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CLINICAL RESEARCH

Masticatory rhythm 3 months after treatment with unilateral implant-supported fixed partial prosthesis: A clinical study

Laura Khoury-Ribas, DDS,[a] Raul Ayuso-Montero, DDS, PhD,[b] Eva Willaert, DDS, PhD,[c] Maria Peraire, MD, DDS, PhD,[d] and Jordi Martinez-Gomis, DDS, PhD[e]

ABSTRACT

Statement of problem. Whether treatment with an implant-supported fixed partial prosthesis (ISFPP) affects the masticatory rhythm in patients with unilateral posterior missing teeth is unclear.

Purpose. The purpose of this prospective clinical study was to determine the change in masticatory rhythm in participants with unilateral posterior missing teeth 3 months after treatment with an ISFPP and to assess whether treatment influenced the stability of the masticatory rhythm.

Material and methods. Thirty participants (mean age 59 years; 17 women) with unilateral posterior missing teeth were treated with 1-, 2-, or 3-unit ISFPPs. Ten healthy individuals (mean age 36 years; 8 women) with a complete natural dentition were included in a control group. In this prospective study, each participant performed 3 masticatory assays (freestyle, unilateral right, and unilateral left) at baseline and at the 3-month follow-up. Each assay comprised 5 trials of 20 cycles masticating pieces of silicone placed in a latex bag. The time needed to complete the 20 masticatory cycles per trial was measured, and the mean masticatory frequency was calculated for each assay. Coefficients of variation were then calculated from the 5 mean values of the masticatory trials. Differences in the data at 3 months and baseline were analyzed by using the Wilcoxon or paired *t* tests. The control and treated groups were compared by analysis of variance or Mann−Whitney *U* tests (α=.05).

Results. After 3 months, participants treated with ISFPPs showed an increase of 8.7% in masticatory frequency during freestyle mastication (P<.001) and an 8.0% increase during unilateral mastication on the treated side (P<.01). At baseline, the coefficient of variation of masticatory frequency on the treated side was higher in the ISFPP group than in the control group during unilateral mastication (P=.033). Three months after treatment, there was a significant reduction in the coefficient of variation during unilateral mastication on the treated side of the ISFPP group (P<.001). The treatment group also reached a masticatory frequency similar to that of the control group (75 and 78 cycles per minute, respectively).

Conclusions. Treatment with ISFPPs accelerated the masticatory rhythm of individuals with unilateral posterior missing teeth, who achieve similar rhythms to those with complete natural dentitions. The stability of the masticatory rhythm was also restored, indicating an improvement in masticatory function. (J Prosthet Dent 2021;126:553-9)

Partial edentulism affects more than half the US population aged 50 years or older.[1] Oral function, and consequently nutritional status, can be reduced in individuals with posterior tooth loss.[2] Missing teeth can be replaced with tooth-supported fixed or removable prostheses[3] or implant-supported fixed partial prostheses

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[a]Assistant Professor, Department of Prosthodontics, Faculty of Medicine and Health Sciences, School of Dentistry, University of Barcelona, Barcelona, Catalonia, Spain; and Assistant Professor, Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain.
[b]Assistant Professor, Department of Prosthodontics, Faculty of Medicine and Health Sciences, School of Dentistry, University of Barcelona, Barcelona, Catalonia, Spain; and Assistant Professor, Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain.
[c]Assistant Professor, Department of Prosthodontics, Faculty of Medicine and Health Sciences, School of Dentistry, University of Barcelona, Barcelona, Catalonia, Spain; and Assistant Professor, Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain.
[d]Full Professor, Department of Prosthodontics, Faculty of Medicine and Health Sciences, School of Dentistry, University of Barcelona, Barcelona, Catalonia, Spain; and Full Professor, Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain.
[e]Associate Professor and Serra Hunter Fellow, Department of Prosthodontics, Faculty of Medicine and Health Sciences, School of Dentistry, University of Barcelona, Barcelona, Catalonia, Spain; and Assistant Professor, Oral Health and Masticatory System Group (Bellvitge Biomedical Research Institute) IDIBELL, L'Hospitalet de Llobregat, Barcelona, Catalonia, Spain.

Clinical Implications

Masticatory rhythm in patients with unilateral posterior missing teeth is impaired. Treatment with ISFPPs can normalize and stabilize this abnormal masticatory function.

(ISFPPs)[4] to restore the masticatory function, which includes masticatory performance, laterality, and rhythm.[5,6]

Masticatory rhythm can be expressed as masticatory frequency (in cycles per minute or in Hz) or as the duration of a masticatory cycle (in seconds or milliseconds).[7] The faster a masticatory rhythm, the higher the masticatory frequency, and the lower the masticatory cycle duration. Normal masticatory frequency values are 70-90 cycles/min, with values <70 cycles/min considered slow and values >90 cycles/min considered fast.[8-11] Masticatory frequency varies more between individuals than within individuals, but it remains constant with age.[7,12-14] Men have a slightly higher masticatory frequency than women,[14] and those with temporomandibular disorders (TMDs) or Down syndrome tend to have slower masticatory frequency compared with healthy controls with natural teeth.[15,16] Although several properties of food affect masticatory frequency at different phases of mastication, frequency has been reported to remain relatively stable with different food types and morsel sizes when considering the entire mastication sequence.[13]

In cross-sectional research, different masticatory frequencies have been observed among individuals restored with complete dentures, removable partial dentures, implant-supported overdentures, or fixed prostheses.[17-19] Some characteristics of the occlusion, such as posterior unilateral reverse articulation and the type of dynamic occlusion, have been related to the masticatory cycle duration,[20,21] but the relationship between missing teeth and masticatory frequency has not been established. Although masticatory frequency has been shown to correlate positively with the meal weight,[22] the relationship between body mass index and masticatory frequency is not clear.[23-25]

Masticatory rhythm can also be expressed as the stability of masticatory frequency when assessing the within-individual variability in masticatory frequency. This is perhaps the parameter with the most reproducible values between trials in a single individual.[7,14] A high stability of masticatory frequency is considered characteristic of a healthy person because individuals wearing complete dentures or diagnosed with TMD show different levels of reduced mastication frequency compared with healthy controls.[14,15] Furthermore, poorer masticatory performers have been reported to exhibit significantly more within-individual variability in masticatory cycle duration than better performers.[26]

Whether events such as oral treatments affect intraindividual masticatory frequency has been the focus of prospective studies. It has been reported that enforced unilateral mastication increased the frequency,[27] as does orthodontic treatment or TMD treatment.[20,28] In edentulous individuals, the duration of the masticatory cycle was also reduced by treatment with new removable dentures or by the provision of implant-supported overdentures.[29-33] However, little information exists about whether treatment with a fixed partial prosthesis influences masticatory frequency in individuals with partial edentulism. Given that treatment with an ISFPP in patients with unilateral posterior missing teeth has been shown to improve masticatory performance and laterality,[34,35] it would be interesting to know whether this approach also improves masticatory rhythm.

The purpose of this prospective clinical study was to determine the changes in masticatory frequency among participants with unilateral posterior missing teeth between baseline and 3 months after treatment with ISFPPs. Secondary aims were to assess the effect of ISFPPs on the stability of masticatory frequency and to explore the association of different factors with changes in masticatory frequency. The null hypothesis was that ISFPP treatment would not alter masticatory frequency in patients presenting unilateral posterior missing teeth.

MATERIAL AND METHODS

Thirty-one individuals with unilateral posterior missing teeth attending the University of Barcelona's Dental Hospital from October 2015 to July 2018 were prospectively invited to participate in this study. All participants were adult, lacked at least 1 premolar or molar tooth on one side, and were scheduled for restoration with an ISFPP. Participants were excluded if they had orofacial pain or periodontal disease, were receiving active orthodontic treatment, or required other restorative treatment in the 3 months after prosthesis placement. Ten healthy individuals with complete natural dentition were included in a control group by convenience sampling. All individuals had participated in a previous investigation.[34,35] The sample size was calculated based on masticatory performance as the primary outcome by consulting recently published results.[34] Informed consent was provided by all participants, and the study was approved by the Ethics Committee of University of Barcelona's Dental Hospital (Code 2015/27).

The clinical procedures have been described in detail elsewhere.[34] Briefly, individuals who had 1 missing tooth received 1 implant, whereas individuals who had 2 or 3 missing teeth received 2 implants. Silicone impressions were obtained after 90 days to fabricate ISFPPs, which were screw-retained metal-ceramic prostheses. All prostheses were adjusted to the occlusion at the intercuspal position. Articulating paper marks were recorded after a heavy clench and no marks after a light clench. No contacts were present during laterotrusion or during protrusion.

Age, sex, and the number of teeth were obtained from clinical histories and examinations. Unilateral maximum occlusal force was measured at baseline by using an occlusal force transducer (gnathodynamometer; Technical University of Catalonia) in the region of the second premolars. This was recorded 3 times while changing the order of each test, and the highest value was recorded.[36]

The occlusal contact area was measured in the intercuspal position using occlusal registration material (Occlufast Rock; Zhermack), aiming for contact with an interocclusal distance of ≤200 μm.[37-39] Occlusal registrations were obtained for all participants, trimmed, scanned, and analyzed with a computer software program (UTHSCSA Image Tool 3.0; University of Texas Health Science Center).

Each participant performed 3 masticatory assays of 5 trials of 20 masticating cycles of 2 g Optozeta (Optosil P Plus; Kulzer GmbH and Zetalabor; Zhermack SPA). Optozeta pieces were made by following the instructions by Albert et al and were placed in a latex bag and then sealed.[6,40,41] One assay involved freestyle mastication in which the participant was instructed to masticate the latex bag naturally. The other 2 assays involved either masticating the silicone unilaterally alternating between sides.[42]

For each assay, masticatory performance was assessed by the degree of comminution of the silicone test food. Particles from 5 trials (10 g) were dried and passed through a sequence of 8 sieves (from 0.25-5.6 mm) after shaking for 1 minute.[42] After establishing the cumulative weight distribution of the sieve contents, median particle size (MPS) was calculated by using the Rosin−Rammler equation for each participant.[43] A higher MPS indicated poorer masticatory performance.

During each of the 5 freestyle mastication trials, a single operator (L.K.-R.) observed the side toward which the jaw moved during closure in each cycle and classified them as right-side (+1), left-side (-1), or neither (0). Masticatory movements were video recorded during each freestyle masticatory assay and masticatory sequences were revised.[35] The asymmetry index (AI) was calculated by considering all cycles as follows: (number of right strokes − number of left strokes)/(number of right strokes + number of left strokes).[44] The unilateral masticatory index was calculated as the absolute AI value and expressed the degree of unilateral mastication.

The time needed to complete 20 masticatory cycles per trial was measured, and the frequency for the average masticatory cycle per trial was calculated. Masticatory frequency was defined as the ratio of masticatory cycle number to masticatory time.

The occlusal contact area in the intercuspal position, masticatory performance, masticatory laterality, and masticatory frequency were determined before, immediately after, and 3 months after prosthetic treatment in the ISFPP group. For participants in the control group, these parameters were assessed at baseline and after 3 months.

The mean masticatory frequency data were distributed normally in each assay according to the Shapiro−Wilk test. Therefore, mean values from the control and treated groups were compared by using independent *t* test, while for the number of restorative units, comparison was by analysis of variance. Intraindividual differences of the data at the 3-month follow-up and at baseline or between 2 masticatory styles were analyzed by using paired *t* tests.

The coefficients of variation of the masticatory frequencies from the 5 mean values for the masticatory trials were calculated for each assay and were not distributed normally according to the Shapiro−Wilk test. Therefore, the control and treated groups were compared by Mann−Whitney *U* tests, and intraindividual differences between the data at 3-month follow-up and at baseline were analyzed by Wilcoxon tests.

Multiple linear regression models were conducted using a stepwise forward method to establish whether baseline variables (age, sex, maximum occlusal force, and baseline masticatory frequency) and treatment-related variables (number of restorative units, arch restored/not restored, and differences in occlusal contact area, unilateral mastication index, and masticatory performance) were significantly associated with the change in masticatory frequency between styles. All analyses were performed by using a statistical software program (IBM SPSS Statistics for Windows, v25; IBM Corp) (α=.05).

RESULTS

One participant treated with a single implant-supported prosthesis was excluded because she was not available for the second follow-up visit. Therefore, 17 women and 13 men in the ISFPP group and 8 women and 2 men in the control group were analyzed. Their masticatory-related characteristics at baseline are shown in Table 1. There were no significant differences between the control and ISFPP group regarding the maximum occlusal force, the masticatory performance, or masticatory asymmetry (P>.05). However, the number of natural teeth and the occlusal contact areas were significantly different between groups requiring different numbers of restorative units (P<.05). Fifteen, 9, and 6 participants received 1, 2, and 3 restorative units, respectively. Restorations were performed in the maxillary arch in 17 (57%) participants

Table 1. Participant characteristics (mean ±standard deviation) according to dental status and masticatory function by treatment group

Group	n	Age (y)	No. of Natural Teeth	Maximum Occlusal Force (N)	OCA (mm^2)	MPS (mm)	Unilateral Masticatory Index
No treatment	10	35.6 ±12.6	28.2 ±1.5	464 ±124	70.3 ±26	3.68 ±1.2	0.37 ±0.4
ISFPP group	30	58.8 ±13.5	25.6 ±1.7	343 ±160	49.0 ±28	4.03 ±1.3	0.66 ±0.4
1 restorative unit	15	57.6 ±17.1	26.3 ±1.6	390 ±172	59.6 ±32	3.93 ±1.2	0.57 ±0.4
2 restorative units	9	60.7 ±8.7	25.3 ±1.5	332 ±147	42.3 ±15	3.69 ±1.3	0.79 ±0.3
3 restorative units	6	58.8 ±10.6	24.0 ±1.3	252 ±123	31.5 ±21	4.80 ±1.1	0.70 ±0.4
P	–	.004	<.001	.065	.019	.276	.073

ISFPP, implant-supported fixed partial prosthesis; MPS, median particle size; OCA, occlusal contract area.

Table 2. Masticatory frequency determined using freestyle mastication for different treatment groups at different times

		Masticatory Frequency (Cycles/min) (Mean ±Standard Deviation)			
Group	n	Baseline	Immediately After Treatment	3 mo After Treatment/Follow-up	Changes in Masticatory Frequency at 3 mo; Mean (95% CI)
No treatment	10	73.8 ±10	–	75.8 ±12	2.0 ±-2.8 to 6.9
ISFPP group	30	69.1 ±11	72.7 ±11	75.2 ±10	6.0 ±2.8 to 9.3*
1 restorative unit	15	68.6 ±11	75.3 ±13	75.9 ±12	7.3 ±3.4 to 11.1*
2 restorative units	9	68.9 ±9.8	70.7 ±10	72.8 ±7.1	3.9 ±-5.5 to 13.4
3 restorative units	6	70.6 ±14	69.4 ±9.8	76.8 ±11	6.1 ±-1.0 to 13.3
F	–	0.50	0.76	0.22	–
P	–	.687	.480	.884	–

CI, confidence interval; ISFPP, implant-supported fixed partial prosthesis. **P*<.001 Paired samples test between baseline and 3-month follow-up.

and in the mandibular arch in 13 (43%) participants, and on the left-hand side in 17 (57%) participants and on the right-hand side in 13 (43%) participants.

At baseline, freestyle masticatory frequency was similar among the groups that received 1, 2, or 3 ISFPPs. At 3 months, masticatory frequency had increased by 8.7% in participants treated with any ISFPP (*P*=.001), the most notable effect being in individuals treated with 1 unit (Table 2). The masticatory frequency in the ISFPP group had improved to a level similar to that of the control group (approximately 75 cycles per minute).

At baseline, unilateral masticatory frequencies on the treated and nontreated sides were not significantly different in any of the ISFPP groups compared with the control group (Table 3). At 3 months, there were no significant differences between groups on either side. Participants treated with ISFPPs showed significant increases in masticatory frequency of 8% and 5% on the treated (*P*<.01) and nontreated (*P*<.05) sides, respectively. At 3 months, participants masticated more slowly during freestyle mastication than during enforced unilateral mastication on the treated side (*P*=.002; 95% CI, 1.2-4.9 cycles/min difference).

Intraindividual variability in masticatory frequency is shown in Table 4 by group and masticatory assay. At baseline, the coefficient of variation for masticatory frequency in the ISFPP group was higher than that in the control group during unilateral mastication on the treated side (*P*=.033). At 3 months after treatment, the ISFPP group showed a significant reduction in the coefficient of variation during freestyle (*P*<.041) and unilateral (*P*<.001) mastication on the treated side, but no significant change on the nontreated side (*P*>.05). There were no significant differences between groups by masticatory assay (*P*>.05).

The increase in masticatory frequency during either freestyle or unilateral mastication on the treated side was not associated with age, sex, maximum occlusal force, number of restorative units, arch restored, or difference in occlusal contact area, unilateral mastication index, or masticatory performance at 3 months. Baseline masticatory frequency was associated with the change in masticatory frequency during either freestyle (adjusted R square= -0.16; *P*=.007) or unilateral mastication (adjusted R square= -0.34; *P*<.001). The lower masticatory frequency at baseline, the higher the change at 3 months.

DISCUSSION

The study determined that treatment with ISFPPs was associated with increased masticatory rhythm in patients with unilateral posterior missing teeth. Therefore, the null hypothesis was rejected. The increase in masticatory frequency was observed during freestyle and unilateral mastication, albeit to a lesser degree on the nontreated side during unilateral mastication. The increase in masticatory frequency was complemented by a reduction in the intraindividual variability of this frequency not only during freestyle mastication but also during mastication on the treated side. These results were consistent with studies that reported an increase in masticatory frequency in edentulous individuals after the insertion of new complete dentures or implant-retained overdentures.[29-33]

Table 3. Masticatory frequency during unilateral-style mastication for different treatment groups at different times

Group	n	Treatment Side (or Right Side): Masticatory Frequency (Cycles/min) (Mean ±Standard Deviation) Baseline	After Treatment	3 mo	Change of Masticatory Frequency at 3 mo (95% CI)	No Treatment Side (or Left Side): Masticatory Frequency (Cycles/min) (Mean ±Standard Deviation) Baseline	After Treatment	3 mo	Change of Masticatory Frequency at 3 mo (95% CI)
No treatment	10	78.9 ±8.4	—	80.3 ±11	1.4 ±-2.7 to 5.4	78.4 ±6.8	—	80.2 ±9.4	1.8 (-2.2 to 5.8)
ISFPP group	30	72.0 ±12	73.5 ±11	77.7 ±9.4	5.7 ±1.7 to 9.8[b]	74.2 ±11	77.9 ±11	77.8 ±9.1	3.7 (0.8-6.5)[a]
1 restorative unit	15	70.8 ±12	73.6 ±11	75.7 ±8.0	5.0 ±1.0 to 8.9[a]	72.2 ±12	77.6 ±12	76.7 ±9.5	4.5 (0.8-8.2)[a]
2 restorative units	9	73.8 ±12	75.0 ±9.5	78.1 ±9.8	4.3 ±-5.0 to 13.5	77.1 ±10	78.8 ±11	78.8 ±10	1.7 (-5.5 to 8.8)
3 restorative units	6	72.3 ±13	71.1 ±14	82.2 ±12	9.9 ±-3.9 to 13.1	74.6 ±7.6	77.5 ±7.6	79.2 ±6.6	4.6 (-3.9 to 13.1)
F	—	1.07	0.22	0.81	—	0.94	0.04	0.30	—
P		.378	.807	.496	—	.432	.965	.824	—

CI, confidence interval; ISFPP, implant-supported fixed partial prosthesis. [a]*P*<.05. [b]*P*<.01 Paired samples test between baseline and 3-month follow-up.

Table 4. Intraindividual variability in masticatory frequency during free and unilateral mastication by treatment group and time

Group	n	Freestyle Mastication: Coefficient of Variation % (±Standard Deviation) Baseline	3 mo	Treatment Side (or Right Side): Coefficient of Variation % (±Standard Deviation) Baseline	3 mo	No Treatment Side (or Left Side): Coefficient of Variation % (±Standard Deviation) Baseline	3 mo
No treatment	10	5.66 ±2.6	5.27 ±3.9	5.35 ±3.5	4.54 ±3.5	5.34 ±3.9	5.02 ±3.6
ISFPP group	30	7.21 ±4.7	4.96 ±2.2[a]	7.48 ±3.0	4.18 ±1.9[b]	4.94 ±2.5	5.11 ±2.9
P		.612	.724	.033	.701	.678	.701

ISFPP, implant-supported fixed partial prosthesis. [a]*P*<.05. [b]*P*<.001 Wilcoxon test between baseline and 3-month follow-up.

Participants with unilateral posterior missing teeth had an average masticatory frequency of 69.1 cycles/min during freestyle mastication, and 3 months after treatment, this had increased to 75.2 cycles/min, which was close to the 75.8 cycles/min observed in dentate individuals, within the normal range.[6,8-10] The group with unilateral posterior missing teeth also approached normal values during unilateral mastication. Although the sample size was sufficient to detect intraindividual differences in masticatory frequency in the ISFPP group, the interindividual differences in masticatory frequency at baseline between the control and ISFPP groups were statistically similar, possibly because masticatory frequency varies more between than within individuals.[7,12] That participants who have lost some posterior teeth displayed increased masticatory frequency 3 months after treatment suggests that the lack of significance in the difference between participants with missing teeth and the controls at baseline might be from a type II error. To detect a statistically significant difference greater than 5 cycles/min, a larger sample size would be required (76 per group). Further research is warranted to demonstrate whether a cause-and-effect relationship exists between losing posterior teeth and reduced masticatory frequency.

Slow frequency mastication has been reported to reduce food intake and improve the ability to detect a foreign object in the food.[11,23] Participants in the present study maintained normal masticatory frequencies (<75 cycles/min), which is below the 100 cycles/min considered fast mastication.[11] Therefore, it is unlikely that these individuals are at an increased risk of swallowing a foreign object or of increased food intake. Furthermore, individuals probably perceived more flavor in the food because of the increased frequency.[22]

Masticatory rhythm can be expressed not only as the average masticatory frequency but also as the stability of masticatory frequency (the coefficient of variation for intraindividual variability). It has been suggested that large variation from the mean frequency values could indicate impaired masticatory function and a decrease in the coefficient of variation after dental treatment could indicate improved masticatory function.[8,9,14,26] Before treatment, the intraindividual variability of masticatory frequency was higher during freestyle mastication and during mastication on the side with missing teeth. This may be explained by the central pattern generator responsible for repetitive masticatory cycles altering the motor output in response to information received from sensory receptors in the periodontal ligament and masticatory muscles on the side with missing teeth. Three months after treatment, information from sensory receptors on the treated side became more constant and balanced compared with the other side.[14]

In the present study, only baseline masticatory frequency was identified as a baseline variable that accounted for the increase in masticatory frequency, indicating that those with slower mastication would derive more benefit from the ISFPP treatment than those with faster mastication. No significant correlation was identified between variables related to prosthetic treatment, including an increased occlusal contact area, the number of restorations, the improved masticatory performance, or the improved masticatory laterality. It appears that the putative loss of masticatory rhythm was probably multifactorial but that it can be restored at 3 months after treatment with an ISFPP.

Limitations of the present study include that only 1 test food was used to assess the first phase of comminution, limiting generalizability to other food types, including natural foods. Although the mean age of participants in the control group was lower than in the ISFFP group, the increase in masticatory frequency has not been associated with age or sex and it has been reported that masticatory rhythm remains constant with age.[14] Randomized controlled trials focused on contemporary prosthodontic interventions are required to recommend one tooth replacement strategy over another.[4]

Treatment with ISFPP in individuals with unilateral posterior missing teeth increased masticatory frequency and reduced intraindividual variability to normal levels. The authors are unaware of a previous controlled prospective study that demonstrated that this treatment approach improved masticatory rhythm. The present results provide support for dental clinicians in both decision-making and counseling for patients regarding the optimal tooth replacement strategy for unilateral posterior missing teeth. The improvement in masticatory rhythm with ISFPP should be discussed along with any other potential benefits (overall improved masticatory performance and laterality,[34,35] esthetics, and occlusal stability) and costs (financial, risks, and complications).

CONCLUSIONS

Based on the findings of this prospective clinical study, the following conclusions were drawn:

1. After individuals with unilateral posterior missing teeth were treated with ISFPPs, masticatory rhythm was improved after 3 months, achieving similar levels to those with a complete natural dentition.
2. The ISFPP treatment improved the stability of masticatory frequency.
3. None of the potential explanatory factors were associated with the observed changes in masticatory rhythm.

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Corresponding author:
Dr Jordi Martinez-Gomis
Campus de Bellvitge
08907 L'Hospitalet de Llobregat
Barcelona, Catalonia
SPAIN
Email: jmartinezgomis@ub.edu

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