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 two titanium dental implants. Patients were evaluated after receiving a new set of fully removable dentures (stage 1), after surgery during provisionalization 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*: .010). This indicates improvement. Satisfaction with speech evolved significantly from 68% pretreatment to 82% in stage 3 (*P*: .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.

Keywords: edentulous mandible; implant; long term study; oromyofunction; overdenture; patient satisfaction; speech

What is known:

Previous studies on fixed dentures and conventional dentures in the edentulous jaw reveal a certain impact on articulation, oral function and OHRQoL. All studies stress the vulnerability of the /s/ sound.

What this study adds:

This study is the first longitudinal study on overdentures in the mandible that focuses on articulation and oral function. Besides the prospective design, the use of two independent speech language pathologists to assess articulation disorders is very unique in literature. We learn that articulation disorders are likely to occur during treatment. There are no significant changes in articulation and oromyofunctional errors during treatment. The /s/ sound is still distorted in 37% of the participants. There is significant improvement of OHRQoL and satisfaction with speech.

1 INTRODUCTION

When adjustments are made to the orofacial and dental structures, the possible impact on different functions and quality of life cannot 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 to 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]

In summary, research on articulation and oromyofunction in overdentures in the mandible is scarce, while 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.

2 MATERIALS AND METHODS

2.1 Patient selection and clinical treatment procedure

This study was part of a project assessing clinical outcome of two 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 article. All patients were edentulous in both jaws at intake. We may refer to Glibert and colleagues[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 did not suffer from systemic diseases and were nonsmokers 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.: $P = .085$; $P = .251$; $P = .401$). Hence, it was concluded that both groups could be included in the results. Table 1 displays detailed patient information. Eighteen 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*: .085	*Z*: −1.148 *P*: .251	*Z*: −0.839 *P*: .401

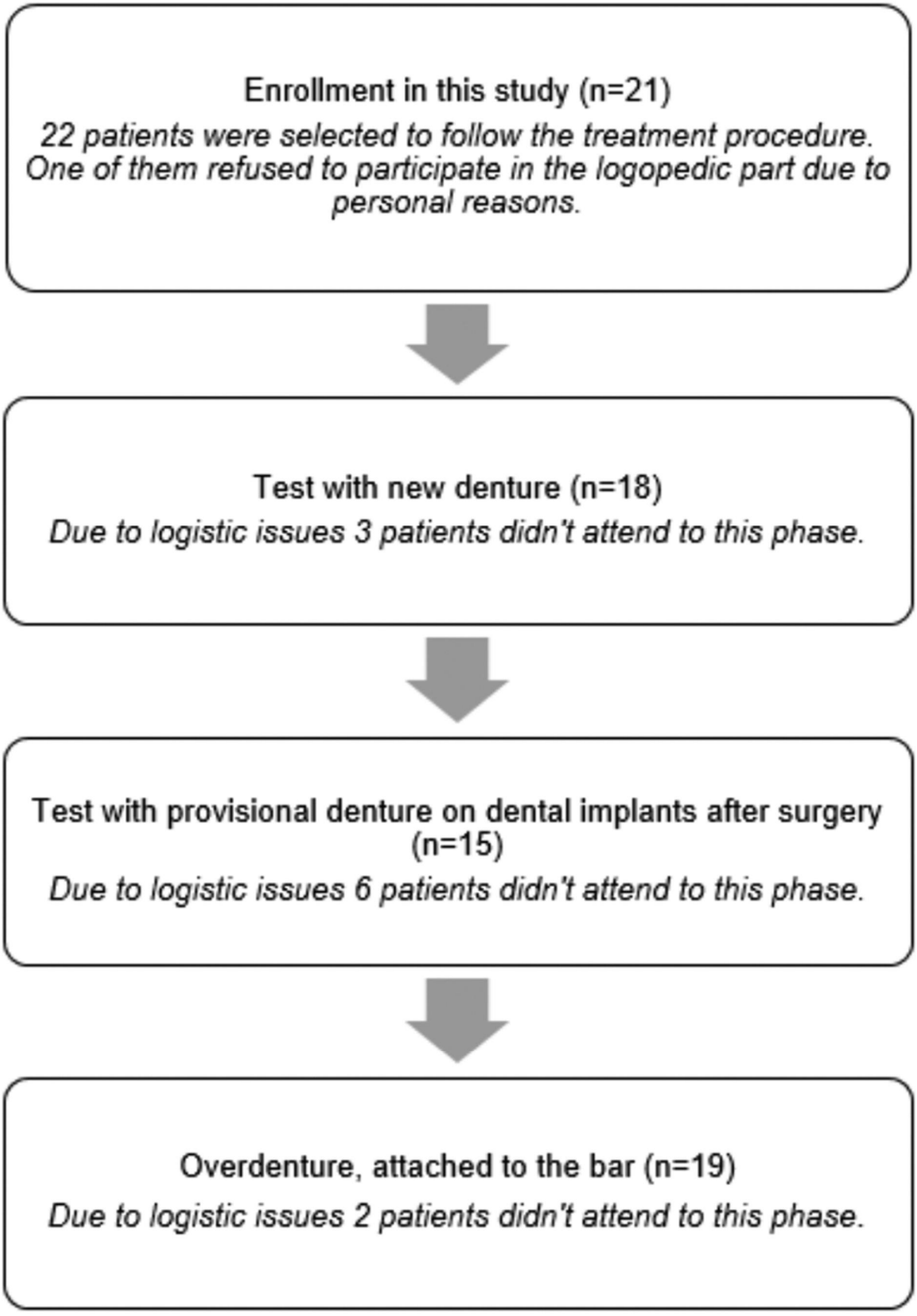

FIGURE 1. Flowchart of the study population

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 anesthesia 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). Antibiotics and analgesics were administrated immediately after surgery. After 1 week, sutures were removed and the denture base was adjusted whenever required for pain relief or pressure points. The participants were checked after 1 and 2 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; 3 M ESPE; Saint Paul, Minnesota) 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 (Ester Fonteyne and Carine Matthys).

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.

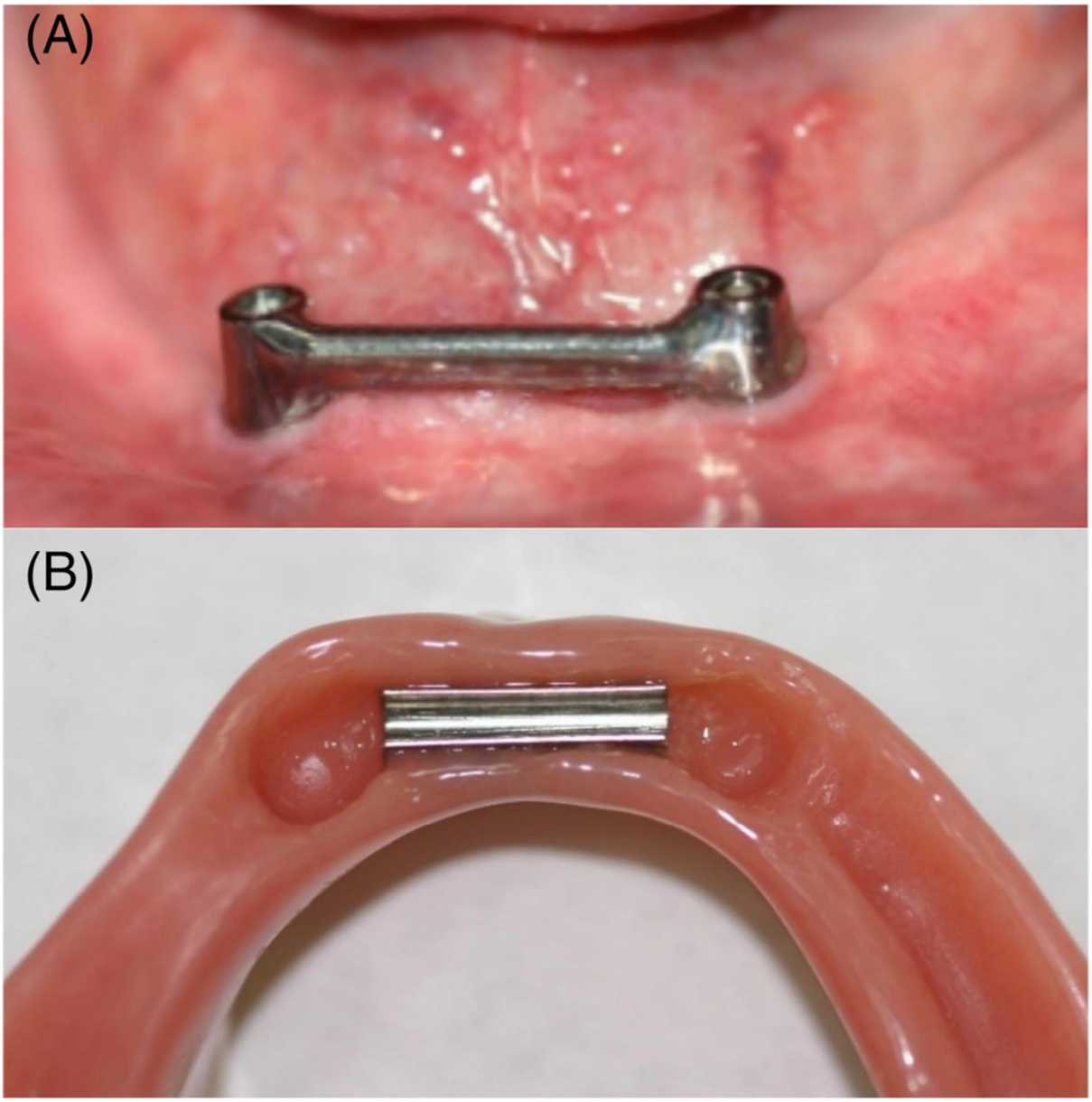

FIGURE 2. (A) Implant retained bar and (B) overdenture attachment in the mandible

2.2 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; second 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; Ester Fonteyne), 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 min.

2.3 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 and colleagues.[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 show), /ʒ/ (as in garage), /t/, /d/, /n/, /l/, /r/ and /f/ sounds, based on the protocol of Jacobs and colleagues.[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 (Ester Fonteyne and Laurence Becue). One SLP (Laurence Becue) 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 was used to derive the four spectral moments (ie, mean, SD, skewness, and 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.

2.4 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 (Ester Fonteyne) and perform certain movements with the facial and oral muscles. No visual modeling 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 and colleagues [31] was adjusted to evaluate the functions, relevant to this study population (eg, the evaluation of the velopharyngeal function was omitted). The whole protocol was video-recorded and evaluated independently by two SLPs (Ester Fonteyne and Laura Bruneel). One SLP (Laura Bruneel.) was blinded for the stage of the treatment. A task was classified to be normal or disturbed. Interrater reliability is displayed in Table 2.

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

	Inter examiner reliability	New denture (n)	Provisional denture (n)	Overdenture (n)	New-provisional	Provisional-overdenture	New-overdenture
					P value	*P* value	*P* value
Phonetic error of the /s/	0.71	11/18	8/15	7/19	.625	.500	.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	.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	.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/							
	0.94	1/18	1/15	0/19			
Addental							
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			
		Mean 1.13	Mean 0.87	Mean 0.65			
					Z: −0.852	Z: −0.589	Z: −1.721
Number of speech errors per person		(0–4)	(0–4)	(0–2)			
					P = .394	*P* = .556	*P* = .085
		SD 1.39	SD 1.29	SD 0.83			

- *Note:* The level of significance after Bonferroni correction was set at $\alpha = 0.05/3$.

2.5 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[32] and van der Meulen and colleagues[33]). The OHIP-14 consists of 14 items divided in seven 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.

2.6 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.

3 RESULTS

3.1 Articulation

Tables 3 and 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:

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

	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	.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	.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	.500	.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	.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* = .148	*Z*: −0.330 *P* = .741	*Z*: −1.663 *P* = .096

- *Note:* The level of significance after Bonferroni correction was set at $\alpha = 0.05/3$.

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 4). 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.

TABLE 4. Type of articulation errors and their definitions (Pena-Brooks and Hegde[11])

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

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.

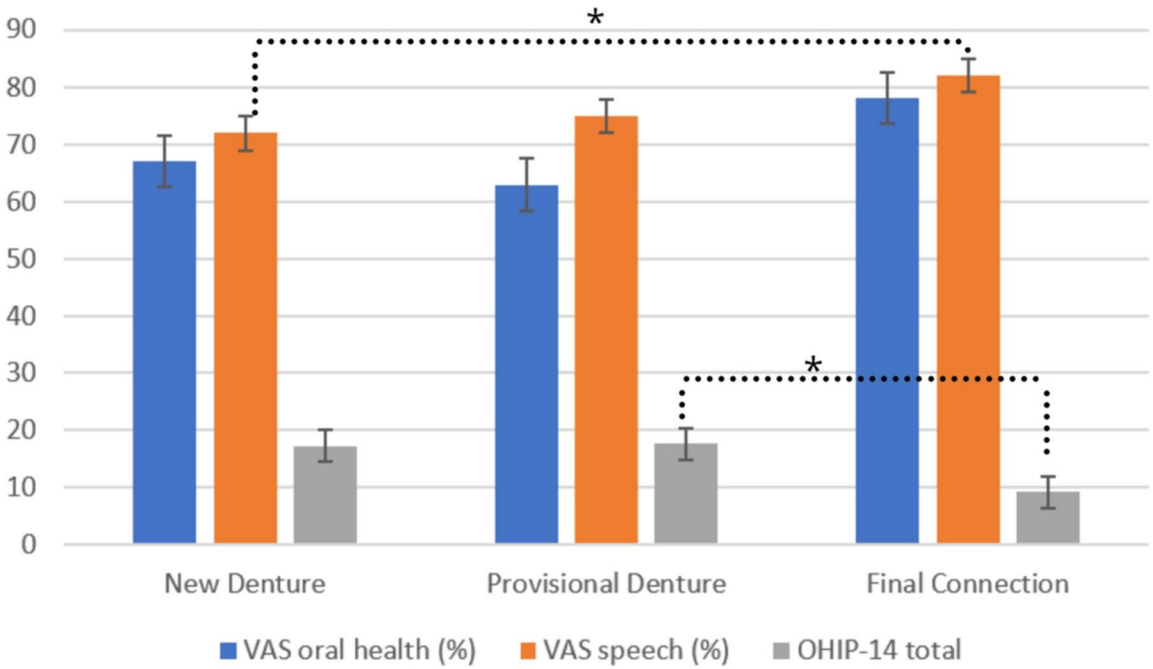

FIGURE 3. Sample outcomes of the spectral analyses in subject 1. The spectral moments of the /s/ sound in “set” with the new denture (A) mean freq. 9888 Hz; SD 1344 Hz; skewness −2.165; kurtosis 18.83, and peak freq. Value 10 046 Hz. The spectral moments of the /s/ sound with the provisional denture (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 5. Oromyofunctional evaluation: problems with oromyofunctional behavior assessed during the stages of the mandibular overdenture treatment (preoperative, provisional loading, and final connection)

	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	.500	1	.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* = .722	*Z*: −0.528 *P* = .597	*Z*: −0.049 *P* = .961

- *Note:* The level of significance after Bonferroni correction was set at $\alpha = 0.05/3$.

3.2 Oromyofunctional behavior

Table 5 displays the results of the oromyofunctional evaluation during treatment. Of the 25 test items, six items where affected at some point during treatment in six 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 provisionalization 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.

3.3 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 17.4/56 to 17.7/56 and finally 9.8/56. 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: .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: .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.

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)

		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* = .724	*Z*: −1.958 *P* = .050	*Z*: −1.775 *P* = .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* = .906	*Z*: −2.585 *P* = .010	*Z*: −1.59 *P* = .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* = .286	*Z*: −1.434 *P* = .152	*Z*: −2.497 *P* = .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			

- *Note:* The level of significance after Bonferroni correction was set at $\alpha = 0.05/3$.

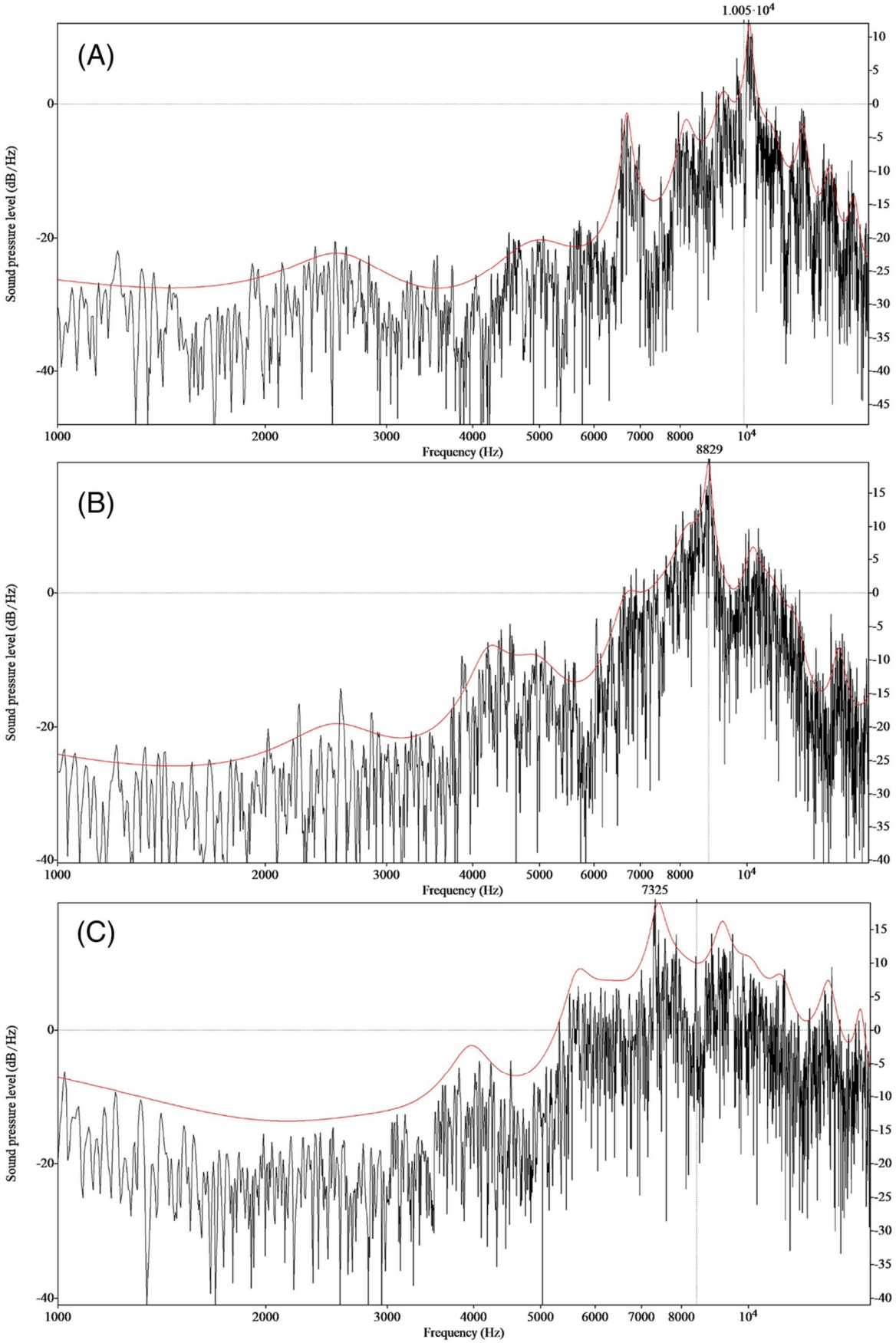

FIGURE 4. Satisfaction with overall status and speech (scale 100) and OHIP-14 total (scale 56) for the treatment over time. Bars indicating standard error are included. *Indicates $P < .05/3$

4 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 (eg, 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 and colleagues 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 and colleagues and Heydecke and colleagues 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 and colleagues and the study of Jacobs and colleagues 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 five of the six 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 provisionalization 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 does not 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 and colleagues[21] in fixed dentures in the maxilla. 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.

CONFLICT OF INTEREST

Mrs. Fonteyne acknowledges the supporting grant for the clinical study from Southern Implants Inc. (Irene, South Africa).

AUTHOR CONTRIBUTIONS

Ester Fonteyne: concept/design, data analysis/interpretation, drafting article, approval of article, statistics, data collection. Carine Matthys: data analysis/interpretation, critical revision of article, approval of article, data collection. Laura Bruneel: concept/design, data analysis/interpretation, drafting article, critical revision of article, approval of article, statistics, data collection. Laurence Becue: concept/design, critical revision of article, approval of article, data collection. Hugo De Bruyn: concept/design, critical revision of article, approval of article. Kristiane Van Lierde: concept/design, critical revision of article, approval of article.

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