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-year follow-up

Ester Fonteyne Master of Science [1], Eline Burms Master of Science [2], Carine Matthys PhD[3], Kristiane Van Lierde PhD, Professor [4,5], Hugo De Bruyn PhD, Professor [2,6]

[1] Periodontology and Oral Implantology, Department of Oral Health Sciences, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

[2] Department of Oral Health Sciences, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

[3] Clinic for Removable Prosthodontics, Department of Oral Health Sciences, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

[4] Department of Speech, Language and Hearing Sciences, Faculty of Medicine and Health Sciences, Ghent University, Ghent, Belgium

[5] Department of Communication, University of Pretoria, Pretoria, South Africa

[6] Department of Dentistry, Radboud University Medical Center, Nijmegen, the Netherlands

*Correspondence to: Ester Fonteyne, Periodontology and Oral Implantology, Department of Oral Health Sciences, Faculty of Medicine and Health Sciences, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium. Email: ester.fonteyne@ugent.be

Abstract

Background: Implant-supported overdentures (IOD) are becoming a more commonly 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-related quality of life (OHRQoL) in edentulous patients during and after treatment with maxillary IODs.

Materials and methods: Twenty-one patients receiving an IOD participated in speech assessment. They were examined preoperatively 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 3 years after connection (p = 0.001). Significant improvement of all seven 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.

What is known

- Previous studies on fixed dentures, overdentures, and conventional dentures in the edentulous maxilla reveal a negative impact on articulation in speech and OHRQoL compared to normal dentition.
- The prevalence of articulation disorders in denture treatment in the maxilla ranges from 30% to 87%.
- All studies stress the vulnerability of the /s/ sound.

What this study adds

- This is the first study describing and evaluating the impact on speech and the impact on oral health-related quality of life in detail, from pretreatment until 3 years follow-up using overdenture treatment.
- We can confirm the vulnerability of the /s/ sound and the significant improvement of oral health-related quality of life after connection of the overdenture to the implants.

1 INTRODUCTION

The elderly population is growing worldwide and edentulism increased with 27% between 2006 and 2016.[1, 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 colleagues 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 and colleagues concluded that there is a positive correlation between denture satisfaction and OHRQoL. Especially 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 and colleagues 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 colleagues. 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 and 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 have 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 seven 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 (eg, /f/, /v/, and /s/) and plosives (eg, /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 colleagues 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.

2 MATERIALS AND METHODS

2.1 Patient selection

The current clinical logopedic 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 four 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.

2.2 Subjects

Twenty-two 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.

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

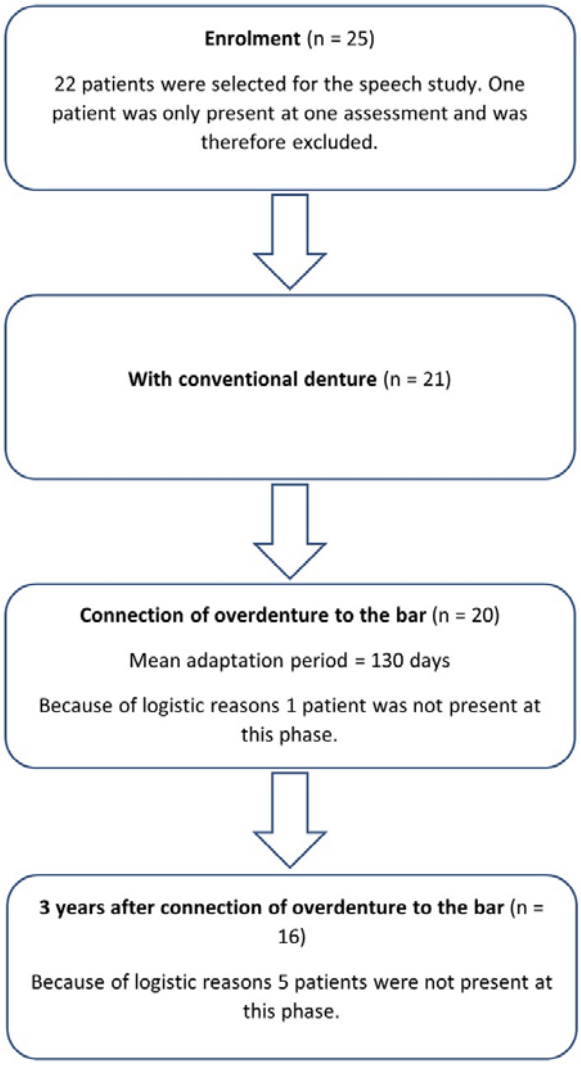

FIGURE 1: Flowchart of the study population

2.3 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 precise 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 mucoperiosteal 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 4 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]

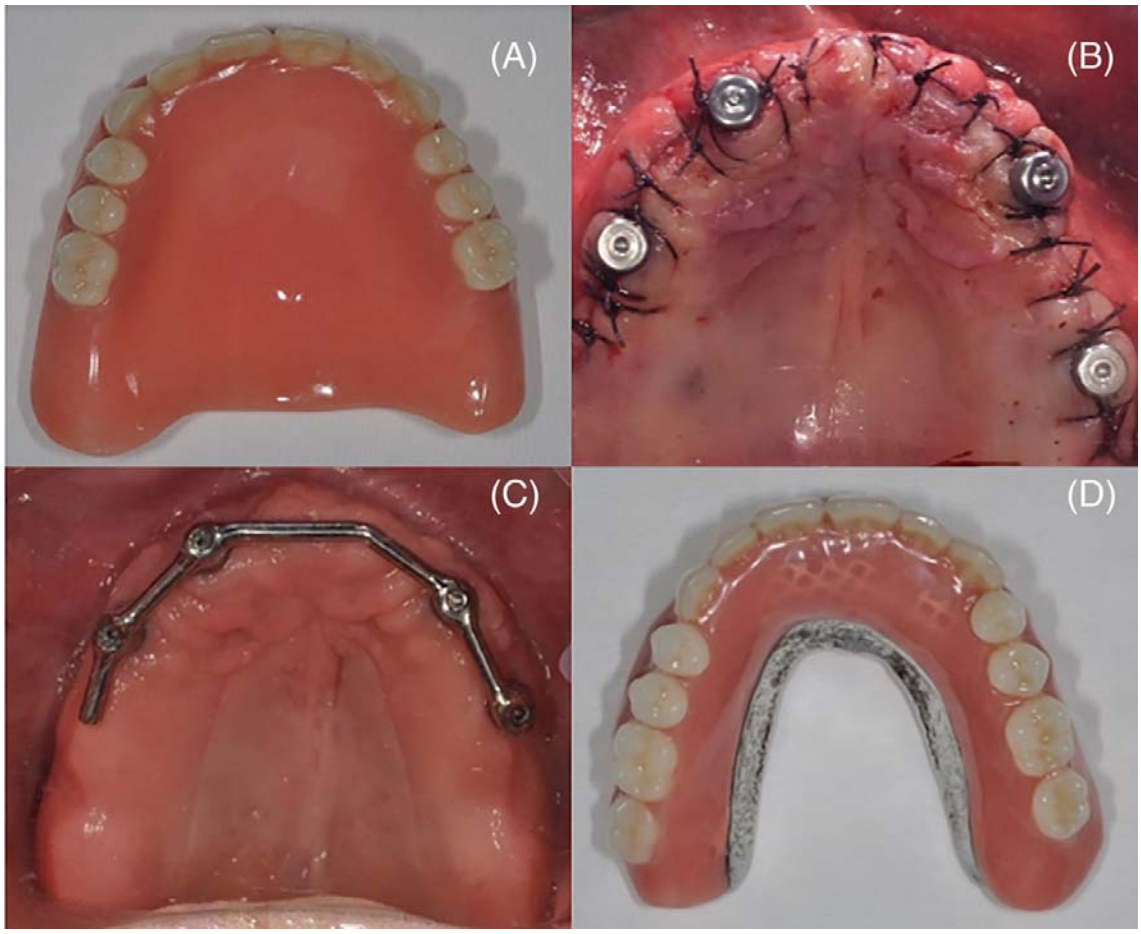

FIGURE 2. Preoperative stage with conventional denture with full palatal coverage (A). Immediately after one-stage implant surgery with abutments and healing caps perforating the soft tissues (B). Connection of the implants with a titanium milled bar after a 4 months healing period (C). Top view of the final overdenture without palatal coverage (D).

2.4 Articulation

The logopedic 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 preoperatively 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 4 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 3 years after connection. The position of the 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 and colleagues.[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 min 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.[36] The subject was asked to name 135 different pictures of ordinary objects and actions presented in color 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 (Ester Fonteyne and Eline Burms). One SLP was blinded for the stage of the treatment. Inter-rater 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.

2.5 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) (Figure A1).[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.

2.6 Statistical analysis

The Wilcoxon matched-pairs signed rank test was used to compare intrapatient 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 $\alpha = 0.05/3$

TABLE 2. Articulation disorders according to the picture naming test (PNT)

Articulation disorder	Definition	Inter-rater 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 (eg. push)				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	$p = 0.059$	$p = 0.319$	$p = 0.776$

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 $\alpha = 0.05/3$.

(=0.0167). SPSS Statistics 27 (IBM SPSS Statistics for Windows, version 27.0; IBM Corp., Armonk, NY) was used to analyze the data. A post hoc power analysis indicated 72%–100% power for the speech-related variables.

The authors state compliance with the STROBE checklist.

3 RESULTS

3.1 Articulation

The type and number of articulation disorders (with definition) measured with the picture naming test and the inter-rater reliability of the consensus evaluation is displayed in Table 2. The inter-rater reliability of the two SLPs was high for all speech sounds (80.3%–100%). Overall distortions of the /s/, /z/, /t/, /d/, /l/, /n/, and /r/ 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.

3.2 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 these questions vary from 1.70/4 at baseline to 0.95/4 after IOD connection and 0.81/4 after 3 years.

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)

	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			

Note: After Bonferroni correction, the significance level was set at $\alpha = 0.05/3$.

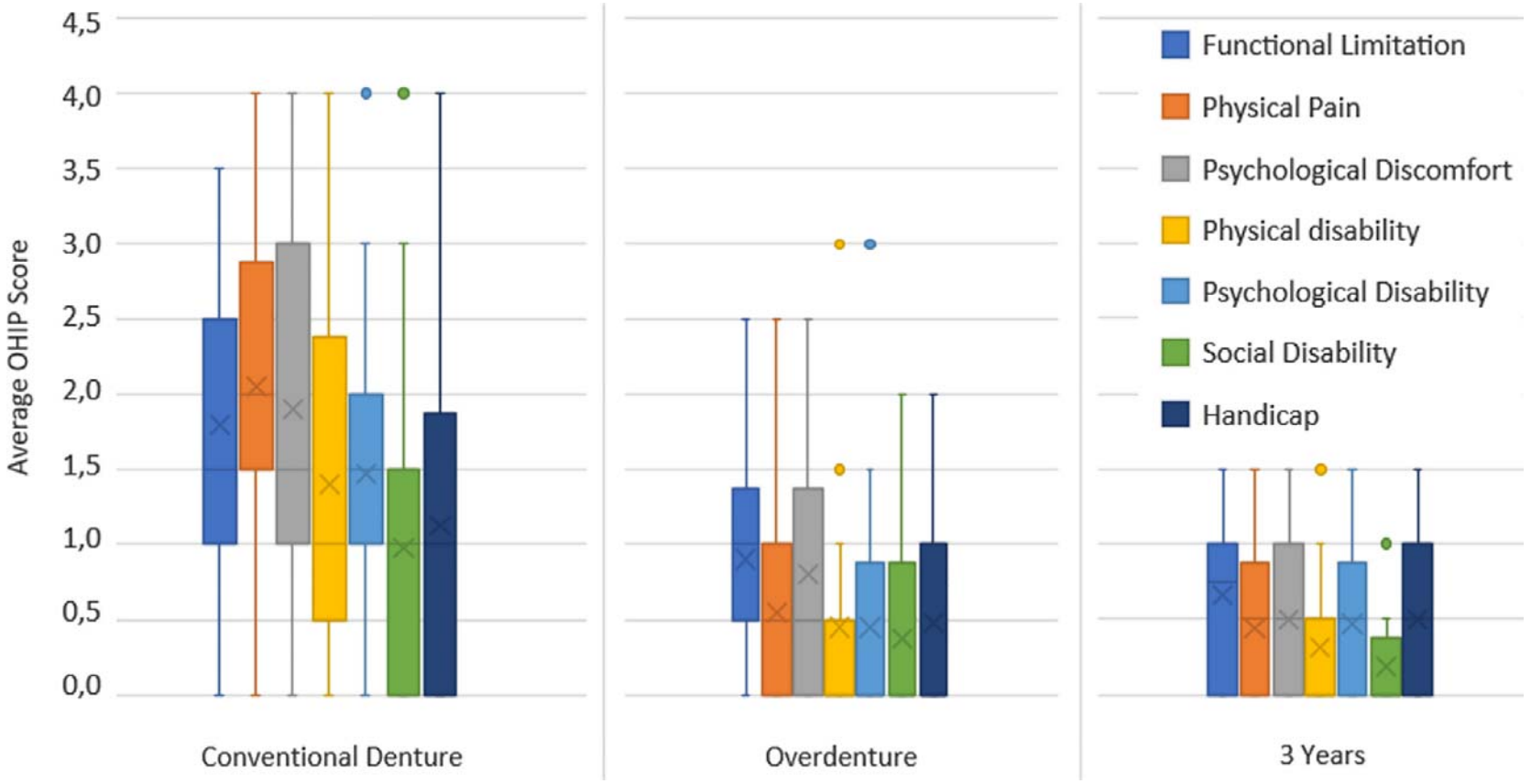

FIGURE 3. Boxplot representation of the seven domain scores of the OHIP-14 with conventional denture, connected overdenture and after 3 years in function

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.

4 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).

First 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] Pretreatment 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 could not 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 pretreatment 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, 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, second, 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 pretreatment. 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 and De Bruyn 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 3-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 3 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 pretreatment to 3 years follow-up in IOD. The study of Lundqvist and colleagues reported results of 21 patients, treated with a FID. Ninety-four percent 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, pretreatment, 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 and colleagues on mini-dental implants (MDI) in the maxilla.[19] In the review of Sharka and colleagues, 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 dropout, 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.

5 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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CONFLICT OF INTEREST

Prof. De Bruyn reports on behalf of Ghent University and Radboud University Medical Center a research collaboration with Southern Implants Inc. (Irene, South Africa).

AUTHOR CONTRIBUTIONS

Ester Fonteyne: Concept/design; data analysis/interpretation; drafting article; critical revision of article; statistics; data collection; approval of article. **Eline Burms**: Data analysis/interpretation; drafting article; critical revision of article; statistics; data collection; approval of article. **Carine Matthys**: Critical revision of article; approval of article; data collection. **Kristiane Van Lierde**: Concept/design; critical revision of article; approval of article. **Hugo De Bruyn**: Concept/design; critical revision of article; approval of article; funding.

APPENDIX A.

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?					

FIGURE A1. English version of the shortened Oral Health Impact Profile

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