.

Table 2. *Articulation disorders according to the PNT. The type and number of articulation disorders evaluated during the different phases of maxillary overdenture treatment (preoperative with conventional denture, connection of the overdenture to the bar and 3 years follow-up after connection). The significance level was, after Bonferroni correction, set at α=0.05/3.*

Articulation disorder	**Definition**	**Interrater reliability** (%)	**Conventional denture** (n)	**Overdenture** (n)	**3 years follow-up** (n)	**Conventional denture – overdenture** p-value	**Overdenture – 3 years follow-up** p-value	**Conventional denture – 3 years follow-up** p-value
/s/		80.3	10/21	5/20	6/16	0.289	0.687	0.727
Simplex	/s/ sound with insufficient frication		4/21	3/20	5/16			
Stridens	/s/ sound with a whistle sound		6/21	2/20	1/16			
/z/		93.3	3/21	1/20	2/16	0.500	1	1
Simplex	/z/ sound with insufficient frication		1/21	0/20	2/16			
Stridens	/z/ sound with a whistle sound		2/21	1/20	0/16			
/t/		95.8	1/21	0/20	1/16	1	1	1
Addental	/t/ sound with the tongue against the central incisors		0/21		1/16			
Interdental	/t/ sound with the tongue between the upper and lower incisors		1/21		0/16			
/n/		100	0/21	0/20	1/16	1	1	1
Interdental	/n/ sound with the tongue between the upper and lower incisors				1/16			
/l/		92.6	1/21	1/20	2/16	1	1	1
Addental	/l/ sound with the tongue against the central incisors		0/21	0/20	1/16			
Interdental	/l/ sound with the tongue between the upper and lower incisors		1/21	1/20	1/16			
/r/		100	1/21	0/20	1/16	1	1	1
Interdental	/r/ sound with the tongue against the central incisors		1/21		1/16			
/ ʃ /		100	0/21	0/20	1/16	1	1	1
Simplex	/ ʃ / sound with insufficient frication (e.g. pu<u>sh</u>)				1/16			
Number of articulation disorders per patient			Mean: 1.00 (0–3) SD 0.775	Mean: 0.55 (0–2) SD 0.686	Mean: 1.13 (0–5) SD 1.544	p = 0.059	p = 0.319	p = 0.776

Table 3. *Satisfaction and oral health-related quality of life: VAS overall oral health satisfaction (%), total OHIP (0-56), VAS satisfaction with speech (%) and OHIP-14 question 1 ('Have you had trouble pronouncing any words because of problems with your teeth, mouth or denture?') presented during the different phases of maxillary overdenture treatment (preoperative with conventional denture, connection of the overdenture and 3 years follow-up). After Bonferroni correction, the significance level was set at α=0.05/3.*

	Conventional denture mean (n)	**Overdenture** mean (n)	**3 years follow-up** mean (n)	**Conventional – Overdenture** p-value	**Overdenture – 3 years follow-up** p-value	**Conventional – 3 years follow-up** p-value
VAS overall (%)	64.05 (13–95) SD 26.56	82.95 (36–100) SD 16.65	81.69 (62–100) SD 13.26	p = 0.008	p = 0.629	p = 0.005
OHIP total (0–56)	21.45 (0–49) SD 12.19	8.00 (0–32) SD 7.87	6.13 (0–14) SD 4.91	p < 0.001	p = 0.374	p = 0.001
VAS speech (%)	70.62 (26–100) SD 21.60	79.70 (50–100) SD 15.33	82.63 (58–98) SD 12.78	p = 0.126	p = 0.865	p = 0.009
OHIP question 1						
Never	5/20	8/20	6/16			
Hardly ever	4/20	7/20	7/16			
Occasionally	4/20	3/20	3/16			
Fairly often	6/20	2/20	0/16			
Very often	1/20	0/20	0/16			

Statistical analysis

The Wilcoxon matched-pairs signed rank test was used to compare intra-patient changes in number of articulation disorders, oral health-related quality of life, and satisfaction with their speech and their overall oral health, between the different phases of the treatment. To compare the type of articulation disorders, the McNemar's test was performed. The Cohen's kappa coefficient was used to rate the inter-rater reliability. The Bonferroni correction for multiple comparisons was applied and all significance levels were set at $\alpha = 0.05/3$ (= 0.0167). SPSS Statistics 27 (IBM SPSS statistics for Windows, version 27.0. Armonk, NY: IBM Corp) was used to analyse the data. A post hoc power analysis indicated 72% to 100% power for the speech related variables.
The authors state compliance with the STROBE checklist.

Results

Articulation

The type and number of articulation disorders (with definition) measured with the picture naming test and the interrater reliability of the consensus evaluation, is displayed in table 2. The interrater reliability of the two SLPs was high for all speech sounds (80.3%–100%). Overall distortions of the /s/, /z/, /t/, /d/, /l/, /n/, /r/ and were found. In the first phase, patients with CD (with palatal coverage) show mainly distortions of the /s/ and /z/ sounds (resp. 10/21; 47.6% and 3/21; 14.3%). When the IOD was connected to the bar, the palatal coverage was removed. At this moment, the number of articulation disorders observed declined (/s/ (5/20; 25%) and /z/ (1/20; 5%). After a follow-up period of 3 years, subjects presented again mainly with distortions of the /s/ (6/16; 37.5%) and /z/ (2/16; 12.5%) sound.

The number of articulation disorders per patient measured with the PNT declined clinically between the CD phase (mean = 1.00) and IOD phase (mean = 0.55). During the 3-year follow-up an increase was observed in comparison with the first two phases (mean = 1.13). There were no statistically significant results in the type or the number of articulation disorders between the different phases of treatment and follow-up.

Satisfaction and quality of life

The scores of satisfaction and OHRQoL, measured using respectively the VAS and Dutch OHIP-14, reported by the patients, is shown in table 3. The mean satisfaction of both overall oral health and speech improved during treatment. The average overall satisfaction increased significantly when comparing the CD with the IOD (p:0.008; z: -2.670) and the CD with 3-year follow-up (p:0.005; z: -2.840). The total OHRQoL improved during treatment and follow-up registered with a decreasing OHIP-14 total score. At the start the mean score was 21.45/56. When the IOD was connected to the bar, the score declined significantly to 8.00/56 (p<0.001; z: -3.617). At the 3-year follow-up, a score of 6.13/56 was reported. Comparing the original denture with the IOD 3 years after connection, resulted in a significant decrease of the OHIP-14 total score (p:0.001; z: -3.240).

The patients' satisfaction with their speech improved significantly when comparing the CD with palatal coverage and the 3 years in function (p:0.009; z: -2.613). The responses of the patients on the first question of the OHIP-14, questioning the impact of the IOD on speech, reflect the increased satisfaction with their speech. The mean scores of this questions vary from 1.70/4 at baseline to 0.95/4 after IOD connection and 0.81/4 after 3 years.

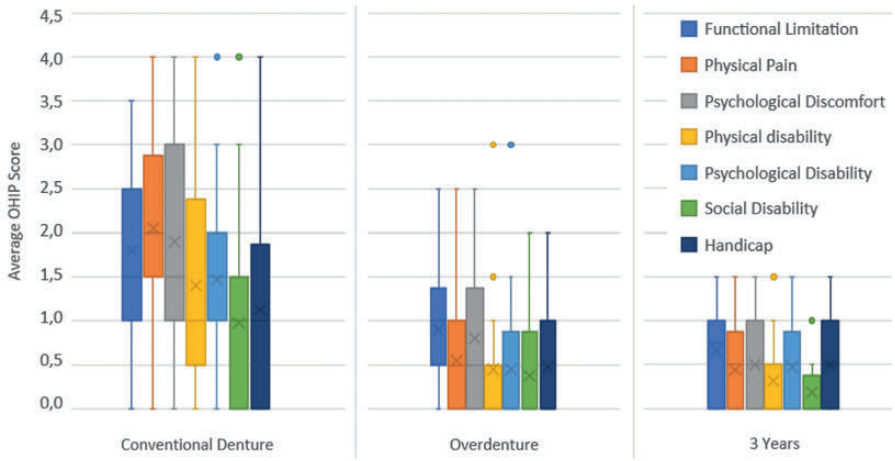

Fig. 3: *Box plot representation of the 7 domain scores of the OHIP-14 with conventional denture, connected overdenture and after 3 years in function.*

Figure 3 shows the evolution of the main domain scores on the OHIP-14. All domains (D1-7) improved significantly when comparing the preoperative situation to the situation when the IOD is connected to the implants. There was no extra improvement on any of the domains of the impact on oral health after 3 years compared to the situation shortly after connection.

Discussion

The use of IODs in treatment of the edentulous maxilla is becoming commonly used in the dental clinic.[8,9] Still some answers are needed to provide patients with sufficient information. This study examined the possible risk of causing speech problems and the impact on quality of life and satisfaction in patients treated with maxillary IODs (without palate).

Firstly the impact of the treatment on articulation of speech sounds was examined. The production of speech sounds is a complex process. It is influenced by the position of the articulators when the airflow passes through the mouth. When treating patients with dentures, changes are made in the area of important speech structures, like the teeth, alveolar ridge, and hard palate.[24] Pre-treatment patients, presented in the dental clinic, wore CDs in the maxilla and were in search of a stable solution. The palatal coverage of the CD was removed in the design of the IOD. This action provides more space for the tongue to move upwards, but sharpens the angle of the alveolar ridge. Because of the delicate nature of speech production, we expected this major adjustment to the denture to cause some additional changes in the articulation pattern of the patients. We couldn't confirm this expectation with significant results. Articulation disorders occurred in all stages of IOD treatment but no significant differences were found between the stages. In literature, problems with /s/, /z/, /ʃ/, /ʒ/, /t/, /d/, /l/, /n/ and /r/ sounds are reported during and after treatment with dental rehabilitation.[18,23,26,28] Except for the /ʒ/ sound, these findings are similar to the results in this study. Remarkable is that 47.6% of the subjects produced a distorted /s/ sound pre-treatment and this is still present in 37.5% after a follow-up period of 3 years. This is also shown in previous studies on maxillary FID and IOD treatments.[18,23,26-29] The /s/ sound in particular is sensitive to changes in the oral cavity as it is produced

with the tongue tip close to the upper or lower alveolar ridge. This is a well-known articulation disorder in dental rehabilitation.[18,23,26–28,30,33] Because of the remaining articulation problems when converting to the IOD, we can conclude that removing the palatal coverage along with better retention and stability of the denture, does not solve all articulation disorders. According to Collaert and colleagues (2015), a reduction of the palatal volume in the (pre)molar region of a FID can result in improvement or even return to baseline level of speech.[33] Besides the palatal thickness, the inclination of maxillary central incisors influences speech. The palatal or labial inclination of these incisors can result in direct changes of the production of the /s/ sound.[34] As expected, no distortions of the (semi-) vowels were observed. This is parallel to previous studies.[23,27,28,30] Vowels are produced without constriction in the oral cavity. For this reason, a denture has little impact on the production of vowels.

This study, secondly, focused on the possible influence of the dental situation on satisfaction and quality of life. Besides the professional evaluation of articulation of speech sounds by the speech language pathologists and the dental treatment by the dentist, it is important to take the subjective experience of patients into account. Patients reported low scores for overall satisfaction and OHRQoL pre-treatment. According to literature, chewing ability, denture comfort, stability and retention are the most reported patient complaints in CD wearers.[8] In the present study, the overall satisfaction with oral health increased significantly when comparing the CD and the IOD. The reviews of Sharka (2019) and De Bruyn (2015) reported both increased patient satisfaction, as well as no improvement regarding satisfaction in patients satisfied with their maxillary denture.[9,18] An explanation can be that patients signing up for this study are not satisfied or have difficulties adapting to their CD. The OHRQoL, measured by the OHIP-14, improved during all stages of treatment and after a three year follow-up period. This was also reported by other authors researching maxillary IODs.[19,20]

The satisfaction with articulation proficiency increased during all phases of treatment. Simultaneously a higher OHRQoL concerning speech, measured by the first question of the OHIP-14, was reported. A significant increase of satisfaction with speech was observed when comparing CD with three years follow-up. This is remarkable, because the number of speech disorders

(especially the /s/ sound), is not significantly lower when converting to the IOD or after 3 years follow-up. This was also seen in other studies.[18,28] It is possible that patients already had speech disorders in the past which are not related to their denture that are 'normal' for the individual patient. Moreover it is possible that patients rate not only the sound but also the comfort of their speech. This is a feature a speech language pathologist cannot assess. Until now there is no study comparing satisfaction to speech from pre-treatment to 3 years follow up in IOD. The study of Lundqvist et al (1992) reported results of 21 patients, treated with a FID. 94% of these individuals considered themselves free of phonetic problems after 3 years follow-up. In this case, still a small amount of subjects were rated as having a 'slightly distorted /s/ quality'.[29] This is in agreement with our findings.

Figure 3 shows the averages on the seven domains of the OHIP-14. It is very clear that the difference between the impact of the denture, pre-treatment and the impact of the denture after connection and at follow-up is significantly better for all domains. There is no further improvement after connection of the IOD to the implants. These results are confirmed by the results of Van Doorne et al. (2020) on Mini Dental Implants (MDI) in the maxilla.[19] In the review of Sharka et al. (2019), some studies reported increased OHRQOL when treated with IODs in all domains except physical pain. Others showed improvement, especially in the handicap and psychological domains.[17]

The major strength of this study is the prospective design and the use of two speech language pathologists for the evaluation of speech. The combination of articulation assessments and patients' satisfaction with their overall oral health and speech, and OHRQoL makes it possible to take into account both the consensus evaluation by the speech language pathologists and subjective results reported by the patients. The negative side effect of a longitudinal design is the risk of drop-out, as is also the case in this study. Another difficulty in our study is the fact that patients already have complaints about their oral condition before they participate to the study. Ideally, a speech assessment should be performed with the original dental state so the articulation disorders that are already present, can be listed. In this way, articulation disorders related to the treatment can be detected independently from already existing distorted sounds. This study should be reproduced with (if possible) bigger sample

sizes to be able to generalize our findings to the wide study population. A last limitation is the use of self-report to assess hearing difficulties. Because of the small sample size, the power of the post hoc test was too small to actually state that there was no difference between the outcomes of the 'disturbed hearing' group and the 'normal hearing' group. This needs to be corrected in future research.

Future research should also focus on how the different shapes of dentures influence speech sounds and how the speech problems can be solved.

Conclusion

Articulation disorders occur in all stages of the treatment. It was not possible to determine significant differences in speech performance during treatment and after 3 years follow-up. Still several speech disorders occur during treatment. The /s/ sound is the most vulnerable sound in all stages. Patients' satisfaction and OHRQoL improved after connection of the IOD to the implants and after 3 years follow-up compared to the CD. Patients report more satisfaction with speech after removal of the palatal coverage at the moment of connection to the implants. It is important for dentists to be aware of the possible effects of dental treatment on speech and to inform patients accordingly.

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Appendix

OHIP-14					
In the last six months	Never	Hardly ever	Occasionally	Fairly often	Very often
1) Have you had trouble pronouncing any words because of problems with your teeth, mouth or dentures?					
2) Have you felt that your sense of taste has worsened because of problems with your teeth, mouth or dentures?					
3) Have you had painful aching in your mouth?					
4) Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?					
5) Have you been worried by dental problems?					
6) Have you felt tense because of problems with your teeth, mouth or dentures?					
7) Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures?					
8) Have you had to interrupt meals because of problems with your teeth, mouth or dentures?					
9) Have you found it difficult to relax because of problems with your teeth, mouth or dentures?					
10) Have you been a bit embarrassed because of problems with your teeth, mouth or dentures?					
11) Have you been a bit irritable with other people because of problems with your teeth, mouth or dentures?					

12) Have you had difficulty doing your usual jobs because of problems with your teeth, mouth or dentures?					
13) Have you felt that life in general was less satisfying because of problems with your teeth, mouth or dentures?					
14) Have you been totally unable to function because of problems with your teeth, mouth or dentures?					

App 1. *English version of the shortened Oral Health Impact Profile.*

CHAPTER 4

Speech evaluation during maxillary mini-dental implant overdenture treatment: A prospective study.

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Abstract

Background: Large proportions of patients are edentulous and wear removable dentures leading to reduced functional comfort and less oral health related quality of life. Satisfaction with the oral situation after implantation depends on the outcome in eating comfort, speech comfort and esthetics. Modification in form and location of the teeth may affect speech. The aim of this study is to determine speech, oromyofunctional behavior, satisfaction with the treatment and the impact on quality of life of the horse–shoe overdenture retained by mini–implants (MDI) in the maxilla.

Methods: This prospective multicenter cohort study included 32 patients for treatment. 5 to 6 implants were placed, atraumatically piercing the mucosa. Patients were evaluated three times during treatment (preoperatively with conventional prosthesis including full palatal coverage (CD), postoperatively with provisionally relined CD and with horse–shoe overdenture on MDI). The assessment included a phonetic evaluation, examination of oromyofunctional behavior, evaluation of the impact on quality of life (OHIP–14) and a rating of satisfaction with the treatment and speech on a visual analog scale.

Results: Several speech sounds are found to be disturbed before treatment. In the next two stages of the treatment the number of speech issues decreases. In the final stage ten people show minor speech problems, especially with the /s/ sound. In this stage seven people still present with oromyofunctional problems, especially whistling problems. In this last stage people are very satisfied with the treatment (83%) and with speech (84%). The impact on quality of life is low (8.23/56).

Introduction

Speech is a part of a larger system called communication. In this study we focused on the part of speech called articulation. Articulation involves the movement of the speech production mechanism, the so-called articulators (e.g., the jaw, lips, tongue and the soft palate). This mechanism molds the air stream, coming from the lungs, against the other structures in the mouth (alveolar ridge, hard palate and teeth) or narrows the airstream, resulting in high pitched sounds. Speech sounds are characterized by the way the speech structures are positioned.[1] In the study of articulation disorders, different causes of deviant speech are known. There are two main categories in articulation problems. Firstly, functional problems caused by a wrong use of the articulatory muscles. Secondly, organic problems which appear due to changes of the structures responsible for articulation.[1] Hence, it is obvious that modifications in the form and location of teeth, as is the case with tooth loss, denture wearing or tooth rehabilitations, may affect speech. Life expectancy is rising and provided that oral hygiene measures are applied properly, patients will keep their natural teeth longer and functional. However, large proportions of patients are edentulous and wear removable dentures leading to reduced functional comfort and less oral health related quality of life.[2] Lack of stability and retention as well as decreased chewing ability is the most prevalent patient complaint.[3] Moreover, long time removable denture wearing induces further bone resorption and decreases functionality of the denture. Dental implants are useful in the improvement of denture retention and the overdenture on two implants in the lower jaw has been suggested as the minimal standard of care.[4] Long-term implant survival for dentures is in the order of 93% to 97%.[5] For the majority of the edentulous patients, a 2-4 mandibular implant overdenture provides a satisfying treatment solution with 95% implant survival after 10 years.[6] Treatment with conventional dental implants of at least 3.5mm diameter is the most common way to anchor a dental prosthesis.[7] However, some patients present with an advanced resorption of their jawbone whereby regular dental implants cannot be placed due to limitations in bone morphology. In those cases often invasive reconstructive bone regenerative procedures are required with higher costs, more morbidity and higher barrier for treatment as compared to conventional implant placement.[8,9] Furthermore, aging edentulous patients are often medically compromised and benefit more from minimally invasive

surgery. In the light of this evolution, one piece mini-dental implants (MDI) with diameter less than or equal to 2.5mm should be considered as an alternative treatment solution for improved denture retention.[10,34]

Treatment with MDI is introduced early 2000 and in general its outcome is promising although the clinical outcome defined by implant survival, bone stability or complications is often underreported especially in the upper jaw. Literature on treatment outcome related to implant survival, load resistance and quality of life is scarce. Also, the effect of this treatment on people's speech is lacking.[10] The latter has been investigated mainly using regular diameter implant supported overdentures in mandible[11, 12] and fixed dentures in the mandible[11–14] and maxilla,[11, 13, 15, 16] as well as single tooth replacements[17]. A frequently heard complaint is the occurrence of distortions of the /s/ sound during speech.[7,11–18] One of the causes of deviations in the pronunciation of the /s/ sound is the angle of the frontal teeth.[19] Changes in thickness of the ridge and the palate of the prosthesis are also found to be an important factor in the occurrence of speech problems in patients treated with fixed rehabilitation.[20, 21] Because the production of most consonants involve speech structures in the upper jaw (palate, upper incisors) it is to expect that speech problems are more likely to occur when people are treated with reconstructions in the maxilla compared to reconstructions in the mandible.[18] It is also possible that other problems present depending on which jaw is treated. As suggested in the research of Jacobs et al. (2001) there are especially problems with the fricatives (s and z) in fixed rehabilitation of the maxilla and fixed reconstruction in the mandibula seems to cause more problems with the plosives (t and d).[11] Figure 1 shows the tongue contact position with the palate forming the speech sounds. This palate is covered differently with conventional dentures compared to an overdenture with horse-shoe design. It is plausible to say that different shapes of dentures (e.g. with and without palatal coverage) can cause other distortions especially in the maxilla.

Van Lierde et al. (2012) examined the difference in articulation problems in different kinds of fixed dental rehabilitation in the maxilla and found a significant difference between articulation in people who have different kinds of dental rehabilitation. Most problems were observed in fixed rehabilitation on implants followed by conventional dentures and the least problems were seen

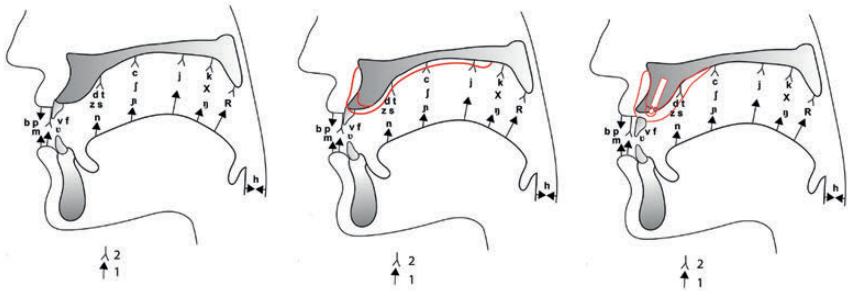

Fig 1. *Sagittal view on the oral cavity with contact spots of the tongue (1) to the palate (2) with normal dentition (left), conventional denture (middle) and horse-shoe overdenture on MDI (right).*

in rehabilitation with single implants. All groups had normal oromyofunctional behavior and reported mostly problems with the /s/ sound.[14] Additionally, clinical experience shows that dental implants placed in a resorbed alveolar processus are often mispositioned due to the resorption of the crest in palatal direction. Because of that, overdentures can have to wide bucco-lingual volumes, causing obstruction of the tongue during speech or movement. The study of Collaert et al. (2015) states that it is possible that removing some of the volume of the denture on the palatal side of the premolar region can solve this problem. In their study ten edentulous patients who received fixed prosthesis in the maxilla were examined for speech problems at four occasions with proper adaptation. They found that in some patients the /s/ sound seemed distorted, even after adaptation. After reduction of the volume of the premolar region of the denture all patients returned to baseline speech or improved speech.[22] The most common distorted sounds are the /s/, /z/, /ʃ/ (as in **sh**ow), /ʒ/ (as in gara**g**e) and /t/.

Research on oromyofunctional behavior does not report severe problems in implant treatment of any kind. [13, 14, 16, 23] Research of Molly and coworkers (2007) showed an increase of tongue thrust in patients receiving fixed dentures in the maxilla. This is the frontal position of the tongue during rest and swallowing. This could be affected by the conversion of a palate covering denture to an implant prosthesis without palatal coverage.

There has been a lot of research about patients satisfaction after dental rehabilitation.[24] In general, patients are more satisfied when rehabilitated with single crowns compared to fixed dentures on implants or removable implant retained overdentures.[14] Compared to fixed dentures on implants, people are more satisfied with overdentures on implants.[25] Satisfaction with the oral situation after implantation depends on the outcome in eating comfort, speech comfort and esthetics.[26]

Based on the afore mentioned literature one can assume that maxillary overdentures retained by mini–implants may affect speech, especially problems with the /s/ sound, and mild problems with articulation and oromyofunction, are likely to occur. It is important for dentists to inform the patients before starting the treatment, that speech can be affected and a certain adaptation period including further adjustments of the prosthesis may be required.
The main object of this study is to determine speech, oromyofunctional behavior as well as satisfaction with the treatment and the impact on quality of life in patients treated with a horse–shoe shaped overdenture retained by mini–implants in the maxilla. Changes in speech from the preoperative condition, with the original conventional removable denture, to the provisional denture and fixation of the horse–shoe overdenture on the mini–implants are assessed by a professional speech therapist, who worked independently from the clinician.

Methods and materials

Patient selection and clinical procedure

The clinical study was designed as a prospective multicenter cohort study in patients seeking treatment for poor stability and discomfort with their conventional denture. Patients were included if the following criteria were met: patients aged 50 years or older with a fully edentulous maxilla (either with or without a complete removable prosthesis); they had to be partially or fully dentate in the mandible consisting of a natural dentition, a combination of natural teeth and partial prosthesis without tooth supported prosthesis or an implant–supported overdenture or fixed bridges on implants.

The study protocol was set up according to the principles of the Helsinki Declaration on clinical research (1975, revised in 2002). All patients received detailed oral and written information about the study protocol, treatment plan, financial costs, follow-up period, and potential risks and complications. A written consent was obtained from each patient before being enrolled in the study. The study was approved by the Ethical Committee of the Ghent University Hospital on clinical research involving human beings (EC/2014/1253) and by the Ethical Committee of the General Hospital AZ ZENO Knokke-Blankenberge.
The mini dental implants (MDI) used in this study were made in one piece of a high strength pure titanium class 4 with a screw part diameter of 2.4 mm and a coronal ball attachment of 1.8 mm width (ILZ, Southern Impl. Inc, Irene, South Africa). Patients were treated under local anesthesia with free-handed flapless surgery. This means that the surgeon is piercing the mucosa and preparing the implant bed without reflecting a mucoperiosteal flap. Preoperative cone beam computed tomography (CBCT) planning and adaptation of the conventional denture in a surgical guide was performed for proper implant positioning. 5 to 6 implants were inserted with the ball head of the MDI extending 3 mm to 5 mm above the mucosa. No sutures were needed and ice packs were provided immediately after surgery. Detailed written postoperative instructions were discussed thoroughly and given to the patient. All patients were advised to abstain from denture wearing one week postoperatively until the denture was adapted for provisional loading. Additional space underneath the prosthesis was prepared to make room for the transmucosal implant ball head. The conventional prosthesis including the full palatal coverage was relined with Coesoft soft reliner gel (GC America, Chicago, Illinois, US). After 6 months the final prosthetic connection with a palatal free and reinforced horse-shoe denture was established. The prosthetic housings in the denture were imbedded by a dental lab to allow fixation of the denture with the ball attachments on the implants. Figure 2 shows the shape of the dentures in the different stages of the treatment.

Methods

The evaluation of the subjects took place in two dental clinics (University Hospital Ghent and Cosmipolis Bruges), in a testing room separated from other practices in the clinic, and adapted for phonetic evaluation. Patients were evaluated three times during their treatment (preoperatively, with provisional

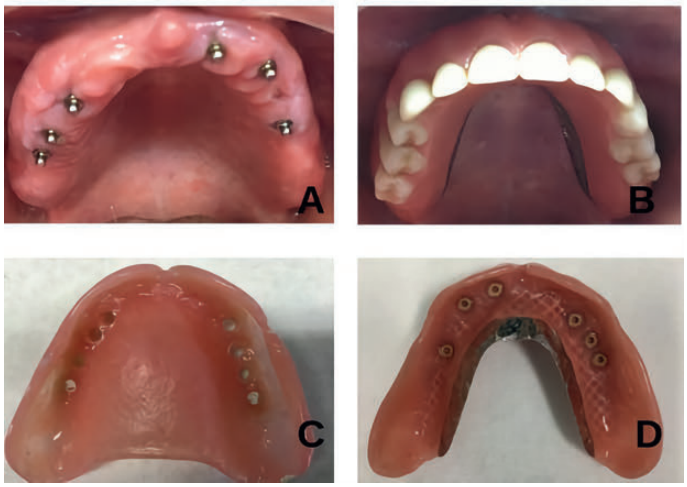

Fig 2. *Case P.M. with view on the maxilla after implant surgery (A) and with horse shoe overdenture in the mouth (B). The provisional denture (C) and the horse-shoe overdenture (D) are displayed below.*

denture after surgery and with fixed denture on MDI). Positioning of the test (the camera, test items and score form) was each time the same. The subjects were invited by the independent speech therapist. Each time an adaptation period of minimum one month was respected. The subjects were evaluated according to the methods used in the study of Van Lierde et al. (2011)[17] including an assessment of articulation, oromyofunctional behavior and satisfaction. The whole test took 20 minutes.

Articulation

A perceptive evaluation was used to assess the articulation of the subjects. The evaluation was performed by means of a picture naming test. [27] This test requires the subjects to name 135 pictures of common subjects and actions. It elicits all speech samples containing instances of all Dutch single sounds and most consonant clusters in all permissible syllable positions. The samples were recorded digitally with a video camera recorder (Sony Corporation, DCR-SR75E, Tokyo, Japan). The evaluation included a phonetic inventory and phonetic analysis. A sound was considered to be present in the inventory when at least two instances of the production were found. Two speech-language therapists (E.F and L.B.) firstly rated independently. In case of disagreement, the samples were replayed and discussed until a consensus was reached. Interrater reliability is displayed in table 1.

Oromyofunctional behavior

The oromyofunctional behavior was examined by means of the protocol of Lembrechts et al. (1999).[28] Patients were asked to perform certain tasks with their oral muscles. This protocol contains an evaluation of the tongue function (tongue position at rest, tongue protrusion, tongue retraction, tongue lifting against the upper lip, tongue lifting against the lower lip, lateral movements of the tongue, click one's tongue), jaw movement (lateral movement of the jaw, jaw opening), lip movement (lip position at rest, lip closure, dispersion of the corners of the mouth, lip protrusion, lip strength), facial muscles, spontaneous mime and integrated movements (blowing, sucking, whistling). Swallowing water and saliva were observed to evaluate the tongue position and muscle tension of the lip during swallowing. The oromyofunctional behavior was measured and video recorded as proposed in the protocol. A three-point rating scale was used for function (0= normal, 1= disturbed, 2= impossible). At last the presence of the following oromyofunctional disorders was verified with a questionnaire: presence of sucking habits, mouth breathing, lip incompetence, slavering, nail biting and bruxism.

Satisfaction and quality of life

To measure the Oral health related Quality of Life the Dutch version of the shortened Oral Health Impact Profile (OHIP-14) [29] was used. This questionnaire consists of 14 items divided in 7 domains being: functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. We used one question of the domain 'functional limitation' (Have you had trouble pronouncing any words because of problems with your teeth, mouth, dentures or jaw?) to determine the impact of the prosthesis on speech. The items were rated by a Likert-scale ranging from 0 (no discomfort) to 4 (high discomfort). A total OHIP-14 score is assessed by counting the scores of the 14 individuals questions. A score of 56/56 is indicative for maximal negative appreciation and 0/56 indicates that there are no issues at all. Subjects were also asked to rate overall satisfaction with their oral health and the satisfaction with their speech on a visual analogue scale of 10 cm (VAS) with on the end of the scale reflecting 100% maximal satisfaction and the other end of the scale corresponding 0% to complete dissatisfaction. To minimize bias, the patients were asked to fill in the questionnaires prior to the speech assessment and prior to the clinical assessment of the dental situation.

Statistical Analysis

To compare the changes between the different stages of the treatment a paired samples t-test and a McNemar test was used. We estimated inter-examiner reliability using Cohen's Kappa. All levels of significance were set at p=0.05. For analysis of the data SPSS statistics 25 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp) was used.

Results

Subjects

From 40 consecutively referred patients, 32 signed the informed consent to participate. One patient refused speech assessment by the independent speech therapist and the other patient couldn't speak due to neurological problems. Finally 30 patients were enrolled in the treatment protocol. 13 females, 17 males with a mean age of 62.6 (SD 9.0). All participants were native speakers of Dutch. In total 10% (3/30) reported hearing problems,13.3% (4/30) reported open mouth breathing, 10% (3/30) reported bruxism, 6.7% (2/30) reported swallowing problems and 10% (3/30) reported drooling. A treatment of the edentulous maxilla with complete horse-shoe overdentures on MDI's was performed in this group.

30 patients records are available preoperatively, records of 26 patients with the provisional fixation of the denture on MDI and 25 patients were examined with their final overdenture. Dropout is related to time issues and logistic issues.
All measurements were performed after an adaptation period of minimum one month and after minimal prosthetic corrections were finalized.

Articulation profile

Table 1 shows the results of the perceptual evaluation of speech by the speech therapist in the preoperative condition, with provisional fixation of the denture on the MDI's and with the final overdenture.

The sounds /s/, /z/, /t/, /n/, /l/, /ʃ/ and /ʒ/ are found to be disturbed before treatment in some participants. The most frequently disturbed sound is the /s/. These speech problems consisted of sigmatismus simplex (production of the

/s/ sound with insufficient frication), sigmatismus stridens (production of the /s/ with a whistle), disturbed /ʃ/ (as in the word '**sh**ow') and the /ʒ/ (as in the word 'gara**g**e') and an addental and interdental production of the /t/, /n/ and /l/ (resp. production of the tongue against and between the central incisors). Some people showed a small jaw opening during speech, as if they were mumbling. After insertion of the implants, the provisional denture with palatal coverage was adapted with soft tissue reliner. This temporary adaptation of the denture provide better retention but doesn't change the external shape. A decrease in speech problems was observed. Still a large percentage of the participants show problems in pronouncing the /s/ sound (either sigmatismus simplex of stridens). There is a decrease in number of problems with the apico-dental speech sounds (/t/, /n/ and /l/). In this stage we can conclude that mostly the fricative sounds (/s/, /z/, /ʃ/ and /ʒ/) are difficult to pronounce.

The final horse-shoe denture is connected to the implants a few months later. At that moment the palatal coverage was removed. After an average adaptation period 4 months there is again a decrease in speech problems. In this final stage still ten people show minor speech problems. Nine of them have problems with the /s/ sound (mostly sigmatismus stridens) in combination with a deviant /z/ sound or in one case small jaw opening during speech. One patient presents with a sigmatismus simplex. One other participant only presents an addental /t/.

Table 1. *Articulation issues with definitions (Pena-Brooks and Hegde, 2000) assessed during the stages of the MDI maxillary overdenture treatment (preoperative, provisional loading and final connection). The level of significance according to the paired t-test and the McNemar test.*

	Definition	Inter examiner Reliability %	Preoperative ($n_1 + n_2/n_{tot}$)	Provisional loading ($n_1 + n_2/n_{tot}$)	Final Connection ($n_1 + n_2/n_{tot}$)	Level of significance between preoperative and Provisional *p*-value	Level of significance between provisional and final *p*-value	Level of significance between preoperative and final *p*-value
/s/ stridens (1) + /s/ simplex (2)	Phonetic disorder of the s sound accompanied with a whistle sound (1) + with insufficient frication (2)	85	10+4/30	6+5/26	8+1/25	1	1	0.727
Small jaw opening		81	4/30	4/26	1/25	1	0.250	0.500
/z/ stridens (1) + /z/ simplex (2)	Phonetic disorder of the z sound accompanied with a whistle sound (1) + with insufficient frication.	96	4+0/30	1+1/26	3+0/25	1	1	1
/t/ interdental (1) + /t/ addental (2)	The t sound with the tongue tip between de central incisors (1) + against the central incisors (2)	71	1+2/30	1+1/26	0+2/25	1	1	1
/n/ interdental	The n sound with the tongue tip between the central incisors	100	1/30	0/26	0/25	1	1	1
/l/ interdental	The l sound with the tongue tip between the central incisors	49	1/30	0/26	0/25	1	1	1
/ʃ/ stridens (1) + /ʃ/ simplex (2)	Phonetic disorder of the ʃ sound (as in **sh**ow) accompanied with a whistle sound (1) + with insufficient frication (2)	78	3+0/30	0+1/26	0+0/25	0.625	1	0.500
/ʒ/ stridens (1) + /ʒ/ simplex (2)	Phonetic disorder of the ʒ sound (as in garage) accompanied with a whistle sound (1) + with insufficient frication (2)	100	1+1/30	0+1/26	0+0/25	1	1	0.500
Number of speech issues per person			Mean 1 [0-4]	Mean 0.78 [0-4]	Mean 0.65 [0-2]	Mean dif. 0.222 [-0.207;0.652] p=0.297	Mean dif. 0.292 [-0.198;0.782] p=0.231	Mean dif. 0.385 [-0.012;0.782] p=0.057

Oromyofunction

Table 2 shows the results of the evaluation of oromyofunctional behavior before and during the procedure. Overall there are only 5 functions of the 25 functions evaluated as deviant. In the preoperative condition the participants present with immobility of the jaw (the lateral movement of the mandible is deprived), problems with clicking of the tongue against the palate, problems with whistling and tongue thrust during swallowing. With the provisional denture after insertion of the implants, patients still present with whistling problems, problems with clicking of the tongue against the palate and immobility of the jaw. With the implant connected horse–shoe denture, seven people still present with whistling problems, one participant still has problems with clicking the tongue against the palate, but two people present with the problem of lifting the tongue to the upper lip. This latter occurred in the last stage after insertion of the final prosthesis.

Table 2. *Problems with oromyofunctional behavior assessed during the stages of the MDI maxillary overdenture treatment (preoperative, provisional loading and final connection). The level of significance according to the paired t-test and the McNemar test.*

	Preoperative (n)	Provisional loading (n)	Final Connection (n)	Level of significance between preoperative and provisional *p*-value	Level of significance between provisional and final *p*-value	Level of significance between preoperative and final *p*-value
Immobility of the jaw	4/30	2/26	0/25	0.500	0.500	0.250
Problems with clicking of the tongue	6/30	4/26	1/25	1	0.375	0.125
Whistling problems	11/30	15/26	7/25	0.180	0.039	1
Tongue thrust during swallowing	1/30	0/26	0/25	1	1	1
Tongue lift problems	0/30)	0/26	2/25	1	0.500	1
Number of issues per person	Mean 1.07 [0–3]	Mean 1.15 [0–3]	Mean 0.65 [0–2]	Mean dif. -0.074 [-0.363;0.215] p=0.602	Mean dif. 0.417 [-0.013;0.847] p=0.057	Mean dif. 0.308 [0.010;0.605] p=0.043

Satisfaction and quality of life

Table 3 shows the results of the satisfaction scores and the impact on quality of life, given by the participants. Overall satisfaction and impact on the Oral health related Quality of Life improved with evolving treatment. Especially the final connection to the implants showed to be of utmost importance in the treatment.

An average of total treatment satisfaction (measured by the VAS) evolved from 67% pretreatment to 66% with the provisional denture and finally 83% with the final loading. The satisfaction with speech (measured by the VAS) evolved from 77% pretreatment to 72% with the provisional loading to 84% with the final loading. The OHIP total score is rather high (21.97) preoperatively, this is also reflected in the scores on the first question in the domain 'functional limitation'. The answers to this question ('Have you had trouble pronouncing any words because of problems with your teeth, mouth, dentures, or jaw') reflect the impact of the denture on speech. Pretreatment people answered mostly with 'occasionally', followed by 'hardly ever', 'never', 'fairly often' and 'very often'. With the provisional denture the OHIP total score decreased as well (16.93). The scores on the first OHIP question in 'functional limitation' showed better results. Most people reported to 'never' notice an impact of their denture to their speech. The second most reported answer was 'occasionally' followed by 'hardly ever' and both 'fairly often' and 'very often'. In the last stage of the treatment the average total OHIP score decreases to 8.23. Also participants report mostly 'never' to notice an impact of their denture to their speech, followed by 'hardly ever', 'occasionally' and both 'fairly often' and 'very often'.

Table 3. *Total OHIP-14 (scale 0-56), VAS overall satisfaction(%), OHIP question 1 (%) (n) and VAS speech-related satisfaction (%) reported during the stages of the MDI maxillary overdenture treatment (preoperative, provisional loading and final connection). The level of significance according to the paired t-test.*

		Preoperative	Provisional loading	Final connection	Level of significance between preoperative and provisional *p*-value	Level of significance between provisional and final *p*-value	Level of significance between preoperative and final *p*-value
Satisfaction total (VAS) (%)		Mean 67 [41-100]	Mean 66 [9-100]	Mean 83 [50-100]	Mean dif. -0.002 [-0.088;0.085] p=0.971	Mean dif. -0.128 [-0.217;-0.039] p=0.007	Mean dif. -0.097 [-0.199;0.005] p=0.061
OHIP-14 total score (0-56)		Mean 21.97 [1-56]	Mean 16.93 [0-48]	Mean 8.23 [0-23]	Mean dif. 5.920 [-0.777;12.617] p=0.081	Mean dif. 7.696 [2.595;12.796] p=0.005	Mean dif. 12.75 [7.285;18.215] p<0.001
Satisfaction speech (VAS) (%)		Mean 77 [41-100]	Mean 72 [40-93]	Mean 84 [58-100]	Mean dif. 0.036 [-0.048;0.121] p=0.382	Mean dif. -0.112 [-0.177;0.046] p=0.002	Mean dif. -0.038 [-0.117;0.041] p=0.326
OHIP Question 1 (n) *'Have you had trouble pronouncing any words because of problems with your teeth, mouth, dentures, or jaw'*	Never	5/29	9/26	9/25			
	Hardly ever	7/29	5/26	9/25			
	Occasionally	14/29	8/26	5/25			
	Fairly often	2/29	2/26	1/25			
	Very often	1/29)	2/26	1/25			

Discussion

Speech sounds are the result of delicate interaction of the speech structures and the air stream. The air stream gets well-adjusted by the position of the speech structures and produces the sounds we know as speech sounds. It is known that changes to these structures, as is the case in dental rehabilitation, can cause difficulties in speech production. In this study a horse-shoe implant overdenture design was used. The bucco-lingual dimension of this prosthesis is slightly wider than fixed dentures to allow space for the housing of the attachment system. Pretreatment, patients who were unsatisfied with their removable denture came for treatment and were included in this study. Patients included in this study were referred with retention problems of their existing removable prosthesis. Hence it is reasonable to accept that the speech therapist revealed several problems. Bothur and Garsten (2010) stated that patients' subjective experiences of speech may vary and patients who were previously accustomed to a well fitted conventional denture are not presenting with many speech problems.[30] However, patients with less retention of their denture present with poor speech and poor satisfaction. Their study did not describe in detail the speech problems that occurred. The speech problems reported in our study are similar, yet not completely in agreement to the ones reported in previous studies on conventional removable dentures in the maxilla. In those studies problems with /s/, /z/, /l/ and /t/ are reported.[14, 12] This difference can be due to the fact that in our study the conventional removable dentures were inadequate and not perfect as compared to participants with well fitted and adapted dentures in other studies. Especially because the conventional dentures covered the palate and had unsatisfying retention, the outcome on speech, oromyofunction and satisfaction were rated negatively prior to treatment.[7]

After surgery the prosthesis was adjusted and relined which resulted in less speech problems. It is understandable that the relining of the prosthesis over the implants, led to this improvement of speech. The nature of those distortions is not fully understood and it seems to be reasonable to assume that bad retention may have an impact. Especially the modification in the palatal coverage during the treatment procedure is to be considered as an additional factor affecting speech. The relined dentures covered the palate of the participants. As seen in

fig. 1 the palate is an important structure in forming several consonants. This can explain the remaining speech problems. The importance of the palate plate in conventional dentures was described before by several authors.[20, 21, 31] They highlight the importance of landmarks on the palate to provide the tongue with sufficient referential information to make proper contact to mold the airstream into speech sounds [31] and a strong effect of a palate coverage on speech sounds was found.[20, 21] However studies on speech with fixed dentures without palate coverage are also reporting difficulties with speech. This suggests that not all speech problems in denture wearers can only be related to the coverage of the palate.[12] The remaining speech problems are, as mentioned before, similar to the ones reported in literature on conventional dentures.[12,14] Here it is to stress that the conventional dentures in the post-operative situation were adjusted especially with improved retention by relining of the denture. Despite that, the patients were aware of the transient period of provisionalization of the denture a certain disappointment with the outcome can be expected.

After final connection of the denture (horse-shoe design) to the implants it is striking that the /s/ sound in nine of the 25 subjects is distorted. All of the nine participants who received a horse-shoe design presented with a sigmatismus stridens. As described earlier the difference in shape of the horse-shoe overdenture in comparison to the conventional denture with palate plate is in many ways important to discuss. The production of speech depends on how the speech structures mold the airstream into a recognizable sound. In dental rehabilitation these structures are replaced and/or adjusted, which may influence speech. In the transition from a conventional denture with palatal coverage (which comprises the oral space in vertical dimension) to a horse-shoe overdenture without palatal plate (which comprises the oral space in horizontal dimension), the tongue needs to find back the proper contact places and referential points to be able to mold the airstream in the same way as before. In the majority of the participants this was no problem, especially because a proper adaptation period was respected. Still some participants suffered from problems producing the /s/ sound. This is in agreement with previous studies on overdentures and fixed dentures in the maxilla.[11,14] It is obvious to state that the /s/ sound is the most vulnerable sound in rehabilitation of the maxilla. This was already reported by other authors.[11, 12, 14, 15, 22]

The oromyofunctional behavior of the participants during treatment showed some striking findings. In comparison to primary studies there are more problems to report.[11,13,14] It is possible that this disagreement is due to the difference in dental rehabilitation, age of the participants and way of examination. In our study whistling seems very fragile in all stages of the treatment. Preoperatively participants present with the most deviant behaviors. This can be explained by the bad fit and retention of the denture. It is possible that people put a lot of effort in keeping their denture in place and therefore can't use their oral muscles properly. After relining of the provisional denture, more retention of the denture is accomplished and some of the pretreatment oromyofunctional problems disappeared. But more people present with whistling problems. There is no other report of this kind of problem in previous research mainly because this function was not assessed before. The anatomical changes during whistling are not yet fully understood. We know that the air flow is directed through the pursed lips by the tongue in combination with the hard palate.[32] Due to the denture it is possible that the formation of the right position of the anatomical structures to produce the whistling sound is distorted. In the last phase of the treatment surprisingly tongue lift problems occur in 2 patients. This phenomenon has never been reported. To lift the tongue to the upper lip, the tongue muscles extend in ventral direction, pushing the tongue base up and forward. It is possible that because of the specific shape of the overdenture the movement of the tongue base is obstructed and lifting of the tongue to the upper lip is more difficult in some participants. This is a matter for further research.

Besides the opinion of professionals about function it is equally important to evaluate participants' opinion about their situation. The results obtained by the VAS scales showed both low ratings for total satisfaction and satisfaction with speech pretreatment. This can be explained by the fact that participants apply for this treatment because they are in some way dissatisfied with their situation. Literature states that eating comfort, speech comfort and esthetics are the main causes of dissatisfaction in denture wearers.[26] Surprisingly after relining of the provisional denture, the rates on the VAS slightly drop. It is possible that people expected more of this phase of the treatment or they still suffer from small complications due to the surgery.[33] In the final stage, after loading with the actively retained horse–shoe overdenture the satisfaction rises tremendously

to a level that is comparable to the ones previously reported.[14, 16] In the domain 'functional limitation' participants rated the impact of their denture on speech. Over the different stages of the treatment people reported less impact of their denture on speech. This is also in line with previous studies on speech.[14, 16]
It is worth mentioning that the strength of this study lies in the large sample size, the detailed and professional speech analysis and the longitudinal design. The limitation of this design is the drop-out of the participants during the study due to organizational and logistic issues. It is known that hearing problems can affect speech production. We didn't perform a hearing test before treatment but we asked the patients if they had any hearing conditions. This subjective manner could have been less precise. It was impossible to assess the speech profile of the participants in normal conditions because they presented already with complaints about their dental situation at the start of the study. In an ideal situation we know about possible speech problems in normal conditions, so we can detect what speech problems are due to the treatment and what problems already existed. A last limitation is the fact that only one speech therapist was blinded for time points measured when examining the videos. It is possible that the expectation of the therapist influenced the rating. Still there was a good inter-rater reliability.

It is to highlight that despite the speech problems, assessed by the speech therapists, people are in the end very satisfied with their speech and oral situation. Therefore it is very important to ask patients opinion about their speech and oral situation and the impact of it on their quality of life before pointing out possible problems you notice as a professional. When people give a rating about speech it is possible that besides the sound they produce they also rate the comfort they experience while speaking. This is something speech therapists can't assess. Hypothetically the comfort of speaking is for non-professional speakers more important than the way they sound. It is important to inform patients before treatment about the possible difficulties they may encounter during treatment. In the future research should focus on the possibility to deal with patients with remaining speech problems. To avoid speech problems it is necessary to check if the retention of de denture is sufficient and if the coverage of the palate isn't obstructing good speech production. The shape of the denture should get as close as possible to the shape of a normal oral cave. The technique of Collaert et al. 2015 applied on

fixed dentures may be useful in overdentures as well. It is possible that the reduction of the volume of the resin in the premolar area can solve remaining problems, especially with the /s/ sound. It is to be examined whether the size of the implants influences the size of the prosthesis and therefore affects speech and oromyofunctional behavior. It is possible that the reduction of the volume of the resin in overdentures on MDI is easier because the attachment structure is smaller. Besides the adjustment of the denture it is possible that conventional speech therapy can offer a solution to the remaining speech problems.

Conclusion

Speech and oromyofunctional problems occur during all stages of the treatment. Especially the /s/ sound and the whistling function seem very fragile and occur in all stages. The speech problems seen during the two first stages are similar, yet slightly different from the ones seen in previous studies. Especially the introduction of the horse–shoe overdenture on MDI seemed to be important. People are very satisfied with their oral and speech situation in this last stage, despite the fact that speech therapists detect some difficulties with the pronunciation of in particular the /s/ sound. Therefore it is important for dentists to inform their patients that speech and oromyofunctional problems may occur during treatment, but most likely will disappear after an adaptation period.

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CHAPTER 5

Quality of life and social participation in dental rehabilitation: A personality and multi-informant perspective.

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Abstract

Objectives: Contemporary research on the impact of dental rehabilitation scarcely focuses on the role of personality and social relationships in QoL related to dental implant treatment. To overcome biases related to evaluation with self-reports, descriptions provided by informed external observers are recommended.
Aims: To investigate the impact of implant-supported rehabilitation on quality of life and social participation taking into account patient's personality.

Materials and Methods: Fifty-four patients were included in this study and assigned to either a single unit group (n=15) or a complete jaw restoration group (n=39). Of the 54 participants, 49 nominated an external observer who can evaluate the daily behavior of the patient. Before and after treatment patients and their external observer completed the OHIP-14, the NEO-FFI and the MSPP questionnaires respectively focusing on Oral Health related Quality of Life, Personality and Social participation.

Results and conclusion: The correlations between self- and observer ratings on pre and post treatment outcomes on were insignificant (QoL pre: p=0.086, post: p=0.115, freq. soc. part pre: p=0.944, post: p=0.876, div. soc. part pre: p=0.798, post: p=0.167), suggesting considerable differences in observer perspectives. The traits Neuroticism, Extraversion and Agreeableness were associated with QoL. Openness, Conscientiousness and Agreeableness were associated with social participation. Patients in the complete jaw restoration group reported more impact of the implant treatment on quality of life as compared to the single unit group (p=0.007). The complete jaw restoration group reported an improved quality of life after treatment and significant increases of both frequency (p=0.001) and diversity of social participation (p=0.036). In conclusion there was a minor impact of treatment with single crowns on quality of life and social participation compared to the full denture group. The role of personality and the use of multi-informants in evaluating dental treatment was found important.

Introduction

Life expectancy is rising and hence patients will keep their natural teeth longer and functional. Nevertheless, large numbers of patients are edentulous and in need of wearing dentures. According to Johannsen et al (2012) tooth loss leads to fear, shame and denial affecting patient's social activities [1]. Edentulism can be seen as a chronic disease which requests treatment according to the International Classification of Functioning, Disability and Health (ICF) [2]. In this framework, the outcome of a treatment is described in terms of three main components: Body functions and structures, activity and participation. These three components are in interaction with the health condition, personal factors (including personality) and environmental factors [2]. In the evaluation of any treatment it is important to keep these factors and interactions in mind. Social participation may, according to the ICF, contribute to the feeling of quality of life. Edentulism is not only associated with less oral functionality, but also with loss of social status and less self-esteem. It is hence important and necessary to take all these impacts into account while evaluating the result of dental treatments [3].

Compared to a natural dentition, denture wearing is associated with a reduction in functional comfort and oral health related quality of life. A dental prostheses aims to restore speech, chewing, bite and swallow functions, but also improves aesthetics and facilitate psychosocial functions [4,5]. Lack of stability and retention as well as decreased chewing ability are the most prevalent patient complaints [4]. Dental implants are useful to replace missing teeth or to improve denture stability. As such, an overdenture retained on two dental implants in the lower jaw has been suggested as the minimal standard of care to improve denture retention [6], improve social life and increase self-esteem due to the restored chewing function and improved aesthetics [1].

Quality of life after dental treatments has been substantively investigated the past years [7], examining the influence of edentulism on various domains such as speech and chewing functions, but also aesthetics, self-confidence, different psychological and social factors [8]. The outcome is influenced by gender, age and educational level of the patient. Chen et al (2012), for example, investigated 102 patients with a single unit implant treatment, and showed a

significant impact of treatment on self-esteem, social behavior and aesthetics. Men reported significantly larger effects on aesthetics and self-esteem compared to women, and individuals with a higher educational level reported larger effects on aesthetics and social behavior [8]. Papadaki and Anastassiadou (2011) evaluated the effects of treatment with complete conventional dentures in 80 patients. There were significant correlations between aesthetics of the teeth, speech problems, chewing problems and pain and the item 'going out in public'. Younger people (-65y) had more problems in accepting tooth loss, but were more eager to talk about dental problems with friends or their dentist compared to older people [9]. Heydecke et al. (2005), finally, investigated the impact of conventional prostheses and implant retained overdentures in the mandible on social and sexual activities. Both treatments had significant effects on the items 'avoiding conversations', 'declining invitations' and 'avoiding sport activities', but implant retention enhanced social and sexual activities [10]. Different kinds of rehabilitation have different effects on quality of life and social participation. It is obvious that the impact on quality of life and social participation is more expressed in patients undergoing full denture treatment as shown by Van Lierde and coworkers [11]. In this study the satisfaction of single-tooth implant group measured on a visual analog scale was 100% followed by a satisfaction of 87% for the fixed implant prosthesis group (full denture) and 68% for the removable prosthesis group (full denture).

Personality is the set of psychological traits and mechanisms within the individual that influences our interaction with and adaptation to intrapsychic, physical and social environments [12]. Personality traits help to describe differences among people and contribute to our prediction of individuals' future behavior. There is agreement among personality psychologists that five main dimensions, called the Five-Factor Model (FFM) traits, are the largest common denominator to describe personality differences among individuals. The FFM consists of five broad dimensions, commonly labelled as Extraversion, Agreeableness, Conscientiousness, Openness to experience and Emotional Stability [13]. The dimensions of Extraversion and Agreeableness refer to individual differences in respectively the frequency and quality of social interaction. Extraversion groups traits such as warmth, assertiveness, activity, positive emotions, sociability and excitement-seeking [13], and people with high scores enjoy social attention and feel at ease in social situations [14,15]. Agreeableness refers to traits such as trust,

straightforwardness, altruism, compliance, modesty, and tender-mindedness, with high scorers liking harmonious social relationships [16]. Conscientiousness refers to qualities of work and goal-oriented behavior, grouping traits such as being orderly, self-disciplined and achievement-oriented, leading to more success in different aspects of life, including social relationships [17,18]. Emotional stability describes how people regulate their emotions and handle stress. People scoring high on this trait are sensitive to fear, anger, sadness and frustration [13]. Neuroticism is seen as a chronic condition of sensitivity for irritation and stress which may be relatively independent of the objective situation [19]. Individuals high on Neuroticism may be less satisfied with their physical health, report more symptoms and wait longer before taking any steps in health care [20]. Finally, Openness to experience groups traits such as having fantasy, appreciate arts and aesthetics, and being open to one's feelings, actions, ideas and values [13]. High scorers on openness have a rich imagination, are intellectually curious and love to try out and experiment.

Personality traits demonstrated not only to be important to understand quality of life and interpersonal behavior, but also to comprehend health behavior and health perceptions [20]. The relationships between Extraversion and Neuroticism with quality of life have been extensively meta-analytically documented [5], and the dimensions of Extraversion and Agreeableness have been proposed as the key dimensions describing individual differences in social interaction [21]. Social participation is defined by the ICF-model as 'to be involved in situations of daily life' [2]. The way a person participates in social situations and will avoid other situations depends on the personality traits of the individual and the perception of the self. The personality of a person influences what kind of social situation that person will select, but personality also influences the way a person evokes reactions from others and how a person manipulates situations. Personality traits will also affect how patients handle health problems. Umaki et al (2012) suggested several reasons for non-compliance with oral hygiene measures, including the personality traits of Neuroticism and (low) Conscientiousness, but also psychological stressors and health beliefs of the patient.

Alternatively, personality may also affect the experiencing and reporting of health status and satisfaction with treatment. Despite a technically perfect treatment, some patients are still not satisfied with their oral situation [22,23] and

personality traits may account for this differential experience [24–26]. Al-Omiri et al (2014) found that about 10% of the patients with a conventional prosthesis reported less satisfaction despite a technically and functionally perfect denture. Their research showed that particular personality traits were predictive of this pattern, with Neuroticism associated with lower satisfaction with the final result. Moreover, Conscientiousness was positively, whereas Openness to experience was inversely related to pain tolerance. Extraversion was positively associated with satisfaction with eating [25]. Özhayat et al found that high scores on negative affect and low self-esteem had a negative influence on oral health related quality of life before and after dental treatment. Patients with high scores on negative affect (closely related to neuroticism) reported lower satisfaction with their new dental prosthesis after treatment, despite the fact that the treatment was equally successful as the treatment performed on patients scoring low on negative affect [27]. Torres et al (2011) found in subjects with a prosthodontic treatment in the mandible that Neuroticism was predictive for all scales of the Oral Health related Impact Profile (OHIP) [28]. Quality of life in patients with conventional dentures, was predicted by Neuroticism and Conscientiousness together with gender. Quality of life in patients with dentures on implants could be explained by Neuroticism, Openness and educational level [29]. Therefore we hypothized in the present study an association between the five personality traits and quality of life and social participation before and after dental rehabilitation.

Research on the impact of prosthodontic treatment on quality of life and social relationships in patients almost exclusively relied on self-reports of experienced health status and interpersonal functioning. Although self-reports provide insightful information, there is a methodological problem of common rater bias. Especially when patients have undertaken efforts such as invested time, undergoing surgery, financial consequences, their reported treatment impact may be biased. Costa and McCrae (1987) further argued that we cannot assume that people can rate their own health conditions accurately, because personality traits may bias the perception and reporting of medical symptoms. To overcome these biases, it is recommended to expand self-ratings with reports by an informed external observer who knows the daily functioning of the patient well. Including such extra observer perspective in the evaluation of prosthodontic treatment would be a key innovation in this type of research [19].

Contemporary research on the impact of dental implants on quality of life and social participation paid only marginal attention to the role of personality in the experiencing of quality of life and social relationships and adaptation after surgery.

The aims of the current study are to assess the impact of implant–prosthodontic treatments on quality of life and social participation taking into account a patient's personality and relying on self– and observer ratings of post treatment outcomes.

Materials and methods

Participants and design

Patients in need of implant–related prosthetic treatment consulting the Department of Periodontology and Oral Implantology of University Hospital of Ghent were asked to participate in the investigation. They all completed personality, quality of life and social participation questionnaires one month before treatment and one to two months after implant treatment. Patients were requested to select an observer who knew them well to provide patient descriptions using the same set of inventories. All subjects (patients and observers) gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of University Hospital of Ghent on clinical research involving human beings (EC/2015/1056).
In total 75 out of 54 patients accepted to participate and gave informed consent. The issue of non–response was related to logistic issues, less engagement to participate or the lack of a social network to fill in the external observer form. Fifteen patients received single–unit prostheses, 30 were treated with a two–implant–retained overdenture, 5 received a removable conventional full dentures and the final 4 a fixed implant– supported bridge. Because the latter 5 and 4 cases represent a minor group, too small for further statistically relevant distinction, the removable and fixed complete dentitions were regrouped to one.

Patients were assigned to two groups: Group 1 (N= 15) included those receiving single–unit prostheses, Group 2 (N= 39) enclosed those with complete jaw restorations (with or without implants).

Personality

The Dutch version of the NEO-Five Factor Inventory (NEO-FFI, McCrae & Costa, 2004) was used to assess patients' personality. The NEO-FFI assesses the traits of Neuroticism, Extraversion, Openness to experience, Agreeableness and Conscientiousness, using 60 items (12 items per trait) adopting a five-point rating scale, with as scale-anchors 'strongly disagree', 'disagree', 'neutral', 'agree', and 'strongly agree' [30].

Quality of life

Oral health related quality of life was measured using the Dutch version of the shortened Oral Health Impact Profile (OHIP-14) [28,31] using 14 items to be rated on a Likert-scale ranging from 0 (no discomfort) to 4 (high discomfort). Items were grouped in the domains of functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. Also a total OHIP-14 score was computed across all items, with a score of 56/56 indicative of maximal negative appreciation and 0/56 indicative of no issues at all.

Social participation

The Maastricht Social Participation Profile (MSPP) [32] is a Dutch scale measuring social participation of adults older than 60 years with a chronic disease. The scale consists of four indices: consumptive participation, formal social participation, informal social participation-acquaintances and informal social participation-family. Each index measures diversity and frequency of participation. All items can be scored using 4 options ('not at all', 'less than once a week', 'once or twice a week', 'more than twice a week').

Statistical analysis

SPSS statistics 25 (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp) was used for the analysis of the data. Mann-Whitney U and chi-square tests were used to detect differences between the drop-out group and the continuing patients and the differences between the two study groups. Agreement across informants (self and observer) was evaluated by Pearson correlations. Differences between assessments before and after treatment were explored using a Wilcoxon Matched Pairs test. The influence of personality traits on quality of life and social participation was assessed using multiple

linear regression analysis. Results were considered significant at $p < 0.05$, given the exploratory nature of the analyses.

Results

Of the 54 participants, 49 nominated an external observer. The other participants were not able to appoint an external observer due to the lack of a social network. The external observers were in 68.5% (37/49) the partner, 7.4% (4/49) the son or daughter, 7.4% (4/49) a close friend, 5.6% (3/49) a brother or sister and 1.9% (1/49) selected a cousin. The mean age of the patients in the single unit–group (Group 1) was 60.96 (SD 22.12) including 8 females and 7 males, whereas the mean age of their external observers was 66.65 (SD 24.09) with 10 females and 5 males. The mean age of the patients in the complete jaw restoration group (Group 2) was 63.33 (SD 11.44) with 21 females and 18 males, and the mean age of their external observers was 63.35 (SD 24.41) including 16 females and 18 males.

Fifty–four patient and 49 external observer records were available pretreatment. Post–treatment ratings were obtained after 4 to 8 weeks from 47 patients and 40 external observers. There were no significant differences in age, social participation, quality of life, treatment and gender between those continuing participation and those dropping out. Due to logistic and time issues it was not possible to convince all participants and their external observers to participate in the second wave of the measurement.

The correlations between self and observer ratings for the quality of life (pre–surgery: 0.248, p=0.086, post–surgery: 0.228, p=0.115), frequency of social participation (pre: 0.010, p=0.944, post: 0.023, p=0.876), and diversity of social participation (pre: –0.038, p=0.798, post: –0.201, p=0.167), are all non–significant suggesting considerable differences in perspectives between patients and their observers. Our criterion measures, i.e. quality of life and frequency and diversity of social participation correlated significantly –0.284, p=0.004 and –0.184, p=0.063 before and –0.259, p=0.008 and –0.408, p<0.001 after treatment respectively.

The associations between the five personality traits and self-rated quality of life and social participation across all patients are described in Table 1. Neuroticism and Extraversion (inversely) predicted pre- and post- treatment self-ratings of quality of life, whereas Agreeableness was only a predictor in the pre-treatment condition. Patients higher on Neuroticism and lower on Extraversion reported worse quality of life. Openness to experience showed to be positively associated with both frequency and diversity of social participation in the pre- and the post-treatment conditions. Agreeableness and Conscientiousness only predicted frequency of social participation in the pre-treatment condition.

Table 1. *Spearman correlation between the results on Oral Health impact Profile (OHIP), frequency (Freq. Soc. Part.) and diversity (Div. Soc. Part.) of social participation and the personality traits.*

	OHIP pre n=102	OHIP post n=88	Freq. Soc. Part. Pre n=102	Freq. Soc. Part. Post n=88	Div. Soc. Part. Pre n=102	Div. Soc. Part. Post n=88
Neuroticism	0.356 **	0.233 *	−0.129	0.128	0.006	0.104
Extraversion	−0.212 *	−0.254 *	0.187	−0.044	0.181	0.173
Openness	−0.121	0.032	0.277 *	0.232 *	0.293 *	0.255 *
Agreeableness	−0.334 **	−0.167	0.295 *	0.045	0.148	−0.055
Conscientiousness	−0.121	0.007	0.288 *	−0.084	0.163	−0.016

*p<0.05, **p<0.001

Table 2 reports the results of regression analyses, regressing self-reported outcome variables obtained post-treatment on personality traits, controlling for pre-treatment values. Regressing post-treatment quality of life on personality traits, controlling for pre-treatment self-reported quality of life, showed no added explanatory value, suggesting that personality traits did not affect changes in experienced quality of life after treatment. Similar findings were obtained for regressing frequency and diversity of social relations on personality traits, taking into account their respective pre-treatment values.

Comparing the two study groups pre-operatively on frequency of social participation (z=−0.875, p=0.381), diversity of social participation (z=−1.110, p=0.267) and quality of life (z=−2.412, p=0.016) revealed significantly worse results for initial quality of life in the full denture group. Postoperatively the differences on frequency of social participation (z=−1.249, p=0.212), diversity of social participation (z=−0.953, p=0.341) and quality of life (z=−0.649, p=0.516) were not significant anymore.

Table 2. *Multiple regression coefficients and Beta coefficients for the model with the preoperative measures and the NEO-FFI scales predicting the postoperative measures (Oral Health impact Profile (OHIP), frequency (Freq. Soc. Part.) and diversity (Div. Soc. Part.) of social participation).*

	OHIP Post	Freq. Soc. Part. Post	Div. Soc. Part. Post
Neuroticism	−0.24	−0.058	−0.229
Extraversion	−0.636	0.209	−4.198
Openness	−1.141	1.516	2.314
Agreeableness	1.025	−2.755	−2.348
Conscientiousness	−1.55	1.603	4.792
OHIP Pre	0.556 *	–	–
Freq. Soc. Part. Pre	–	0.5 **	–
Div. Soc. Part. Pre	–	–	0.284*
Adjusted R^2	0.197	0.080	0.072
R^2	0.244	0.134	0.127

*p<0.05 and **p<0.001.

Quality of life and social participation indices for the two study groups pre- and post-treatment are reported in Table 3. Only patients for whom pre- and post-treatment scores were available are enclosed in the analyses. The upper half of the table includes the self-reports, the lower half the observer reports. For the single unit group, patients and their observer did not report significant differences in oral health related quality of life, frequency and diversity of social participation pre- versus post-treatment. The complete jaw restoration group, however, reported a significantly improved quality of life after treatment (z=-2.713, p=0.007)), and significant increases of both frequency (z=3.288, p=0.001) and diversity (z=2.097, p=0.036) of social participation. The observers in this group, however, reported no significant differences.

Table 3. *Mean results on quality of life (OHIP 14-total, max score is 56) and the domains of social participation pre- and posttreatment given by the subjects and their external observer. A reduction in OHIP 14-total score indicates improvement. With Oral Health impact Profile (OHIP), frequency (Freq. Soc. Part.) and diversity (Div. Soc. Part.) of social participation.*

	OHIP 14-total *Mean (SD)*	Freq. Soc. Part. *Mean (SD)*	Div. Soc. Part. *Mean (SD)*
Single Unit group Pre (n=12)	11.50 (10.27)	23.17 (9.31)	13.83 (5.73)
Single Unit group Post (n=12)	10.08 (10.18)	21.42 (9.56))	14.08 (4.81)
Complete denture group Pre (n=34)	19.86 (11.68)	22.15 (7.50)	15.62 (4.00)
Complete denture group Post (n=34)	12.68 (11.68)	26.65 (9.24)	16.82 (5.31)
Single Unit group Pre (extern) (n=13)	10.62 (11.24)	25.54 (8.84)	17.46 (3.28)
Single Unit group Post (extern) (n=13)	10.69 (13.24)	24.62 (9.12)	17.31 (3.45)
Complete denture group Pre (extern) (n=25)	16.44 (9.73)	26.00 (11.05)	15.84 (5.15)
Complete denture group Post (extern) (n=25)	15.84 (13.23)	27.24 (10.19)	16.24 (4.37)

Discussion

The present study examined the impact of dental rehabilitation treatment on quality of life and social participation, taking into account patients' personality ratings and using observer informants beyond patients' self-reports of treatment impact. These research innovations are necessary and timely given that previous investigations have shown that patients' personality may affect the perception of their personal psycho-social conditions and that self-descriptions not necessarily match with observer reports of perceived impact of treatment [7,19,33].

As a consequence of including all patients that presented themselves for reconstructive treatment, three distinctive groups could be recognized. Patients with partial restoration missing one tooth and patients who were edentulous in a full jaw and were either restored with a removable denture (with or without implants) or received a full fixed bridge on several implants. Previous research indicates that patients are more satisfied when treated with respectively implant retained overdentures compared to conventional removable dentures [7]. Studies revealed that improved patient outcomes are comparable between overdenture or fixed bridge [34]. Hence the patients were grouped according to single or_complete jaw restorations. Because the final outcome and the questionnaires pertained to functional and aesthetic repair, it was assumed that oral function and psychosocial activities are comparable irrespective of the fact that their overdenture is removable and the fixed bridge is non-detachable. Still this is an issue for further research.

A first notable finding was that patients in the complete jaw restoration group experienced worse QoL before treatment. This finding is in line with expectations given that they are edentulous or have very bad dentition, while those receiving a single unit denture, in general, only have one missing tooth. After treatment the differences are not significant anymore, suggesting that the full denture group catches up with the single-unit group reaching similar quality of life levels

A second result was that, across patients undergoing different dental treatments, converge between self- and observer ratings of quality of life

and social participation measures (frequency and diversity), was very poor, suggesting unique perspectives of patients and observers on the outcomes of dental treatment. This finding parallels observations by Costa and McCrae (1987), showing that the correlation between patients' self-reported complaints and assessments by physicians were small to moderate [19]. These and our findings together suggest that it is useful to rely on multiple observers to evaluate (dental) treatment impact and include evaluations by knowledgeable others beyond patient self-reports [33].

A third main finding was that personality was related to self-reported quality of life. Fully in line with the literature, those lower on Neuroticism and higher on Extraversion reported higher quality of life [5]. This was true before and after their treatment. Such associations were previously also described for dental patient samples [24–27]. We also found Agreeableness to be associated with higher quality of life, but only in the pre-treatment conditions.

Fourth, Openness to experience was consistently predictive of the pre and post-treatment frequency and variety social participation indicators. These correlations are in line with conceptual expectations, given that people who are higher on Openness are presumed to explore and build broader and more varied social networks. Give its interpersonal nature, it is surprising to notice that the correlations with Extraversion failed to reach significance, perhaps due to small sample size. Agreeableness and Conscientiousness were positively associated with frequency of social participation before treatment, suggesting that these traits facilitate establishing social contacts when still having severe dental problems, but their effect disappears or diminished after reconstructive treatment.

A fifth key finding was that personality did not account for changes in the reported outcomes after dental treatment. In other words, the effect of personality on the reporting of outcomes was already captured by the pre-treatment evaluation of quality of life and social participation.

Sixth and finally, beneficial effects of treatment on quality of life and social participation indices were only observed in the complete jaw restoration group and in the self-reports only. No such effects were observed in the single unit

group. Observers did not report significant differences in any of the study groups. This impact remained unnoticed by observers during the first 4 to 8 weeks after treatment, although we cannot exclude that knowledgeable others would report such beneficial effects in the longer run. In summary, these results show that only the patients in the most severe group reported improvement, both in experienced quality of life and indices of social participation. These findings are plausible because reconstructions with full dentures imply a bigger physical change than single-unit dentures. According to the WHO ICF model (2001), quality of life is an interaction between physical functions, activity, participation, personality factors and environmental factors. The present work suggests that psycho-social improvements of dental treatments are mainly to be expected in complete jaw restoration cases.

Besides strengths and innovations, there are also a number of limitations that have to be taken into account when interpreting the results of the present work. First, although the size of the present sample is comparable or even larger than other studies [10,24–26], it is still small, so we have to be careful when generalizing from this study. Replications with larger samples have to be conducted before we can substantiate and generalize the present interpretations. A second limitation is the timing of the assessment points, both pre- but also post-treatment. In the ideal case, one should have more assessment points spread across time before treatment, so one can better evaluate whether patients catch-up to pre-existing (even before serious dental problems) levels of quality of life or social participation. In the present study, the post-treatment evaluation was scheduled 4 to 8 weeks after treatment (when patients came back in the hospital for a check-up). The fact that we did not pick up beneficial effects in the single unit group or in the reports provided by the observers may be due to the too short time-frame after the intervention. Patients (and their observers) probably need more time to get used to their implants and to observe effects on patients' psycho-social status and participation. Likewise, we cannot exclude that the personality variables would have explained part of the change in quality of life or social participation variance between pre- and post-treatment when the evaluation period would have been longer. A third constraint are the different observers, including partners, but also other types of relatives or knowledgeable others. The insignificant correlations between self- and observer reports suggest heterogeneity in familiarity with the target

subjects. It is recommended that future studies not only increase sample size and expand the number of assessment points across time, but also rely on well-informed observers, preferably the partners of patients, who have most experience with their daily functioning and activities.

In conclusion, present research confirmed the added value of the use of multi-informant evaluation of treatment outcome. There is a considerable role of certain personality traits in predicting quality of life and social participation in dental rehabilitation. Rehabilitation of oral function and esthetics in case of fully edentulous jaws with implant-retained reconstructions has a significantly larger impact on quality of life and social participation compared to the single unit group.

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CHAPTER 6

General discussion and future considerations

General discussion

This PhD focuses on the influence of implant retained overdenture treatment on speech, oromyofunctional behavior, social participation, satisfaction and impact of oral health on patient's quality of life. In a prospective manner, the outcome of various treatment protocols was examined during different stages of the treatment up to 3 years of function. In the past research on this treatment focused on implant survival, peri-implant health, prosthetic or technical aspects. By and large, functionality of the treatment, mostly from the viewpoint of the clinician, prevailed over the patient-centered outcomes, as was reported in the WHO report of 2005 [1]. The current research projects aimed to give more insight in aspects that are beyond the expertise field of the dental care professional. This point of view is of great importance to understand the why, how and when of some clinical issues that may be encountered during implant overdenture treatment. This research was part of several projects performed in collaboration between dental professionals and other health professionals e.g. speech language pathologists and psychologists. The participation of a speech therapist in a multidisciplinary team of clinicians and researchers aimed to fill in some knowledge gaps around this topic for the benefit of the patient.

Clinical outcomes

Patients included in the undertaken research presented in the clinic in search of a stable solution of their edentulous mandible or maxilla. In this thesis three specific patient groups were followed in a multidisciplinary way during their overdenture treatment (resp. mandibular overdenture retained on a bar connecting two titanium dental implants, maxillary overdentures on a titanium milled bar connecting four implants, maxillary complete horse-shoe overdentures on 5-6 mini dental implants (MDI's), figure 5). All patients were in good health and reported no neurological problems. Patients firstly received a new or adjusted conventional denture (CD) (the maxillary CD covers the palate). After surgery, this CD was adjusted to fit provisionally over de implants (the palatal coverage of the maxillary CD is removed). After a healing period the attachment system was installed in the prosthesis to connect to the implants.

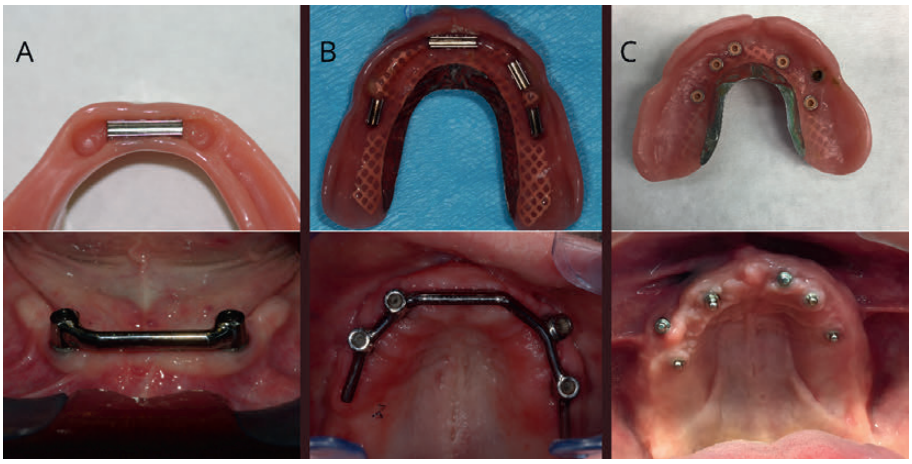

Fig 1. *A view on the implanted jaw (lower image) and the final overdenture (upper image) of subjects in study group paper 1 (A), study group paper 2 (B) and study group paper 3 (C).*

It is important when it comes to knowledge of specific dental care, being a speech-language pathologist or a psychologist, to understand the technical, prosthetical changes required in this kind of treatment. Due to multiple adjustments made to the oral environment during treatment, some (speech) difficulties are to be expected. Especially shortly after the adjustments are made. We aimed in our studies, to give a detailed overview of the trajectory of speech, oromyofunctional behavior, satisfaction and OHRQoL for the three different kinds of overdenture treatments. Without going into detail, an overview of the clinical aspects of the three study groups is provided in appendix. The following sketches the specific technicality of the implant overdenture treatment, which can possibly interfere with our outcome measurements (speech, oromyofunctional behavior,...).

Implant-retained overdentures are anchored over locator abutments or a bar, splinting the implants supracrestally. When patients present with atrophy of the jaw, the bucco-lingual width of the denture can be too small to fit the supracrestal anchoring device. The technically required minimum dimensions of the attachment system inside the overdenture, forces the dental technician to modify the shape of the overdenture. Therefore the overdenture is often wider than the existing prosthesis. The shape of the overdenture can be slightly different to the shape of the initial removable denture. This may, despite the

improved retention of the denture, affect the way the tongue is positioned in the mouth to produce the speech sounds. This possible influence can be both positive (improved retention) and negative (difficulties in tongue movement and positioning to shape the airstream into speech sounds). In light of this it is very important that the surgeon and the dentist collaborate to provide the least possible harm for the patient. Proper implant placement to ensure that the attachment system can be placed within the normal denture size is essential and may overcome many phonetic issues. In addition it adds to proper axial loading of the implant, simplifies the prosthetic procedure, reduces technical complications and facilitates peri-implant maintenance.

Influence of overdenture treatment on speech

The first objective of this thesis was to assess prospectively the influence of changes made to the oral environment during overdenture treatment on speech.

The evaluation of speech was performed using a picture naming test, evaluated by two SLPs. Rater 1 wasn't blinded. Rater 1 and rater 2 evaluated the speech samples independently. Afterwards the results were compared and differences were discussed until consensus was reached. The interrater reliability score was computed on the initial ratings of both SLPs before discussion.

Speech sounds are the result of the delicate interaction of the speech structures and the air stream. It was concluded that articulation errors occurred in all stages of the treatment in the mandible and the maxilla **(paper 1–3)** but there were no significant differences between the stages. Studies on speech in dental rehabilitation in the maxilla report distortions in /s/, /z/, /t/, /d/,/n/, /l/, /r/, /v/ and /f/ sounds[11,24,25,27,28,65]. We can confirm the occurrence of difficulties with the /s/, /z/, /t/, /d/, /n/ and /l/ sounds, supplemented with minor problems in producing the /ʃ/ and the /ʒ/. The /s/ sound in particular is sensitive to changes in the oral cavity as it is produced with the tongue tip close to the upper or lower aveolar ridge. This is a well-known articulation disorder in dental rehabilitation. After connection of the overdenture, both in the mandible and the maxilla, still a percentage of the patients suffered from speech difficulties, especially with the /s/ sound (table 1).

In the transition from a CD with palatal coverage (which comprises the oral space in vertical dimension) to an IOD (implant retained overdenture) without palatal plate (which comprises the oral space in horizontal dimension), the tongue needs to find the proper contact places and referential points to be able to mold the airstream in the same way as before. In the majority of the participants this is no problem. Still some participants suffered from problems producing the /s/ sound. These results were found in **paper 2** (n: 6/16, 37.5% suffered from /s/ problem) and **paper 3** (n: 9/25, 36%).

Because of the remaining articulation problems when converting from CD to the IOD **(paper 2&3)**, we can conclude that removing the palatal coverage along with better retention and stability of the denture, does not solve all articulation disorders.

The 3 year follow up research on maxillary overdentures **(paper 2)** revealed that even after this period, still a great portion of the patients (n: 6/16, 37.5%), suffer from a distorted /s/ sound [66]. This is also shown in previous studies on maxillary FID (fixed implant denture) and IOD treatments. The results of our measurements of satisfaction and OHRQoL show that this doesn't necessarily mean that patients complain about their speech. It is important to notice that there can be discrepancies between the internal standard of professional SLP's compared to non-professionals. The internal standard of a listener is an unstable set of phonetic benchmarks based on previously perceived samples. These standards represent typical examples for normal and deviated speech. The standard of an SLP is different than that of an average person. We didn't rate the grade of this distortion. It is possible that the distortion improved over time, but doesn't meet the standard of the SLPs [67].

In 2021 a systematic review about speech in implant supported and removable complete denture wearers, by Meira et al. (2021), was published. Their aim was to examine the influence of IOD, FIDs and CDs on speech in patients with at least one completely edentulous jaw. Out of initially 2586 articles, only 9 were selected. Only full-length reports of observational and experimental clinical studies were considered. The risk of bias of the individual studies was evaluated by two researchers, using the Joanna Briggs Institute checklists for quasi-experimental and cross-sectional studies [43]. One study of the current

PhD [22] was selected as the only study of the 9 included as having 'low risk of bias' on all items. This was the only study doing so and the other 8 included studies were highly heterogeneous because the parameters assessed, and the methodologies used, were different. They concluded that maxillary FD use may contribute to short-term distortion of the /s/ sound in patients who had previously worn CDs. The /t/ and the /d/ were the second most incorrectly produced sounds with CD and FD. Because of the low number of selected articles and the heterogeneity of the methodologies, these findings should be interpreted with caution.

Influence of overdenture treatment on oromyofunctional behavior

The third aim was to assess prospectively the influence of changes made in the oral cavity during overdenture treatment on oromyofunctional behavior. It is important to assess the position of the articulators in rest and while moving, because this may cause speech problems and problems in integrated movements e.g. mimicry and swallowing, making it less effective. There was no significant difference in occurrence of oromyofunctional problems between the stages of the treatment (**paper 1&3**). Still there were several patients presenting problems with oromyofunctional behavior (table 2).

The oromyofunctional behavior of the participants in our studies showed some striking findings. In comparison to primary studies there are more problems reported. In both rehabilitation of the maxilla and the mandible difficulties with jaw movement, tongue movement and whistling are reported in the present studies [29,31,40]. It is possible that this disagreement is due to the difference in dental rehabilitation, age of the participants and way of examination. It is important to mention that for the items 'immobility of the jaw' and 'whistling problems' the interrater reliability was low. This indicates the difficulty of evaluating oromyofunctional behavior. The use of a panel of SLPs might improve reliability of the results.

Influence of overdenture treatment on Oral Health Related Quality of Life and satisfaction

The fourth aim was to assess prospectively the influence of changes made to the oral environment during overdenture treatment on Oral Health Related Quality of Life (OHRQoL) and satisfaction.

The results of the OHIP-14 and the VAS scales revealed respectively an improvement of impact on OHRQoL and satisfaction with oral health and satisfaction with speech. Despite the considerably high percentage of patients with speech problems in the final stage of the treatment, the satisfaction with speech is high **(paper 1-3)**. It is possible that when patients rate their speech on the VAS and the OHIP-14 form, they consider both their production of the sounds and their comfort of speaking in the evaluation. It is very important to ask the patients opinion about the outcome of the treatment before giving a professional evaluation of their functioning. Besides the overall improvement of satisfaction with oral health and OHRQoL during treatment, the results of the overdenture treatment in the mandible and the maxilla show a slight deterioration after provisionalisation of the denture on both aspects in rehabilitation of the mandible and on satisfaction with oral health in rehabilitation of the maxilla **(paper 1& 3)**. One can assume that patients expect the biggest improvement after surgery, and when this improvement is not what they hoped for, patients may be disappointed. Another explanation can be that the prosthesis applies pressure on the wound after surgery. This can cause discomfort for the patient and possible concerns about the rest of the treatment. This underlines the importance of providing good pre-intervention counseling. One has to stress that the postoperative period may lead to some discomfort. In the final stage, after loading with the actively retained overdenture the satisfaction rises tremendously to a level that is comparable to the ones previously reported. An overview of the results of the final connection of the overdenture to the implants is given in table 1.

Table 1. *Overview of results the assessment of speech, oromyofunctional behavior, OHRQoL and satisfaction after final connection of the overdenture to the implants per patient group.*

	Speech Problems	Oromyofunctional Problems	OHRQoL (OHIP) and Satisfaction (VAS)
Paper 1 Mandible	/s/, /t/, /l/, /n/	Jaw movement, lip movement, whistling, tongue movement.	Mean VAS total 78% Mean total OHIP 9.16 Mean VAS Speech 82%
Paper 2 Maxilla	/s/, /z/, /l/	/	Mean VAS total 82.95% Mean total OHIP 8.00 Mean VAS Speech 82.63%
Paper 3 Maxilla MID	/s/, /z/, /t/	Jaw movement, whistling, tongue movement.	Mean VAS total 83% Mean total OHIP 8.23 Mean VAS speech 84%

The impact of personality on social participation and OHRQoL after implant treatment and the use of multi-informant observations

The last aim of this thesis was to evaluate the impact of personality on social participation and OHRQoL after implant treatment and the use of external observations for evaluation. Personality is the set of psychological traits and mechanisms within the individual that influences our interaction with and adaptation to intrapsychic, physical and social environments [51]. In short, it is a way of describing people's behavior and possibility to adapt in certain situations. Personality may also affect the experiencing and reporting of health status and satisfaction with treatment. In **paper 4** the results showed that the different personality traits were related to self-reported quality of life and social participation, but didn't influence the effect of the treatment on social participation and OHRQoL.

Across patients, converge between self- and observer ratings of quality of life and social participation measures (frequency and diversity), was very poor, suggesting unique perspectives of patients and observers on the outcomes of dental treatment. This suggests that it is useful to rely on multiple observers to evaluate (dental) treatment impact and include evaluations by knowledgeable others beyond patient self-report.

It is important to always look from the point of view of the patient. As a professional, it is our aim to make his or her life more comfortable. The latter suggestion about using multiple observers does not conflict with this aim. Especially when treating certain patients with persisting subjective complaints or questions about their dental situation, it would be interesting to include the observation of a family member or close friend to be able to neutralize the negativity, and so give the patient better insight in the situation.

Strengths and weaknesses of this thesis

This thesis highlights a way of approaching patients undergoing implant retained overdenture treatment that was neglected in the past. The extensive part about impact on speech and OHRQoL and the sidetrack, exhibiting the role of personality and the possibility to use multiple informers when evaluating

overdenture treatment outcome, is a valuable addition to the existing knowledge about this treatment. It is worth noticing that the strength of this thesis lies in the evaluation of articulation by two independent professional speech–language pathologists and the extensive protocol, including evaluation of oromyofunctional behavior, used to evaluate the patients. This method is reliable but can be improved by adding spectral analysis (of the /s/ sound). Especially because the /s/ sound is our most affected sound, comparing spectral characteristics could add more objectivity to the protocol. Also the inclusion of a matched control group and the use of two completely blinded raters, to prevent observer bias, could add to the quality of the study design. The longitudinal, prospective design of the studies in this thesis is of great value but also caused drop–out due to organizational and logistic issues. It is also possible that patients already had some articulation errors during their lifetime. This is impossible to assess because our participants came to the clinic with an existing denture, already influencing articulation and oromyofunctional behavior. In using spectral characteristics to rate speech sounds, it would be possible to detect certain changes in existing speech problems over time, comparing several stages of the treatment [31]. A limitation of the multidisciplinarity of our studies was the absence of a sound–treated room for recording the speech evaluation. Patients attended their appointments at the dental clinic, that doesn't include a sound–treated room. To be able to objectivize the real impact of the background in this room and to make proper adjustments to the room and recording settings, future researchers should estimate the signal to noise ratio of the sound samples used to evaluate speech. This by measuring the background–noise level and comparing it to the speech sound pressure level (e.g. by using PRAAT software[68]). At last, we didn't perform an audiological test to assess possible hearing difficulties. In the individual papers the number of patients that reported hearing difficulties is reported. It is important to know that the average age of our participants in the first three studies was respectively 63.3y, 63.44y and 62.6y. From the age of 65 one can expect age related hearing loss [69], which makes it hard to exclude that group during our kind of research.

Future considerations

The current research provided some answers but also opportunities to work with in the future. Firstly the use of the extensive protocol, including consensus evaluation by two professional SLPs and the addition of spectral analysis to the protocol should be standard for research and clinical use when evaluating speech and oromyofunctional behavior. On this topic, it will be important to find a way in which this evaluation can be performed in a less intensive way, without jeopardizing the reliability. For example in cleft palate literature, Ahl et al. (2018) developed an efficient, but reliable way of evaluating speech, using SLPs perceptual evaluation [70]. On the other hand the inclusion of a control group, gender and age matched, with evaluation of the same outcome measurements at similar timepoints would be an improvement of the study design. The study protocol can be enriched by adding evaluation of spontaneous speech, to be able to detect more subtle changes in the speech pattern and including a larger panel of SLP's for perceptual ratings. The SLP's could use a more detailed way of rating the speech samples by using relative percentage of occurrence of distortions or percentage of consonants correct. Besides the screening, how the remaining articulation errors and oromyofunctional problems can be solved is another research question. It might be needed to adjust the width of the denture to allow the tongue to move properly in the oral cavity to produce correct sounds. This was already suggested by Collaert et al.[34]. Further, articulation therapy could be a solution worth investigating together with the possible use of spectral properties as a biofeedback tool for patients and dentists. On the other side it is to be evaluated if this is the best option for an elderly population. Besides the care after treatment it is still a challenge to find a way to assess possible speech problems before treatment. The possibility that certain patients already had speech difficulties, not related to their dental problems, makes it hard to evaluate the course of the treatment. On the topic of OHRQoL and social participation, the possible effect of personality and the way to handle some patients needs to be more highlighted in dental education. It is a helpful way for the clinician (and the patients) to put certain problems in perspective.

Future research should focus on larger samples to generate robust statistical results. Still it is for this kind of research with a specific treatment in this population (higher age) a great challenge to organize this. Collaboration of

different institutes or enrollment of patients in the study for several consecutive years would be needed. To make this possible, it is extra important to have a broad and collaborating inter–professional network to provide the best research diagnostics and treatment for the wellbeing of the patient. Another unresolved question is how long patients need to adapt to their new oral situation and what characteristics could influence this adaptation time. This information could help in the optimalisation of the design of future research on this topic.

Clinical guidelines

People are after finalization of the overdenture treatment very satisfied with their speech and oral situation, despite persisting speech problems. Therefore it is very important to ask patients opinion about their speech and oral situation and the impact of it on their quality of life before pointing out possible problems you notice as a professional. It is important to inform patients before treatment about the possible difficulties they may encounter during treatment, especially in professional speakers (e.g. professors, ministers, news readers...). To avoid speech problems it is necessary to check if the retention of de denture is sufficient and if the coverage of the palate (in maxillary rehabilitation) isn't obstructing good speech production. The shape of the denture should get as close as possible to the shape of a normal oral cave. To manage that, it is very important that the surgeon and the dentist collaborate to provide the least possible harm for the patient. Proper implant placement to ensure that the attachment system can be placed within the normal denture size is essential and may overcome many phonetic issues.

When you are, as a dentist, convinced of the functionality and size of the denture and the patient still complaints about speech problems, don't get tempted to correct the denture too often. It is important that the patients get used to speaking with their denture. Especially elderly patients, who often have reduced numbers of social contact, and lack speaking a lot, need to be encouraged to 'practice' first for some weeks before demanding correction of the denture. The use of an integrated, multidisciplinary view on a patients' health and health consequences or disability (e.g. by using the ICF model) is helpful and nowadays required to provide the best standard of care in dental practice and beyond.

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CHAPTER 7

Summary and social relevance

Summary

From the age of 17, most people have 28 teeth (wisdom teeth excluded) and ideally keep them lifelong. Most people, due to life events lose some teeth during life. Especially when it comes to food intake and aesthetics, the need for rehabilitation, in case of edentulism, is very high. According to the WHO, edentulism can be considered as a chronic disability, influencing mastication, phonetics and aesthetics. In many cases, rehabilitation with complete removable dentures is the first choice, predominantly dependent on the financial condition of the patient. Long time removable denture wearing increases resorption of the crestal bone of the jaw. As a result, a denture might no longer fit properly, losing its retention. To solve this retention problem dental implant treatment can be useful. The IOD treatment is getting more attention the past years. This makes it important to evaluate the current practice in dental implant rehabilitation

Speech is the result of a complex interaction between the respiratory system (lungs), phonatory system (vocal folds), resonatory system (pharynx, nasal and oral cavity) and the articulatory system (the jaw, tongue, lips, soft palate, teeth, hard palate and the alveolar ridge). When changes are made to the oral structures, as is the case in rehabilitation with full dentures, it is possible that this complex interaction is disturbed and articulation in speech production is affected. The most frequently heard speech complaint in dental rehabilitation is the occurrence of /s/ sound disorders. To evaluate the /s/ sound during speech production, perceptual evaluation by a speech language pathologist (SLP) is commonly used. Since this is a subjective way of evaluation it is advised to perform a consensus evaluation. In search for a more objective way of speech evaluation, it is therefore interesting to explore the potential of using spectral analysis to classify distortions of the /s/ sound. When adjustments are made to the orofacial and dental structures, the possible impact on different functions and quality of life can't be underestimated. On the other hand, people have higher demands and expectations regarding aesthetics, comfort and function. Besides the environmental factors and the health condition of the patient, also personal factors play a role in the way patients deal with their situation. Contemporary research on the impact of dental implants on quality of life and social participation paid only marginal attention to the role of personality in the experiencing of quality of life and social relationships and adaptation after surgery.

The main aim of this PhD project was to describe prospectively the influence of changes made to the oral environment during mandibulary and maxillary overdenture treatment on:

1. Speech **(Papers 1– 3)**
2. Oromyofunctional behavior **(Papers 1& 3)**
3. OHRQoL and Satisfaction **(Papers 1–4)**

Besides this we evaluated the impact of personality on social participation after implant treatment and the use of multi–observer ratings. **(Paper 4)**

Paper 1 determined alterations of articulation, oromyofunctional behavior and Oral Health Related Quality of Life (OHRQoL) in patients replacing complete removable dentures by implant retained overdentures in the mandible. Twenty–one fully edentulous patients received mandibular overdenture retained on a bar connecting 2 titanium dental implants. Patients were evaluated after receiving a new set of fully removable dentures (stage 1), after surgery during provisionalisation on healing abutments (stage 2) and after final connection to the bar (stage 3). Assessments were taken by speech therapists and included evaluation of: articulation (picture naming and reading); oromyofunctional behavior; OHRQoL (OHIP–14 questionnaire) and overall satisfaction and speech (VAS). To measure changes over time, Wilcoxon matched–pairs signed–rank–test and McNemar test was used. There was no significant impact of the treatment on speech nor on the results of oromyofunction. In stage 1 patients had different kinds of articulation errors (mean: 1.21) which evolved to 0.71 and 0.67. In stage 3 especially problems with the /s/ sound are seen in 37% (7/19) of the participants. Results of OHRQoL and satisfaction reveal that the average of satisfaction with oral health evolved from 67%, to 63% and finally 78%. OHIP–14 total score was 17.2/56 in stage 1, 17.67 in stage 2 and evolved in stage 3 to 9.16/56 (p:0.010). This indicates improvement. Satisfaction with speech evolved significantly from 72% pretreatment to 82% in stage 3 (p:0.013).

Conclusion: Despite existing articulation and oromyofunctional disorders after treatment, people are very satisfied with their OHRQoL and their speech. Impact of mandibular denture wearing on OHRQoL declines once connected. It's important to inform patients that speech and oromyofunctional disorders may occur during treatment where especially the /s/ sound is vulnerable.

Paper 2 investigated the changes in speech, satisfaction with speech and overall oral health and the Oral Health Related Quality of Life (OHRQoL) in edentulous patients during and after treatment with maxillary IODs. Twenty-one patients receiving an IOD participated in speech assessment. They were examined pre-operatively with their conventional denture (CD) with full palatal coverage, after connection of the implant-bar connected denture, without palatal coverage, and 3 years thereafter. The examination included assessment of articulation in speech, OHRQoL based on total OHIP-14, and satisfaction with overall oral health and speech (VAS). There was a reduction in mean number of articulation disorders from 1.00 at baseline to 0.55 at connection, although statistically insignificant ($p = 0.059$). Especially the /s/ sound is vulnerable. At 3 years follow-up, still 6/16 (37.5%) of the patients suffered from this speech problem. Overall satisfaction improved from 64.05/100 at baseline to 82.95/100 at connection ($p:0.008$) and remained unchanged with 81.69/100 after 3 years follow-up. Patients' satisfaction with speech increased from 70.62/100 with CD to 82.63/100, 3 years follow-up ($p:0.009$). Total OHIP-14 decreased from 21.45/56 with CD to 8.00/56 ($p<0.001$) with IOD and 6.13/56 three years after connection ($p:0.001$). Significant improvement of all 7 domains in OHRQoL was observed with IOD compared to CD.

Conclusion: Patients treated with maxillary IODs show improved OHRQoL 3 years after connection of the IOD compared to the CD. Even though patients reported improvement of satisfaction and OHRQoL, articulation disorders were still present, suggesting that patients should be informed about possible speech issues.

Paper 3 determined speech, oromyofunctional behavior, satisfaction with the treatment and the impact on quality of life of the horse-shoe overdenture retained by mini-implants (MDI) in the maxilla. This prospective multicenter cohort study included 32 patients for treatment. 5 to 6 implants were placed, atraumatically piercing the mucosa. Patients were evaluated three times during treatment (preoperatively with conventional prosthesis including full palatal coverage (CD), postoperatively with provisionally relined CD and with horse-shoe overdenture on MDI). The assessment included a phonetic evaluation, examination of oromyofunctional behavior, evaluation of the impact on quality of life (OHIP-14) and a rating of satisfaction with the treatment and speech on

a visual analog scale. Several speech sounds are found to be disturbed before treatment. In the next two stages of the treatment the number of speech issues decreases. In the final stage ten people show minor speech problems, especially with the /s/ sound. In this stage seven people still present with oromyofunctional problems, especially whistling problems. In this last stage people are very satisfied with the treatment (83%) and with speech (84%). The impact on quality of life is low (8.23/56).

Conclusion: Speech and oromyofunctional problems occur during all stages of the treatment. Especially the /s/ sound and the whistling function seem very fragile and occur in all stages. People are very satisfied with their oral and speech situation in this last stage, despite the fact that speech therapists detect some difficulties with the pronunciation of in particular the /s/ sound.

Paper 4 aimed to investigate the impact of implant–supported rehabilitation on quality of life and social participation taking into account patient's personality. Fifty–four patients were included in this study and assigned to either a single unit group (n=15) or a complete jaw restoration group (n=39). Of the 54 participants, 49 nominated an external observer who can evaluate the daily behavior of the patient. Before and after treatment patients and their external observer completed the OHIP–14, the NEO–FFI and the MSPP questionnaires respectively focusing on Oral Health related Quality of Life, Personality and Social participation. The correlations between self– and observer ratings on pre and post treatment outcomes on were insignificant (QoL pre: p=0.086, post: p=0.115, freq. soc. part pre: p=0.944, post: p=0.876, div. soc. part pre: p=0.798, post: p=0.167), suggesting considerable differences in observer perspectives. The traits Neuroticism, Extraversion and Agreeableness were associated with QoL. Openness, Conscientiousness and Agreeableness were associated with social participation. Patients in the complete jaw restoration group reported more impact of the implant treatment on quality of life as compared to the single unit group (p=0.007). The complete jaw restoration group reported an improved quality of life after treatment and significant increases of both frequency (p=0.001) and diversity of social participation (p=0.036).

Conclusion: There was a minor impact of treatment with single crowns on quality of life and social participation compared to the full denture group. The role of personality and the use of multi-informants in evaluating dental treatment was found important.

Based on the proposed aims, the following general conclusions and future considerations can be formulated:

1. Articulation errors occur in all stages of the treatment in the maxilla and the mandibula but there were no significant differences between the stages. We can confirm the occurrence of difficulties with the /s/, /z/, /t/, /d/, /n/ and /l/ sounds, supplemented with minor problems in producing the /ʃ/ and the /ʒ/. The /s/ sound in particular is sensitive to changes in the oral cavity as it is produced with the tongue tip close to the upper or lower alveolar ridge. Even after 3 years adaptation, still a great portion of the patients suffered from a distorted /s/ sound. Future research should focus on how to deal with patients with remaining speech problems. Possibly the shape of de denture can be adjusted to provide better tongue mobility or the focus needs to be on speech therapy.

2. The studies revealed, in contrast with existing literature, the occurrence of oromyofunctional problems in all stages of the treatments. There were no significant differences between the stages.

3. Our results showed an improvement of satisfaction with oral health and speech and a lower impact on quality of life after treatment was completed. In contrast with the high rate on speech satisfaction the occurrence of speech problems is high. Given this, it is particularly important for professionals to ask patients opinion about the outcome of the treatment before giving an evaluation of their functioning. During treatment the ratings vary. It is important to give patients a good view on how the treatment will evolve, to make sure the expectations of the treatment are realistic.

4. The results of our study showed that the different personality traits were related to self-reported quality of life and social participation, but didn't influence the effect of the treatment on social participation and OHRQoL. Our findings suggest that it is useful to rely on multiple observers to evaluate dental treatment. It would be very useful in the future for dentists to have more insight in different kinds of patients and how to manage their concerns. It is still our goal as a professional to provide the best situation for the patients quality of life.

Social relevance

Overdenture treatment turns out to be a valuable solution for patients in need of a stable solution for their removable denture in edentulous jaw (either mandible or maxilla). The satisfaction after final connection and follow-up is very high. Even in elderly people with heavily resorbed jaws there is now the possibility to be treated with mini dental implants. Dental rehabilitation is nowadays more than only taking care of teeth. It is about the whole person and his/her comfort. Patients seem to expect a lot of science and they expect clinicians to be informed about every aspect of the treatment. This requires a more translational/multidisciplinary approach.

This thesis gives more insight in how speech problems and oromyofunctional problems may occur in overdenture treatment. This longitudinal insight is rarely reported and adds to the existing literature. Also the use of two independent SLP's in evaluating speech and oromyofunctional behavior is of great value.
The influence of personality on patient related outcome measurements and the use of multi-perspective observations is an important way of looking at patients. It is important for dentists to be informed about how to handle certain patients.

CHAPTER 8

Samenvatting

Samenvatting

Vanaf de volwassenheid hebben meeste mensen 28 tanden (verstandskiezen niet meegerekend) en in het beste geval houden ze die hun hele leven. De meeste mensen verliezen echter, door omstandigheden, een aantal tanden in hun levensloop. Bij tandeloosheid is de nood aan reconstructie vrij hoog, vooral wanneer voedselinname en esthetiek in het gedrang komt. Volgens de WHO kan tandeloosheid gezien worden als een chronische aandoening die de kauw functie, fonetiek en esthetiek beïnvloedt. In veel gevallen is een behandeling met conventionele uitneembare prothesen de eerste keuze, vooral gebaseerd op de financiële status van de patiënt. Langdurig dragen van uitneembare prothese werkt resorptie van het kaakbeen in de hand. Hieruit resulteert dat de prothese mogelijks niet meer goed past en de retentie verliest. Op dit retentieprobleem op te lossen kan een implantaat behandeling nodig zijn. De overkappingsbehandeling krijgt de laatste jaren meer aandacht. Hierdoor is het belangrijk om de huidige praktijk rond deze behandeling in kaart te brengen.

Spraak is het resultaat van een complexe interactie tussen het ademhalingssysteem (longen), het fonetisch systeem, het resonantie systeem (pharynx, neus en mondholte) en het articulatiesysteem (de kaak, tong, lippen, zacht verhemelte, tanden, hard verhemelte en de alveolairen). Wanneer er veranderingen gebeuren aan deze orale structuren, zoals het geval is bij behandeling met volledige prothesen, is het mogelijk dat deze complexe interactie wordt verstoord en de articulatie aangetast. Wanneer het over articulatie gaat, is de meest gehoorde klacht tijdens een tandbehandeling, problemen met de /s/ klank. Om deze /s/ klank te evalueren tijdens spraakproductie is een perceptuele evaluatie door een logopedist is de meest gebruikte manier. Aangezien dit een subjectieve manier is van evalueren, is het nodig om een consensus evaluatie met een tweede beoordelaar te voorzien. Naast deze manier van evalueren is het interessant om de mogelijkheden tot spectrale analyse te gaan onderzoeken. Wanneer er aanpassingen gebeuren in de mondholte en de tandstructuren, is er een grote kans dat er een impact is op verschillende orale functies en levenskwaliteit van de patiënt. Aan de andere kant hebben patiënten hogere verwachtingen en eisen wanneer het gaat over esthetiek, comfort en functie. Naast de omgevingsfactoren en de gezondheidstoestand van de patiënt, spelen persoonlijkheidsfactoren ook een rol in de manier waarop mensen hun gezondheid beoordelen. Recent onderzoek

over de impact van een implantaatbehandeling op de levenskwaliteit en sociale participatie van een patiënt besteedde slechts weinig aandacht aan mogelijke invloed van persoonlijkheid in de ervaring van levenskwaliteit en sociale relaties en adaptatie na chirurgie.

De hoofddoelstelling van dit doctoraatsschrift is om op een prospectieve manier de invloed van veranderingen in de mondholte tijdens mandibulaire en maxillaire behandeling met overkappingsprothesen in kaart te brengen. Het gaat over de invloed op:

1. Spraak **(Papers 1–3)**
2. Oromyofunctioneel gedrag **(Papers 1&3)**
3. Impact op levenskwaliteit en tevredenheid **(Papers 1–4)**

Hiernaast evalueerden we de impact van persoonlijkheid op sociale participatie na een implantaatbehandeling met behulp van een multi–observator beoordeling. **(Paper 4)**

Paper 1 onderzocht veranderingen in articulatie, oromyofunctioneel gedrag en de impact van orale gezondheid op levenskwaliteit bij patiënten die hun conventionele prothese vervangen door een implant gedragen overkappingsprothese in de mandibula. Eenentwintig volledig edentate patiënten kregen een mandibulaire overkappingsprothese op twee implantaten, verankerd met een bar. De patiënten werden geëvalueerd nadat ze een nieuwe volledige prothese kregen (fase 1), na chirurgie waarbij een voorlopige prothese over de 'healing abutments' werd geplaatst (fase 2) en na finale connectie van de overkappingsprothese op de bar (fase 3). Het onderzoek werd gevoerd door een logopedist en bestond een evaluatie van: articulatie (prenten benoemen en lezen); oromyofunctioneel gedrag; invloed van orale gezondheid op de levenskwaliteit (OHIP–14 vragenlijst) en algemene tevredenheid en tevredenheid met spraak (VAS). Om veranderingen tussen de verschillende fasen te detecteren werd een Wilcoxon matched–pairs signed–rank–test en een McNemar test gebruikt. Er werd geen significante impact van de behandeling op spraak en oromyofuncioneel gedrag gevonden. Tijdens de eerste fase vertoonden patiënten verschillende soorten articulatieproblemen (gemiddeld aantal fouten: 1.21) die evolueerden naar 0.71 en 0.67 in de volgende fasen. In fase 3 waren er vooral problemen met de /s/ klank in 37% (7/19) van de patiënten. De OHIP–14 totaalscore was 17.2/56 in de eerste fase, 17.67 in fase

2 en evolueerde naar 9.16/56 (p:0.010) in de derde fase. Dit betekent dat er verbetering optreedt. Tevredenheid met spraak verbeterde significant van 72% in fase 1 naar 82% in de derde fase (p:0.013).

Conclusie: Ondanks overgebleven articulatie en oromyofunctionele problemen na behandeling, zijn patiënten heel tevreden met hun orale gezondheid (en diens impact op de levenskwaliteit) en hun spraak. Het is belangrijk om patiënten goed te informeren dat spraak- en oromyofunctionele problemen kunnen voorkomen tijdens de behandeling en dat vooral de /s/ klank extra kwetsbaar is.

Paper 2 onderzocht de veranderingen in spraak, tevredenheid met orale gezondheid en spraak en de impact van orale gezondheid op de levenskwaliteit bij edentate patiënten tijdens en na hun behandeling met overkappingsprothese op implantaten in de maxilla. Eenentwintig patiënten namen deel aan de spraakstudie. Zij werden voor chirurgie onderzocht met hun conventionele prothese (met palatumbedekking), na connectie van de overkappingsprothese (zonder palatumbedekking) op de 4 implantaten (verbonden met een bar) en 3 jaar follow-up. Het onderzoek bestond uit een evaluatie van de spraak, impact van orale gezondheid op levenskwaliteit (OHIP-14) en evaluatie van de algemene tevredenheid en tevredenheid met spraak (VAS). Er was een vermindering in het gemiddeld aantal spraakproblemen van 1.00 bij de start naar 0.55 bij connectie (niet statistisch significant, p:0.059). Vooral de /s/ klank is kwetsbaar. Tijdens de 3 jaar opvolging, vertoonden nog steeds 37.5% (6/16) van de patiënten problemen met deze klank. De algemene tevredenheid steeg van 64.05/100 bij de start naar 82.95/100 bij connectie (p:0.008) en bleef onveranderd op 81.69/100 bij de 3 jaar opvolging. De tevredenheid met spraak verbeterde van 70.62/100 bij de start naar 82.63/100, bij de 3 jaar opvolging (p:0.009). De totale score op de OHIP-14 daalde (=verbeterde) van 21.45/56 bij de start met een conventionele prothese naar 8.00/56 (p<0.001) na connectie van de overkappingsprothese en 6.13/56 bij de drie jaar opvolging (p:0.001). Er was een significante verbetering van de zeven domeinen van de OHIP-14 wanneer de overkappingsprothese geconnecteerd was in vergelijking met de situatie met de conventionele prothese.

Conclusie: De impact van de orale gezondheid op de levenskwaliteit verbeterde na drie jaar opvolging in vergelijking met de startsituatie bij patiënten behandeld met overkappingsprothesen in de maxilla. Ondanks dat patiënten een verbetering in levenskwaliteit en tevredenheid rapporteren, werden nog steeds articulatieproblemen gedetecteerd. Patiënten moeten goed geïnformeerd worden over mogelijke spraakproblemen tijdens en na de behandeling.

Paper 3 onderzocht spraak, oromyofunctioneel gedrag, tevredenheid en de impact van de behandeling met overkappingsprothese op mini-implantaten in de maxilla, op levenskwaliteit. Er werden 32 patiënten geïncludeerd in deze studie. 5 à 6 implantaten werden a-traumatisch geplaatst. De patiënten werden drie keer tijdens de behandeling geëvalueerd (voor chirurgie met een conventionele prothese, na chirurgie met een voorlopige prothese en na connectie van de overkappingsprothese op de implantaten). Het onderzoek bestond uit een evaluatie van de spraak, oromyofunctioneel gedrag, evaluatie van de impact van de behandeling op levenskwaliteit (OHIP-14) en een meting van algemene tevredenheid en tevredenheid met de spraak (VAS). Er werden verschillende problemen met spraakklanken gevonden voor chirurgie. In de twee volgende fasen van de behandeling daalde het gemiddeld aantal aangetaste spraakklanken. In de laatste fase toonden nog tien patiënten minimale spraakproblemen, vooral problemen met de /s/ klank. In deze fase vertoonden zeven patiënten nog problemen met oromyofuncioneel gedrag, vooral het 'fluiten' was verstoord. Patiënten waren in deze fase heel tevreden met de behandeling (83%) en met hun uitkomst op spraak (84%). De impact op levenskwaliteit in deze fase was laag (8.23/56).

Conclusie: Spraak en oromyofuncionele problemen komen voor tijdens alle fasen van de behandeling. Vooral problemen met de /s/ klank en 'fluiten' blijken erg kwetsbaar en komen voor in alle fasen. Patiënten zijn erg tevreden met hun orale gezondheid en hun spraak tijdens de laatste fase, ondanks het feit dat de logopedisten nog steeds moeilijkheden detecteren.

Paper 4 had als doelstelling de impact van implantaatbehandeling op levenskwaliteit en sociale participatie in kaart te brengen, rekening houdend met de persoonlijkheid van de patiënten. Vierenvijftig patiënten werden

geïncludeerd in deze studie en toegewezen aan ofwel de 'single-unit' groep (n=15) of de 'complete jaw restoration' groep (n=39). Van de 54 participanten, nomineerden er 49 een externe observator die hun dagelijks handelen konden evalueren. Voor en na de behandeling vulden de patiënten en hun externe observator de vragenlijsten OHIP-14, NEO-FFI en MSPP in. Deze meten respectievelijk de impact van orale gezondheid op levenskwaliteit, persoonlijkheid en sociale participatie. De correlaties tussen zelf- en externe observatorevaluatie op de metingen voor en na de behandeling waren niet significant (QoL pre: p=0.086, post: p=0.115, freq. soc. part pre: p=0.944, post: p=0.876, div. soc. part pre: p=0.798, post: p=0.167). Dit suggereert dat er belangrijke verschillen zijn in de twee observatieperspectieven. De trekken Neuroticisme, Extraversie en Altruïsme waren geassocieerd met levenskwaliteit. Openheid, Consciëntieusheid en Altruïsme waren geassocieerd met sociale participatie. De patiënten in de 'complete jaw restoration' groep rapporteerde meer impact van de behandeling op hun levenskwaliteit, vergeleken met de 'single-unit' groep (p:0.007). De 'complete jaw restoration' groep rapporteerde in verbetering in levenskwaliteit na behandeling en significante verhoging in zowel frequentie (p:0.001) en diversiteit van sociale participatie (p:0.036).

Conclusie: Er was een minimale impact van de behandeling met kronen (single-unit groep) op levenskwaliteit en sociale participatie vergeleken met de groep met volledige prothese. De rol van persoonlijkheid en het gebruik van meerdere informanten bij het evalueren van een tandbehandeling bleek belangrijk.

Op basis van de voorgestelde doelstellingen werden onderstaande algemene conclusies en aanbevelingen voor de toekomst geformuleerd:

1. Articulatieproblemen komen voor in alle fasen van de behandeling in de maxilla en de mandibula, maar er waren geen significante verschillen tussen de fasen. We kunnen bevestigen dat er problemen met de /s/, /z/, /t/, /d/, /n/ en /l/ klanken voorkomen, aangevuld met minimale problemen tijdens de productie van de /ʃ/ en de /ʒ/ klank. De /s/ klank is in het bijzonder gevoelig voor veranderingen in de mondholte, aangezien deze geproduceerd wordt met de tongpunt dicht bij de bovenste of onderste alveolen. Na 3 jaar adaptatie vertonen nog te veel patiënten problemen met deze /s/

klank. Toekomstig onderzoek zou moeten focussen op een manier om om te gaan met deze overblijvende spraakproblemen. Mogelijke pistes zijn het aanpassen van de prothesevorm om tongmobiliteit te verbeteren of het aanbieden van articulatietherapie.

2. Onze studies vonden, in contrast met de bestaande literatuur, dat oromyofunctionele problemen voorkwamen in alle fasen van de behandeling. Er waren geen significante verschillen tussen de fasen.

3. Onze resultaten toonden een verbetering in de tevredenheid met orale gezondheid en spraak en een lagere impact van de behandeling op levenskwaliteit na afronding van de behandeling. Ondanks de hoge score op tevredenheid met spraak, werden er articulatieproblemen gevonden na de behandeling. Hierdoor is het extra belangrijk om de mening van de patiënt over hun situatie te vragen alvorens zelf een oordeel te geven. Tijdens de behandeling variëren de resultaten. Het is belangrijk om patiënten een goed beeld te geven over hoe de behandeling kan verlopen zodat de verwachtingen van de patiënt realistisch is.

4. De resultaten van het persoonlijkheidsonderzoek toonden dat de verschillende persoonlijkheidstrekken gelinkt waren aan de zelfrapportering van levenskwaliteit en sociale participatie, maar het effect van de behandeling hierop niet beïnvloedden. Onze bevindingen suggereren dat het interessant kan zijn om informatie van meerdere observatoren te verzamelen in de evaluatie van een tandbehandeling. Het kan vooral nuttig zijn om in de toekomst meer inzicht te verwerven in verschillende soorten patiënten en hoe het best omgaan met hun bezorgdheden. Het is steeds ons doel als professional de beste situatie voor de levenskwaliteit van de patiënten te creëren.

Sociale relevantie

Een behandeling met overkappingsprothese op implantaten blijkt een waardevolle oplossing voor patiënten die op zoek zijn naar een stabiele oplossing voor hun conventionele prothese in de volledig edentate kaak (zowel in de mandibula als de maxilla). De tevredenheid na finale connectie en follow-up is zeer hoog. Zelfs in een oudere populatie met sterk geresorbeerde kaken is er nu de mogelijkheid tot behandeling met mini-implantaten. Tandheelkundige revalidatie is momenteel meer dan enkel de zorg voor de tanden. Het gaat over de volledige patiënt en zijn/haar comfort. Patiënten lijken veel te verwachten van de wetenschap en verwachten dat de clinicus geïnformeerd is over elk aspect van de behandeling. Dit vergt een meer translationele en multidisciplinaire benadering.

Deze thesis geeft meer inzicht in hoe spraakproblemen en oromyofunctionele problemen kunnen voorkomen tijdens behandeling met overkappingsprothesen op implantaten. Deze longitudinale inzichten zijn slechts zelden gerapporteerd en zijn een aanvulling op de bestaande literatuur. Ook het gebruik van twee onafhankelijke logopedisten tijdens de evaluatie van spraak en oromyofunctionele stoornissen is een grote meerwaarde.

De invloed van persoonlijkheid op patiënt gerelateerde uitkomsten en het gebruik van multi-perspectief observaties is een belangrijke manier om patiënten te benaderen.

APPENDIX

Overview of clinical outcomes of the three study groups.

We aimed in this PhD thesis, to give a detailed overview of the trajectory of speech, oromyofunctional behavior, satisfaction and OHRQoL for three different kinds of overdenture treatments:

> *Study group paper 1:* Twenty-one fully edentulous patients received mandibular overdenture retained on a bar connecting 2 titanium dental implants. *Dr. Carine Matthys* (EC/2014/1231)
>
> *Study group paper 2:* Twenty-one patients receiving an overdenture on a titanium milled bar connecting the four implants in the edentulous maxilla. *Dr. Maarten Glibert & Ron Doornewaard* (EC/2015/0338)
>
> *Study group paper 3:* Thirty fully endentulous patients received treatment of the edentulous maxilla with complete horse-shoe overdentures on 5-6 MDI's. *Dr. Luc Van Doorne* (EC/2014/1253)

Overall the periodontal and prosthodontic outcome revealed good implant survival, good bone stability over time and limited number of complications in all research groups [62,63]. The third group, described clinically by Van Doorne et al. in several papers [71,72] included fragile patients with compromised bone condition. This project is presenting an innovative approach in a very difficult patient group, hence explaining why during initial healing more failures were encountered. As a consequence 2 out of 31 patients were losing the functional support of the denture and were considered as dropouts during follow-up. Table 1 gives an overview of the most important results regarding the periodontal and prosthodontic outcome.

Table 1. *Implant survival and prosthetic design of the three study groups *lost implants were replaced after healing to stabilize the prosthesis.*

	Prosthetic type	Prostheses placed	Prostheses in function	Implants placed	Implant survival
Glibert et al. 2018 [62]	Bar retained overdenture on two implants in the mandible	21	21	42	100%
Doornewaard et al. 2021[63]	Implant-supported overdenture on four implants in the maxilla	25	25	98	95.9%*
Van Doorne et al. 2020 [71]	Horse-shoe overdenture on six mini-implants in the maxilla	31	29	185	82.7%*

Research Data Management

The protocol of the studies in this PhD thesis were designed according to the principles of the Helsinki Declaration on clinical research (1975, revised in 2002). All patients signed a written consent statement before being included in the study. Before this consent they received detailed oral and written information about the study protocol, treatment plan, financial costs, follow-up period, and potential risks and complications. The study was approved by the Ethical Committee of the Ghent University Hospital on clinical research involving human beings. The approval numbers are provided in every chapter. This project is stored on the Radboudumc, department server: (H:) THKdata$(\\Umcfs012) under ALG Management, Document Ester Fonteyne onderzoek. The data were coded and the code was stored separately from the documents. This project is stored on the Radboudumc department server: (H:)THKdata$\\UMCFS012\OZ leerstoel I&P\Document Ester Fonteyne onderzoek

The data will be saved for 15 years after termination of the study.

Curriculum Vitae

Personal information

Names: Ester Marijke Robin Fonteyne
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Education

- PhD in Health Sciences
  - Radboud UMC, 2019–2022
  - Ghent University, 2019–2022
- Master of Science in Clinical Psychology
  - Ghent University, 2015–2017
- Bachelor of Science in Clinical Psychology
  - Ghent University, 2014–2015
- Master of Science in Speech Language Therapy
  - Ghent University, 2013–2014
- Bachelor of Science in Audiology and Speech Language Therapy
  - Ghent University, 2010–2013

Teaching Contributions

- Tutor of Master of Dentistry Thesis
  - Ghent University 2019–2021
- Guest Class Oromyofunctional behavior – 3th Bachelor in Audiology and Speech Language Therapy – Prof. dr. K. Van Lierde
  - Ghent University 2021
- Guest Class Complete Prosthesis – 3th Bachelor in Dentistry – Dr. C. Matthys
  - Ghent University 2015

Professional experience

- Research Assistant – Department of Oral Health Sciences, Oral implantology and Periodontology
  - Ghent University Hospital, 2020–Current
  - Ghent University, 2014–2020

- Project manager and ortho-agogic coach, Oranje VZW, 2018-Current
- Oye Lena ONG, voluntary teacher and Speech Language Pathologist for disabled children in Peru, Curahuasi, 2018

Publications

Fonteyne, E, Matthys, C, Bruneel, L, Becue, L, De Bruyn, H, Van Lierde, K. Articulation, oral function, and quality of life in patients treated with implant overdentures in the mandible: A prospective study. Clin Implant Dent Relat Res. 2021; 1– 12. https://doi.org/10.1111/cid.12989

Original paper
Impact factor: 3.932
A1, Quartile 1

Fonteyne, E, Burms, E, Matthys, C, Van Lierde, K, De Bruyn, H. Four–implant supported overdenture treatment in the maxilla. Part II: Speech and oral health related quality of life in patients with implant–supported overdentures in the maxilla: a prospective 3–years follow–up. Clin Implant Dent Relat Res. 2021. doi.org/10.1111/cid.13034

Original paper, gedeeld auteurschap
Impact factor: 3.932
A1, Quartile 1

Fonteyne, E, Van Doorne, L, Becue, L, Matthys, C, Bronckhorst, E, De Bruyn, H. Speech evaluation during maxillary mini–dental implant overdenture treatment: A prospective study. J Oral Rehabil. 2019; 46: 1151– 1160. https://doi.org/10.1111/joor.12852

Original paper, gedeeld auteurschap
Impact factor: 3.837
A1, Quartile 1

Ester Fonteyne, Hugo De Bruyn, Filip De Fruyt, Quality of life and social participation in dental rehabilitation: A personality and multi–informant perspective, Journal of Dentistry: X, Volume 4, 2020, https://doi.org/10.1016/j.jjodo.2020.100021.

Original paper
Impact factor: 4.379
A2, Quartile 1

Van Doorne, L., Fonteyne, E., Matthys, C., Bronkhorst, E., Meijer, G., & De Bruyn, H. (2021). Longitudinal Oral Health–Related Quality of Life in maxillary mini dental implant overdentures after 3 years in function. Clinical Oral Implants Research, 32(1), 23–36. DOI: 10.1111/clr.13677

Original paper
Impact factor: 3.932
A1, rank 18/92

Van Lierde, K. M., Luyten, A., D'haeseleer, E., Van Maele, G. E. O. R. G. E. S., Becue, L., Fonteyne, E., .. & De Pauw, G. (2015). Articulation and oromyofunctional behavior in children seeking orthodontic treatment. Oral diseases, 21(4), 483–492. doi.org/10.1111/odi.12307

Original paper
Impact factor: 3.511
A1, rank 23/92

Portfolio

PhD portfolio of Ester Fonteyne

Institute for Health Sciences
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Department:	**Department of Dentistry**
Graduate School:	**Radboud Institute for Health Sciences**
PhD period:	**01-11-2017 – 14-04-2022**
Promotor(s):	**Prof. dr. H. De Bruyn & Prof. dr. K. Van Lierde**
Copromotor(s):	**Dr. L. Bruneel**

Training activities	**Hours**
Courses	
– RIHS – Introduction Course for PhD Candidates (2021)	15,00
– Radboudumc – introduction day (2021)	6,00
– Radboudumc – Scientific integrity (2021)	20,00
– Ghent University – Toegepaste Data-analyse	150,00
– Ghent University – Sociale vaardigheden	100,00
– Ghent University – Onderzoeksmethoden I	150,00
– Ghent University – Persoonlijkheidspsychologie	100,00
– Ghent University – Statistiek II	150,00
Conferences	
– Research Integrity Symposium (2020)	2,00
Teaching activities	
Lecturing	
– Ghent University – Gastcollege Oromyofunctioneel gedrag (3e Bach Logopedie) (2021)	2,00
– Ghent University – Gastcollege Spraak (3e Bach Tandheelkunde) (2015)	
Supervision of internships / other	
– Ghent University – supervision Masterstudents research (2019-2021)	
Total	**699,00**

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