



Do implant-supported fixed partial prostheses improve masticatory performance in patients with unilateral posterior missing teeth?

Laura Khoury-Ribas^{1,2} | Raul Ayuso-Montero^{1,2}  | Eva Willaert^{1,2}  |
Maria Peraire^{1,2} | Jordi Martinez-Gomis^{1,2} 

¹Faculty of Medicine and Health Sciences, Department of Prosthodontics, School of Dentistry, University of Barcelona, Barcelona, Catalonia, Spain

²Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain

Correspondence

Jordi Martinez-Gomis, Campus de Bellvitge, C/ Feixa Llarga s/n, 08907 L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain.
Email: jmartinezgomis@ub.edu

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Abstract

Objectives: The purpose of this study was to determine the improvement in masticatory performance and satisfaction with chewing ability in partially edentulous patients after treatment with an implant-supported fixed partial prosthesis (ISFPP).

Material and methods: This prospective study included 30 patients (mean age 59 years; 17 women) with unilateral posterior missing teeth treated with one-, two- or three-unit ISFPPs and 10 healthy individuals (mean age 36 years; 8 women) with complete natural dentition to establish the normal levels of mastication. Three variables were determined at baseline and at 3-months' follow-up in all participants: masticatory performance according to the median particle size (MPS) during freestyle mastication and unilateral mastication on each side, and satisfaction with chewing ability using a visual analog scale. Paired samples *t* test and Kruskal–Wallis test were used for intra-group and inter-group comparisons.

Results: The MPS following freestyle mastication decreased significantly at 3 months in both groups. Significant reductions of 21%, 30%, and 42% in the MPS were obtained from unilateral mastication on the treated side after treatment with 1, 2, or 3 restorative units, respectively. Three months after ISFPP, satisfaction with chewing ability improved by 40% in the treatment group.

Conclusions: Freestyle masticatory performance may improve slightly within three months of treatment with an ISFPP and may be similar to that of subjects with complete natural dentition. Patients may obtain a 21%–38% improvement in unilateral mastication on the treated side and a 26%–54% improvement in satisfaction with chewing ability.

KEYWORDS

chewing, dental crown, dental implants, dental occlusion, mastication, therapeutics

1 | INTRODUCTION

Tooth loss is a relatively frequent phenomenon, and the loss of posterior teeth can reduce oral function and affect nutritional status (Dye, Thornton-Evans, Li, & Iafolla, 2015; Sheiham & Steele, 2001).

Traditionally, prosthetic treatment options include dental-supported fixed prostheses in younger age groups and removable dental prostheses in older age groups (Zitzmann, Hagmann, & Weiger, 2007). Although the use of dental implants has increased notably since 1999, the evidence available at present is insufficient to recommend

one tooth replacement strategy over another in adult patients with reduced dentition (Elani, Starr, Silva, & Gallucci, 2018; McLister et al., 2018). A major objective of prosthodontic treatment is to restore or improve masticatory function (Jokstad, Orstavik, & Ramstad, 1998), which includes phenomena such as masticatory performance, masticatory laterality, and chewing rate (Flores-Orozco, Tiznado-Orozco, et al., 2016). Variations in masticatory performance may occur due to either extrinsic or intrinsic factors (Woda, Foster, Mishellany, & Peyron, 2006). Among the intrinsic factors, bite force and dental state (such as number of occlusal units or occlusal contact areas) are key to masticatory performance (Flores-Orozco, Rovira-Lastra, Willaert, Peraire, & Martinez-Gomis, 2016; Hatch, Shinkai, Sakai, Rugh, & Paunovich, 2001; Julien, Buschang, Throckmorton, & Dechow, 1996; Lujan-Climent et al., 2008). Subjective and objective assessments can be achieved by grading the perceived chewing ability or by quantifying the degree of fragmentation of a test food, respectively (Awad & Feine, 1998; van der Bilt, Mojet, Tekamp, & Abbink, 2010; Speksnijder, Abbink, van der Glas, Janssen, & van der Bilt, 2009). Dental silicone, particularly Optozeta pieces placed in a latex bag, is considered a reliable test food for quantifying the degree of fragmentation in subjects with natural dentition and implant-supported fixed partial prostheses (ISFPPs) (Edlund & Lamm, 1980; Khoury-Ribas, Ayuso-Montero, Rovira-Lastra, Peraire, & Martinez-Gomis, 2018; Rovira-Lastra, Flores-Orozco, Salsench, Peraire, & Martinez-Gomis, 2014).

In edentulous patients, the use of implants to support dentures can improve chewing efficiency and perceived masticatory capacity (Boven, Raghoobar, Vissink, & Meijer, 2015; Kroll et al., 2018; Müller et al., 2012). In partially edentulous patients, the use of removable partial dentures, fixed prosthodontics, or implant-supported removable partial dentures improved masticatory function by 10%–30% (van der Bilt, Olthoff, Bosman, & Oosterhaven, 1994; Jensen et al., 2017; Palomares, Montero, Rosel, Del-Castillo, & Rosales, 2018; Wallace et al., 2018). It has also been reported that masticatory performance in patients treated with ISFPPs was better than in patients who received implant-supported removable prostheses or removable prostheses (Gonçalves, Campos, Gonçalves, de Moraes, & Rodrigues Garcia, 2013; Nogawa, Takayama, Ishida, & Yokoyama, 2016), similar to that in patients who received fixed partial dentures (Kumar et al., 2017), and poorer than in patients who underwent endodontic treatment without tooth extraction (Woodmansey, Ayik, Buschang, White, & He, 2009). However, the cross-sectional study designs precluded any meaningful comment on whether improvement occurred in each group. In three prospective studies, significant improvements in chewing ability, mixing, and comminution were observed several weeks after treatment with ISFPPs, respectively (Gonçalves, Campos, & Rodrigues Garcia, 2014; Kang, Lee, Kwon, & Kim, 2015; Meena, Jain, Singh, Arora, & Jha, 2014). In other research, treatment with ISFPPs did not significantly improve unilateral comminution on the treated side among 12 patients (Fueki et al., 2016). This apparently contradictory result may be due to the limited sample sizes and the failure to include appropriate control groups. Consequently, when missing posterior teeth are restored,

the degree of masticatory improvement produced by ISFPPs remains unknown. This issue requires clarification to ensure that dentists can provide partially edentulous patients with accurate information about the optimal therapy.

We aimed to determine the degree of improvement in masticatory performance in patients with unilateral posterior missing teeth after treatment with an ISFPP. In addition, we aimed to determine the degree of improvement in satisfaction with chewing ability after treatment and to explore the association of various factors such as the number of restorative units or the increase in occlusal contact area with the degree of improvement in masticatory function. The null hypothesis was that treatment with ISFPPs does not improve masticatory performance in patients with unilateral posterior missing teeth.

2 | MATERIAL AND METHODS

2.1 | Study design and subject selection

Thirty-one partially edentulous adults (18 women and 13 men) who attended the Barcelona University Dental Hospital were invited to participate in this prospective study. The inclusion criteria were the absence of at least one premolar or molar on a single side that was to be restored with an ISFPP, and the presence of natural teeth as antagonists. Participants were excluded if they had periodontal disease or orofacial pain, were receiving ongoing orthodontic treatment, or were due to receive any restorative treatment in the three months after prosthesis placement. Ten healthy individuals (eight women and two men) with complete natural dentition were chosen by convenience sampling and used as a control group. All participants provided informed consent, and the study was approved by the Ethics Committee of Barcelona University Dental Hospital (Code 2015-27). The investigation was conducted from October 2015 to July 2018 (including recruitment, follow-up, and data collection) in accordance with the principles of the Helsinki Declaration and with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

2.2 | Clinical procedures

For each participant in the ISFPP group, a previous cone beam tomography was evaluated to determine the implant position. Implants were placed by postgraduate students under the supervision of experienced professors, according to standard procedures, without surgical templates, and following the manufacturer's instructions. The most frequently systems used were Avinent (Avinent Implant System) and Biohorizons (BioHorizons), in which single unit restorations were internal connections and multiple unit restorations were external ones. Patients who had one missing tooth received one implant, whereas patients who had two or three missing teeth received two implants.

Conventional procedures for screw-retained prostheses direct to implant were performed by postgraduate students under

supervision by experienced professors. Silicone impressions for the fabrication of ISFPPs (porcelain fused to metal) were obtained 90 days after the surgery. Two weeks later, the ISFPPs were screwed in place with a torque gage (25–30 Ncm), in accordance with each manufacturer's instructions. Screw access openings were restored with compacted polytetrafluoroethylene and a light-cured composite. Finally, all ISFPPs were adjusted to each patient's occlusion at the intercuspal position, using articulating paper with contact at heavy clench and no contact at light clench. No contact was allowed during laterotrusion or protrusion.

2.3 | Data collection

Age, sex, and the number and type of teeth were obtained from by clinical history and examination. Data included the Angle class, vertical overlap, and horizontal overlap, and the number of restored occlusal functional units was scored based on a molar tooth comprising two units and a premolar comprising one unit (Lujan-Climent et al., 2008). At baseline, unilateral maximum bite force was measured for two different regions, between the second premolars on the right and left sides, and in the absence of this tooth, between first premolars or first molars using a bite force transducer (Gnathodynamometer, Technical University of Catalonia). The vertical height of the bite fork was 20.5 mm, and this device was calibrated with loads from 0 to 1,200 N by means of a compression test machine at the Department of Materials Science and Metallurgy of the Technical University of Catalonia (Barcelona, Spain). Unilateral maximum bite force was recorded three times for each side, changing the order of each test and selecting the highest value regardless of the side measured (Riera-Punet, Martinez-Gomis, Paipa, Povedano, & Peraire, 2018).

Occlusal contact area in the intercuspal position, satisfaction with chewing ability, and masticatory performance during freestyle mastication, unilateral mastication on the right-hand side, and unilateral mastication on the left-hand side were determined before, immediately after prosthetic treatment, and three months after prosthetic treatment in the ISFPP group. For the control group participants, these parameters were determined at baseline and at 3-month follow-up.

The occlusal contact area in the intercuspal position was measured on the left and right using bite registration material (Martinez-Gomis et al., 2009). Occlusal registrations (Occlufast Rock, Zhermack) were obtained from all subjects, trimmed, scanned, and analyzed by computer software (UTHSCSA Image Tool 3.0, University of Texas Health Science Center). Occlusal contact was considered an interocclusal distance of 200 μ m or less, the value that best correlates with masticatory performance (Lujan-Climent et al., 2008).

Each participant performed three masticatory assays, each consisting of five trials of chewing 2 g of Optozeta (Optosil P Plus, Heraeus Kulze; Zetalabor, Zhermack) for 20 cycles. Optozeta tablets were 5 mm thick and 20 mm in diameter; they were made according to the instructions of Albert et al. and cut into quarters, and three of the quarter tablets were placed in a latex bag and sealed (Albert, Buschang, & Throckmorton, 2003; Khoury-Ribas et al., 2018;

Rovira-Lastra et al., 2014). One assay involved freestyle mastication in which the participant was asked to chew the latex bag naturally. The other two assays involved chewing the silicon unilaterally (i.e., right-hand side in one and left-hand side in the other); the order of trials was varied (Rovira-Lastra, Flores-Orozco, Ayuso-Montero, Peraire, & Martinez-Gomis, 2016). Masticatory performance was evaluated for each assay by the degree of comminution of the silicon test food. For each assay, particles from five trials (10 g) were dried for 24 hr and passed through a series of eight sieves (from 0.25 to 5.6 mm) while being shaken for 1 min. After the cumulative weight distribution of the sieve contents was determined, the median particle size (MPS) was calculated for each subject using the Rosin–Rammler equation $[Q_w(X) = 1 - 2E^{-(X/X_{50})^b}]$, where $Q_w(X)$ is the fraction of particles by weight with a diameter smaller than X , the MPS (or X_{50}) is the size of a theoretical sieve through which 50% of the weight can pass, and b describes the breadth of particle size distribution (Olthoff, van der Bilt, Bosman, & Kleizen, 1984; Rosin & Rammler, 1933).

The degree of satisfaction of participants with their ability to chew was determined quantitatively using the question: "At this moment, how is your degree of satisfaction in terms of chewing ability?", by means of a visual analog scale anchored by "extremely dissatisfied" (0%) and "completely satisfied" (+100%) at either end (Awad & Feine, 1998; Meng & Gilbert, 2007; Riera-Punet, Martinez-Gomis, Zamora-Olave, Willaert, & Peraire, 2019).

2.4 | Statistical analysis

The sample size was determined by considering a type I error of 0.05, a power of 0.8, and a clinically relevant improvement of 15% in the masticatory performance (van der Bilt et al., 1994; Kang et al., 2015), which would represent a difference in the MPS greater than or equal to 0.6 mm between sessions of an adult population with complete natural dentition (Lujan-Climent et al., 2008). Based on this, and assuming a standard deviation (SD) of 1.3 mm and an estimated drop-out rate of 5%, 31 participants were required (Lujan-Climent et al., 2008). Data for mastication and for the occlusal contact area in different groups (control group and ISFPP groups regarding the number of restorative units) were not distributed normally (Shapiro–Wilk's test). Therefore, control and treated groups were compared using Mann–Whitney U test, and groups regarding the number of restorative units were compared using the Kruskal–Wallis and pairwise comparison. Differences between the data at 3-month follow-up and baseline were calculated for each group, and their distributions were found to be normal (Shapiro–Wilk's test), thus allowing analysis by paired t tests. A multiple linear regression model, using a stepwise forward method, was performed to examine whether the baseline variables (age, sex, overbite, overjet, and maximum bite force) and treatment-related variables (number of restorative units, number of functional units, arch restored, and variation in the occlusal contact area) significantly explained the improvements in freestyle masticatory performance, unilateral masticatory performance, or satisfaction with chewing ability. Significance values were adjusted by the

Bonferroni correction for multiple tests. p -values of <0.05 were considered statistically significant, and all the analysis was conducted using the IBM SPSS Version 24 (IBM Corp.).

3 | RESULTS

Only one participant treated with a single ISFPP did not attend follow-up and was excluded. Therefore, 25 females and 15 males participated in this study. One occlusal record from a patient treated with two restorative units was removed from the analysis because it was obtained in an inadequate mandibular position. The baseline clinical characteristics by number of restorative units are shown in Table 1. There were no significant differences in facial index, Angle class, overjet, overbite, maximum bite force, and gender between ISFPP and control groups. Restorations were in the upper arch in 17 patients (57%) and in the lower arch in 13 (43%). The average number of occlusal functional units restored in the ISFPP group was 2.6:1.5, 3.3, and 4.3 occlusal functional units were restored for patients treated with one, two, or three implant-supported prosthetic units, respectively.

The MPS obtained by freestyle mastication was similar at baseline among the groups, but decreased significantly after three months in both the control group and in the ISFPP group treated with one restorative unit (Table 2). After three months, there were no significant differences between the groups. Regardless of the

number of restorative units, the MPS fell by 14.8% in the ISFPP group and by 9.7% in the control group (Table 2).

At baseline, the MPS after unilateral mastication on the treated side was higher in the group to be treated with three restorative units than in the group to be treated with one unit or controls (Table 3). However, significant reductions of 20.8%, 30%, and 42.1% were seen in the MPS three months after treatment with one, two, or three units, respectively ($p < 0.01$; paired t test). At three months, there were no significant differences between groups in the masticatory performance on the treated side. Although masticatory performance was similar between groups at baseline and 3-months on the untreated side (Table 3), there was a slight reduction in the MPS (7.8%) in the ISFPP group.

The satisfaction with chewing ability improved in the treatment group at three months ($p < 0.001$ paired t test; Table 4). The greatest improvement was seen for patients who received three units, in whom satisfaction with chewing ability rose from 46% before treatment to 90% at follow-up. In the ISFPP group, there was no significant correlation between improved satisfaction with chewing ability and improved masticatory performance during either free-style ($r = 0.13$; $p = 0.48$; Pearson) or unilateral mastication ($r = -0.27$; $p = 0.15$; Pearson).

At baseline, participants in the ISFPP group had fewer occlusal contact areas than those in the control group ($p = 0.003$; Mann-Whitney U test; Table 5). In the ISFPP group, the occlusal contact area on the treated side increased ($p < 0.001$; paired t test) at

TABLE 1 Participants' characteristics by treatment group

Group	<i>n</i>	Age (years)	No. of natural teeth	Overbite (mm)	Overjet (mm)	Maximum bite force (N)
No-treatment	10	35.6 (12.6)	28.2 (1.5)	1.9 (1.2)	2.9 (1.7)	464 (124)
ISFPP Group	30	58.8 (13.5)	25.6 (1.7)	2.8 (1.7)	2.7 (1.2)	343 (160)
1 restorative unit	15	57.6 (17.1)	26.3 (1.6)	3.0 (1.6)	2.9 (1.2)	390 (172)
2 restorative units	9	60.7 (8.7)	25.3 (1.5)	2.9 (2.4)	2.4 (1.3)	332 (147)
3 restorative units	6	58.8 (10.6)	24.0 (1.3)	2.3 (1.0)	2.6 (0.9)	252 (123)
Significance Kruskal-Wallis		0.004	<0.0005	0.456	0.772	0.065

Note. Abbreviation: ISFPP, implant-supported fixed partial prosthesis.

TABLE 2 Masticatory performance during freestyle mastication in each treatment group by assessment time

Group	<i>n</i>	MPS (mm) Mean and SD			Relative reduction of MPS at 3 months, % (95% CI)
		Baseline	After treatment	3-month follow-up	
No-treatment	10	3.68 (1.15)		3.32 (1.23)	9.7 (1.9 to 17.4)*
ISFPP Group	30	4.03 (1.27)	4.01 (1.35)	3.44 (1.08)	14.8 (5.2 to 24.4)**
1 restorative unit	15	3.93 (1.25)	3.39 (0.92)a	3.27 (0.96)	16.9 (7.5 to 34.5)*
2 restorative units	9	3.69 (1.32)	4.12 (1.61)ab	3.32 (1.25)	10.0 (-11.1 to 31.1)
3 restorative units	6	4.80 (1.13)	5.4 (0.74)b	4.03 (1.08)	16.0 (-11.5 to 43.4)
Significance Kruskal-Wallis ^a		0.276	0.025	0.329	

Note. Abbreviations: ISFPP: implant-supported fixed partial prosthesis; MPS: median particle size; SD: standard deviation.

^aDifferent letters indicate significant differences ($p < 0.05$) considering significant values adjusted by the Bonferroni correction for multiple tests.

* $p < 0.05$. ** $p < 0.01$ paired samples t test between baseline and 3 months follow-up.

TABLE 3 Masticatory performance during unilateral mastication in each treatment group by assessment time

Group	n	Treated side (or right side for controls)			Untreated side (or left side for controls)		
		MPS (mm) Mean and SD		Relative reduction in MPS % (95%CI)	MPS (mm) Mean and SD		Relative reduction in MPS % (95%CI)
		Baseline	After treatment		Baseline	After treatment	
No-treatment	10	4.19 (1.39)a	3.84 (1.61)	8.4 (−1.2 to 18.1)	3.68 (1.39)	3.51 (1.46)	4.6 (−4.3 to 13.6)
ISFPP Group	30	4.73 (1.33)	4.12 (1.28)	29.3 (20.5 to 38.1)***	3.52 (1.21)	3.42 (1.14)	7.8 (1.0 to 14.7)*
1 restorative unit	15	3.97 (1.16)a	3.47 (0.84)a	20.8 (7.4 to 34.2)**	3.21 (0.99)	3.04 (0.72)	8.8 (0.9 to 16.7)*
2 restorative units	9	5.09 (1.09)ab	4.46 (1.45)ab	30.0 (15.3 to 44.7)**	3.41 (1.21)	3.19 (1.24)	6.4 (−0.2 to 13.1)
3 restorative units	6	6.11 (0.56)b	5.22 (1.15)b	42.1 (30.6 to 53.6)***	4.47 (1.42)	4.13 (0.90)	7.7 (−22.6 to 38.2)
Significance Kruskal–Wallis ^a		0.002	0.023	0.833	0.241	0.14	0.177

Note. Abbreviations: ISFPP: implant-supported fixed partial prosthesis; MPS: median particle size; SD: standard deviation.

^aDifferent letters indicate significant differences ($p < 0.05$) considering significant values adjusted by the Bonferroni correction for multiple tests. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$ paired samples t test between baseline and 3 months follow-up.

three months, whereas no change was seen on the untreated side ($p > 0.05$; paired t test).

Stepwise multiple regression was performed for the final analyses (Table 6), finding that no single baseline or treatment-related variable significantly affected the reduction in MPS during freestyle mastication. By contrast, the number of restorative units was the most important factor affecting the reduction in MPS on the treated side, accounting for 42% of the variation (adjusted R^2 ; $F = 29.6$; $p < 0.0005$). The model described that each restorative unit should decrease the MPS by 0.72 mm (95% CI 0.45–0.98), which equated to a 15.2% (95% CI 9.5%–20.8) decrease in the initial MPS. In addition, the analysis showed that the number of restorative units was the most important factor affecting change in satisfaction with chewing ability ($B = 11.2$; 95% CI 5.3–17.0), accounting for 26% of the variation (adjusted R^2 ; $F = 14.4$; $p = 0.001$).

4 | DISCUSSION

The results of this study suggest that treatment with ISFPPs improves masticatory performance in patients missing posterior teeth unilaterally. The degree of improvement in mastication on the treated side was quantified as a 0.7 mm reduction in the MPS (15%) for each restorative unit. This improvement was confirmed within subjects, by comparing before and after treatment and by comparing treated and untreated sides; it was also confirmed between subjects, by comparing with a control group that had a complete natural dentition.

Treatment with ISFPP improved the comminution element of masticatory performance on unilateral (treated side) and freestyle assessments, though to a much greater degree in the unilateral assessment. During freestyle mastication, most subjects tend to move the bolus from one side after a few cycles to reduce fatigue and to increase the flavor obtained. By contrast, in the enforced unilateral mastication, the bolus is retained in the same place and the masticatory cycles are more uniform and make the comminution more efficient, especially for a uniform bolus (Rovira-Lastra et al., 2014). Although the freestyle mastication reproduces the clinical situation more closely, the unilateral improvement could explain the true effect of ISFPP on masticatory improvement without the influence of other factors that may affect the freestyle mastication, such as the degree of masticatory laterality or the number of side changes while chewing (Rovira-Lastra et al., 2014). Therefore, the results for these two styles of mastication should be considered complementary, and a difference should be expected. The improvement in comminution in the present study was consistent with that reported by Kang et al. (2015) who found that ISFPP improved the mixing ability by 14% after unilateral restoration of lost molar teeth. Although mixing ability evaluates the ability to mix a food bolus, the similar results to those obtained with MPS assessment indicate that unilateral posterior ISFPPs improve masticatory performance. In the future, it might be interesting to study whether unilateral treatment with ISFPP alters normal masticatory laterality and other aspects of masticatory function.

TABLE 4 Satisfaction with chewing ability perceived by the participant for different treatment groups at different times

Group	n	Satisfaction with chewing ability (VAS 0–100) Mean (SD)			Relative improvement at 3 months, % (95% CI)
		Baseline	After treatment	3-month follow-up	
No-treatment	10	75.1 (25)		76.4 (26)	1.7 (–5.8 to 9.3)
ISFPP Group	30	60.5 (22)	69.9 (20)	84.7 (18)	39.9 (26.2 to 53.6)***
1 restorative unit	15	65.4 (20)	73.6 (17)	86.4 (13)	32.1 (12.8 to 51.4)**
2 restorative units	9	61.9 (25)	63.0 (29)	78.3 (27)	26.6 (1.7 to 51.4)*
3 restorative units	6	46.3 (17)	71.0 (10)	89.8 (8)	94.0 (63.2 to 124.7)***
Significance Kruskal–Wallis		0.053	0.787	0.482	

Note. Abbreviations: ISFPP: implant-supported fixed partial prosthesis; SD: standard deviation; VAS, visual analog scale.

* $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$ paired samples t test between baseline and 3 months follow-up.

TABLE 5 Occlusal contact area on the treated and No-treated side for different groups at different times

Group	n	Treated side (or right side for controls)				Untreated side (or left side for controls)			
		Occlusal contact area in mm ² Mean (SD)			Variation in occlusal contact area, mm ² (95%CI)	Occlusal contact area in mm ² Mean (SD)			Variation in occlusal contact area, mm ² (95%CI)
		Baseline	After treatment	3-month follow-up		Baseline	After treatment	3-month follow-up	
No-treatment	10	37.0 (18)		36.1 (17)	–0.9 (–2.6 to 0.7)	33.3 (12)		33.4 (13)	0.1 (–1.9 to 2.0)
ISFPP Group	29	20.9 (16)	21.5 (18)	26.7 (18)	5.8 (2.5 to 9.1)***	28.1 (16)	29.2 (17)	30.2 (16)	2.1 (–0.9 to 5.0)
Significance Mann–Whitney U test		0.003		0.12		0.332		0.365	

Note. Abbreviations: ISFPP, implant-supported fixed partial prosthesis; SD, standard deviation.

*** $p < 0.001$ paired samples t test between baseline and 3 months follow-up.

TABLE 6 Stepwise regression models of factors related to the reduction in median particle size (MPS) determined using unilateral mastication on the treated side and related to the improvement in satisfaction with chewing ability 3 months after treatment

Model	Variables included	B (95%CI)	R	R _a ²	F (sig)
Reduction on the MPS unilaterally on the treated side					
1	Number of restoration units	0.72 (0.45 to 0.98)	0.66	0.42	29.6 (<0.0005)
Improvement in satisfaction with chewing ability					
1	Number of restoration units	11.2 (5.3 to 17.0)	0.52	0.26	14.4 (0.001)

Note. Abbreviations: R_a²: adjusted R² (fraction of variance explained). F (Sig.): F-value and significance.

Treatment with ISFPP also improved satisfaction with chewing ability by approximately 40%. The failure to show correlations between objective and subjective changes in masticatory function in either this or other studies (van der Bilt et al., 1994; Kang et al., 2015) indicates that patients are influenced by factors that we do not consider when assessing their chewing ability. Nevertheless, ISFPP not only achieves objective improvement in masticatory performance but also satisfies patients' expectations.

Three months after ISFPP treatment, patients' masticatory performance was comparable to that of participants with complete natural dentition in terms of freestyle mastication, unilateral mastication (on both the treated and untreated sides), and subject-perceived chewing, consistent with the findings of Nogawa et al. (2016).

The results of this study will provide much-needed evidence on the objective and subjective masticatory improvement that can be expected following unilateral ISFPP treatment. Furthermore, the percentage of improvement is around or higher than 15%, a figure that can be considered clinically relevant. When counseling patients, this issue could be discussed along with other potential benefits (e.g., improved esthetics and occlusal stability) and costs (e.g., financial, risks, and complications).

The occlusal contact area at the intercuspal position has been reported to be key for masticatory performance in cross-sectional studies of populations with natural dentition (Flores-Orozco, Rovira-Lastra, et al., 2016; Julien et al., 1996; Lujan-Climent et al., 2008). In the present study, although the occlusal contact areas were increased

on the sides treated with ISFPPs, the number of restorative units was a more important factor in explaining the improvement in unilateral masticatory performance and satisfaction with chewing ability. This may be because clinicians are unable to differentiate high- and low-force contacts reliably on articulating paper (Kerstein & Radke, 2014), even though articulating paper and occlusal foils are the most widely applied methods for occlusal adjustment and have been used to assess the number of occlusal contacts in research (Caro, Peraire, Martinez-Gomis, Anglada, & Samsó, 2005). We cannot dismiss the possibility that using an interocclusal distance other than 200 µm might have made the increase in occlusal contact area more relevant.

Interestingly, statistically significant increases in masticatory performance scores (5%–10%) were found on the untreated side in patients treated with ISFPP. Similar results were also observed in another study which suggested that the restoration of missing posterior teeth could improve objective masticatory performance on untreated sides (Fueki et al., 2016). However, we showed that the masticatory performance of freestyle mastication was also significantly improved for control subjects at follow-up (approximately 10%). These results are more compatible with a training effect after performing the masticatory assays with the artificial test food than with a true benefit of the prosthodontic treatment. Additionally, biological variability and the measurement error associated with the masticatory tests could also have contributed to the reduction in MPS in the control group.

This study has several limitations. Although the sample size was sufficient to find masticatory improvement in the ISFPP group, the small number of participants in the groups treated with two or three restorative units might not have been large enough to find significant comparisons and regression analysis findings should be interpreted with caution. The measurements immediately after treatment may also have been unreliable if patients felt discomfort or fatigue. Another weakness was that only one artificial test food was used to assess the first phase of comminution, meaning that the results are only applicable to that food type.

5 | CONCLUSIONS

In patients with unilateral posterior missing teeth, freestyle masticatory performance may be slightly improved three months after treatment with an ISFPP and may achieve levels similar to those in subjects with complete natural dentition. However, this improvement seems not to depend on the number of restorative units. In addition, patients may obtain a 21%–38% improvement in unilateral mastication on the treated side and a 26%–54% improvement in satisfaction with chewing ability.

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AUTHOR CONTRIBUTIONS

L. K-R. contributed to conception and design, data acquisition, analysis and interpretation, drafted and critically revised the manuscript; R. A-M. and J. M-G. contributed to conception and design, data analysis and interpretation, drafted and critically revised the manuscript; E. W. and M. P. contributed to design, data interpretation, and critically revised the manuscript.

ORCID

Raul Ayuso-Montero  <https://orcid.org/0000-0002-8090-0564>

Eva Willaert  <https://orcid.org/0000-0002-9876-357X>

Jordi Martinez-Gomis  <https://orcid.org/0000-0003-3497-093X>

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