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Chewing side preference and laterality in patients treated with unilateral posterior implant-supported fixed partial prostheses

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Abstract

Background: It is not clear to what extent chewing is improved by unilateral oral rehabilitation with implant-supported fixed partial prostheses (ISFPPs).

Objectives: This study aimed to investigate whether patients treated with unilateral ISFPPs in the maxilla use their prostheses during mastication to the same extent as they used their contralateral natural teeth. A further aim was to investigate whether there is a correlation between preferred chewing side and laterality.

Methods: Chewing side preference was assessed in 15 participants treated with unilateral ISFPPs in the maxilla. The first, second, third, fifth and tenth chewing cycles were assessed, and the test was repeated 10 times. All participants also answered a questionnaire about their chewing side preference.

Results: Most of the participants presented bilateral chewing, but two (13%) chewed only on the ISFPP. There was no statistically significant association between the objectively assessed chewing side and dental status (natural teeth or ISFPPs) during any of the recorded chewing cycles ($p > .1$).

There were statistically significant correlations between both the subjectively reported usually preferred chewing side and the subjective chewing side preference during the test and the objectively assessed chewing side for the first three chewing cycles ($p < .01$). No correlation was found between handedness and the objectively assessed chewing side.

Conclusion: In the present study, most participants chewed bilaterally, and chewing was performed both on the ISFPP and on the natural teeth. No correlation was found between the preferred chewing side, objectively or subjectively determined and laterality.

KEYWORDS
chewing side, chewing side preference, dental implants, mastication, oral rehabilitation

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1 | INTRODUCTION

Chewing is an individualised, complex process controlled by the central nervous system (CNS). The regulation of chewing is influenced by information from several peripheral sensory receptors including muscle spindles in the jaw-closing muscles and receptors in the temporomandibular joints. There are also mucosal receptors inside the mouth and mechanoreceptors in the periodontal ligament around the roots of the teeth.[1]

When missing teeth are replaced by implant-supported prostheses (ISPs), the periodontal ligament and the periodontal mechanoreceptors (PMRs) are no longer present. Therefore, no sensory information from the region of the ISP can be sent to the brain to help control masticatory movement.[2] The absence of periodontal mechanoreceptors influences jaw motor control, as described in experimental studies of patients with dental implants.[3–5] Intact sensory information from PMRs is important for normal regulation of low contact as well as high biting forces.[5,6] Hence, lack of inputs from periodontal afferents can explain the impairment of mastication in patients with implant-supported fixed prostheses (ISFPs) in both jaws.[4] In 2018 Grigoriadis and Trulsson reported that individuals with bimaxillary ISFPs lack signals from the PMRs; they have reduced adaptation of muscle activity during the masticatory sequence due to impaired boosting of the jaw-closing muscle activity during tooth-food contact. The authors concluded that sensory information from PMRs appears to be most critical during the beginning of the masticatory sequence when initial food contact occurs whereas prediction of food properties based on information from other mechanoreceptors is used more effectively later in the masticatory sequence.[7]

The peripheral feedback system changes when teeth are replaced by dental implants because of the absence of PMRs. In such a case, other peripheral mechanisms may operate.[8,9] These are input mainly from muscle spindle,[7] but also from the temporomandibular joint (TMJ) and cutaneous, mucosal and/or periosteal mechanoreceptors. They provide information for oral kinaesthetic sensibility in relation to jaw function and artificial tooth contacts. However, it is unclear how these different mechanoreceptors contribute to osseoperception in patients with implant-supported prostheses.[1,8,9]

Treatment with implant-supported fixed or removable partial or complete prostheses improves masticatory performance.[10–12] It increases maximum bite force and improves patient satisfaction as compared with removable prostheses.[10–12] One study reports that rehabilitating unilateral posterior tooth gaps with implant-supported prostheses increased satisfaction with chewing ability and promoted a bilateral chewing in patients with unilateral posterior missing teeth.[13] Another recent study by the same group reported that treatment with an implant-supported fixed partial prosthesis (ISFPP) accelerated the masticatory rhythm of individuals with unilateral posterior missing teeth.[14] Numerous studies have indicated that treatment with fixed implant-supported prostheses is associated with high survival rate of implants and prostheses in maxillary edentulous patients.[15] It is also associated with high survival rate of single implants[16,17] and in partially edentulous patients.[18,19] In addition to the positive objective outcome regarding the prognosis, people treated with dental implants are often very satisfied with the outcome. In a recent questionnaire study carried out in Sweden, 96% of patients treated with ISPs were satisfied with the prostheses regarding chewing. Moreover, 94% were satisfied regarding aesthetics, 8–14 years after implant installation.[20] In addition, most of the patients experienced no difference in comfort between natural teeth and implants.[20] Today, dental implants have become a routine therapy to replace missing teeth. Both the objective and the subjective outcome in terms of improved function and patient satisfaction is considered adequate. On the other hand, the relation between chewing side preference and dentition in patients with a unilateral ISFPP is not fully investigated. Preferred chewing side (PCS) may be associated with missing teeth[21] or with laterality, defined as handedness, footedness and eyedness, rather than with status of the dentition.[22] Or there may be no relation between PCS and laterality (handedness).[23,24]

It is of interest to find out whether patients chew on their ISFPPs as much as they do on their natural teeth, despite the reduced sensory inputs from a dental implant-supported prosthesis compared with a natural tooth. The null hypothesis was that there is no difference in chewing side preference depending on dentition. The aim of this study was to investigate whether patients with unilateral ISFPPs prefer to chew on the ISFPP or on the dentated side. A further aim was to examine whether there was an association between chewing side preference and laterality, defined as handedness.

2 | MATERIALS AND METHODS

2.1 | Selection procedure for test food and observation method: pilot test

A pilot test was conducted to decide on an appropriate method to establish the PCS, and to determine whether the PCS was changed during chewing and repeated tests, and to find an appropriate test food. Four types of test foods with different consistencies were tested: nuts, cocktail tomatoes and two types of candy—M&M's peanut and Vit Kubik (see below).

Five staff members from the Karolinska Institute (Huddinge, Sweden) participated in this experimental test. They all had good general and oral health, as well as a good dental status, including teeth from 17 to 27 and from 37 to 47.

Visual inspection (observation) of the chewing side was conducted. We wanted to use a test food that was eatable and not an artificial test food. Others have reported the use of artificial test foods as well as natural food. However, there seems to be no consensus on what kind of test food should be used when chewing side preference is assessed.[13,25,26] After trying different types of food and confectionary with different consistencies, we decided to use a candy, Vit Kubik (Dals Konfektyr AB, Bengtsfors, Sweden),

in the study. The candy is white in colour with an initially moderately hard consistency. It is large enough (2.5 cm * 2.5 cm * 1.5 cm) to be seen during the first part of the chewing process since it is almost impossible to chew it with the lips closed. During chewing, it changes consistency and becomes softer but remains in one piece. Therefore, it has a suitable consistency and elasticity, remains in a single piece during chewing and allows registration of chewing on both a moderately hard and a soft texture. Each participant ate 10 pieces of candy, one piece at a time. Two of the authors (Z.A. and K.S.) observed the first three chewing cycles of each participant for the first five pieces and recorded the chewing side. Between chewing cycles five and 10, the test food could not be reliably observed. Therefore, for the last five pieces of candy it was decided to stop the participants chewing during the fifth and tenth chewing cycles in order to record the position of the piece of candy. This can be considered a modified version of the method described by Kazazoglu et al.[27] who used a piece of chewing gum and recorded the first, third, fifth and seventh chewing cycles. Both authors recorded the same chewing side for all chewing cycles and participants throughout the test; hence, the inter-observer agreement was 100%.

None of the participants changed chewing sides during the first three chewing cycles and the PCS was determined as the side on which the first three chewing cycles occurred for that chewing sequence. Most participants started chewing on a different side for each piece of candy, and the first three chewing cycles always took place on the side where the chewing started.

2.2 | Test participants

This study was conducted at the Karolinska Institute. Participants were recruited from patients referred to a specialist clinic, Folktandvården Stockholm County, and a private practice in Norrköping, Sweden. None of the patients were treated by the investigators.

2.2.1 | Inclusion criteria

Patients with unilateral posterior ISFPP in the maxilla and with natural teeth or a tooth-supported fixed prosthesis (TSP) at least including the second premolar in the other three quadrants were included.

2.2.2 | Exclusion criteria

Exclusion criteria were natural teeth remaining posterior to the ISFPPs and temporomandibular disorder (TMD) symptoms.

A total of 27 individuals fulfilling inclusion and exclusion criteria were identified in the dental records. Of these, 22 could be reached by mail or telephone and 15 individuals (nine women and six men) aged 47–84, with a mean age of 69 years, accepted participation and were included. The participants had two-, three- or four-unit ISFPPs (Astra Tech or Straumann), replacing missing posterior teeth on one side of the maxilla. The ISFPPs had been in use for 3–120 months (mean 57 months). Two participants received their ISFPPs three and 4 months, respectively, before the test. The other participants had received their ISFPPs more than 3 years previously. The implants were positioned on the right side in six participants and on the left side in nine participants (Table 1), with no natural dentition posterior to any of the ISFPPs.

TABLE 1 Position of implant-supported fixed partial prosthesis (ISFPP) and percentage (%) of the 10 repeated sequences performed on the implant prosthesis during the first three, the fifth and the tenth chewing cycles

Participant	Implant FDP position	1st–3rd cycles	5th cycle	10th cycle	PCS
1	L	60	80	10	L
2	R	60	60	30	R
3	L	40	40	50	R
4	L	50	60	40	B
5	R	20	70	60	L
6	R	100	100	90	R
7	L	100	100	90	L
8	R	60	60	60	R
9	L	80	40	50	L
10	L	50	30	70	B
11	L	70	50	70	L
12	R	30	10	40	L
13	L	90	0	50	L
14	R	60	50	70	R
15	L	40	40	70	R

Abbreviations: B, bilateral (50/50); L, left side; PCS, preferred chewing side (≥60% of chewing cycle); R, right side.

The study was approved by the Regional Ethical Review Board in Stockholm (dnr 2009/1850-31/2). The participants were fully informed and signed an informed consent form before starting the study.

2.3 | The behavioural task and experimental procedure

Each participant was seated on an office chair at a table and asked to eat a piece of candy (Vit Kubik). An observer sat at the opposite side of the table and visually observed which side of the mouth the candy was on during the first three chewing cycles, as well as during the fifth and tenth cycles. After the fifth and tenth chewing cycles, the participant was asked to stop chewing and open their mouth in order to allow the observer to see which side the candy was on. Immediately thereafter, the participant

continued to chew. After the tenth chewing cycle the participant could choose to continue to chew until swallowing or spit out the candy. The chewing side used during the first three, the fifth and the tenth chewing cycles was recorded for each piece of candy. The task was repeated 10 times for each participant, which means that each participant chewed 10 pieces of candy. The side where the first three chewing cycles took place in ≥60% of all 10 studied chewing sequences was registered as the objectively determined PCS for the participant.

The participants were also asked to fill in a questionnaire (the questionnaire was developed by the authors Z.A. and K.S.) including the following questions:

1. Which side did you mostly chew on during the test?
2. Which side do you usually chew on?
3. If you had a preferred side in either of the two questions above, why did you prefer either the right or the left?
4. Are you right- or left-handed?
5. Do you experience any difficulties when chewing food?

2.4 | Statistical analysis

Descriptive and analytical statistics were performed using IBM SPSS Statistics, version 25.0 (IBM Corp.). The Fisher–Freeman–Halton Exact test was used to determine whether there was a significant association between subjectively preferred and objectively assessed PCS and dental status (implant side, tooth side). The same test was used to determine whether there was a significant association between the subjective PCS in questions 1 and 2 above and the objectively assessed PCS during the first three, the fifth and the tenth chewing cycles. Values of $p < .05$ were considered statistically significant.

3 | RESULTS

All the chewing cycles that were studied were easy to observe visually. None of the participants changed their chewing side during the first three chewing cycles with any of the pieces of candy. However, all but two (13%) of the participants started chewing on different sides for the first three chewing cycles during the 10 repeated sequences (Table 1). The two (13%) participants who persistently used one chewing side during all test sequences started by chewing on the ISFPP. Six participants (40%) chewed mainly (i.e. during ≥60% of the recorded chewing cycles) on the ISFPP side, six participants (40%) chewed on both sides and three (20%) chewed mainly on their natural teeth during all chewing sequences. Thirteen participants (87%) alternated between the left and right side on the first three, and the fifth and tenth chewing cycles during the test. There was no statistically significant association between the objectively assessed chewing side and dental status (natural teeth or ISFPP) during any of the recorded chewing cycles (i.e., the first to the third, and the fifth and the tenth cycle): $p > .5$, $>.5$ and $>.1$, respectively. Two participants (13%) chewed unilaterally during ≥90% of all recorded chewing cycles, both chewing on the ISFPP.

There was a correlation between the subjectively reported chewing side during the test and the objectively assessed chewing side during the first three chewing cycles and the fifth chewing cycle ($p < .01$ and $<.05$, respectively) but not during the tenth chewing cycle ($p > .5$) (Table 2). There was also a strong correlation between the subjective usually preferred and the objectively assessed chewing side during the first three chewing cycles ($p < .01$). There was no correlation between the subjective usually preferred and the objectively assessed chewing side during the fifth ($p > .5$) or the tenth ($p > .1$) chewing cycles.

Among those nine participants (60%) who gave a specific chewing side in response to questions 1 and/or 2 and who answered question 3, four (26.6%) said they did not know why this was their PCS. Three participants (20%) answered that they chewed on the ISFPP side for a reason: one (6.6%) answered that it was more comfortable to chew on the ISFPP side, especially hard food; one (6.6%) preferred chewing on the ISFPP because he had a TSP on the other side, which he considered to be weak. The third (6.6%) answered that he chewed on the ISFPP side because he frequently bit his tongue on the other side. Two participants (13%) answered that they preferred chewing on their natural teeth: one (6.6%) said it was because he had more tactility on the side with natural dentition, and that it felt better to chew on natural teeth. The other (6.6%) answered that it was her habit to chew on her natural teeth because she had recently received the ISFP on the other side and she had been edentulous on that side for a long time.

Regarding question 4 (Are you right- or left-handed?), 13 (87%) participants answered that they were right-handed. One participant (6.6%) said that she was left-handed and one (6.6%) answered that she was both right- and left-handed (Table 2). There was no correlation between handedness and the objectively assessed chewing side for any of the recorded chewing cycles; the first three $p > .5$; the fifth $p > .5$; and the tenth $p > .1$. Regarding question 5 (Do you experience any difficulties when chewing food?), none of the 15 (100%) participants reported any chewing difficulties.

4 | DISCUSSION

Replacing missing posterior teeth with implant-supported prostheses to restore chewing ability is a common prosthetic treatment. A lack of sensory input from the prostheses and a masticatory impairment is reported in full arch implant-supported prostheses.[7] However, rehabilitation with ISFPPs in partial tooth losses in the posterior area have been reported to improve patients' perception of chewing ability and promote more bilateral chewing.[13,21] In addition, in a patient group rehabilitated with mostly posterior ISFPP, Chochlidakis and co-workers described a high patient-reported general satisfaction and patient-acceptance of ISFPP as a useful treatment for partial edentulism.[18]

TABLE 2 Position of implant-supported fixed partial prosthesis (ISFPP), handedness and usually preferred chewing side (PCS), preferred and registered chewing side during the test and participants with unilateral chewing

			Answers to questions 1 and 2			
Participant	Handedness	ISFP side	Preferred chewing side during test	Usually preferred chewing side	Registered chewing side, cycles 1–3 (≥60%)	Unilateral chewing during test, cycles 1–3 and 5
1	R	L	R/L	R/L	L	
2	R/L	R	R	R	R	
3	R	L	R	R	R	
4	R	L	R/L	R/L	R/L	
5	R	R	R/L	R/L	L	
6	R	R	R	R	R	R
7	R	L	L	L	L	L
8	R	R	R/L	R/L	R	
9	L	L	R/L	L	L	
10	R	L	R/L	R/L	R/L	
11	R	L	L	R/L	L	
12	R	R	L	L	L	
13	R	L	R/L	L	L	
14	R	R	R	R	R	
15	R	L	R	R	R	

Abbreviations: L, left side; R, right side.

In the present study, the objectively and subjectively assessed PCS showed that chewing was performed to the same extent on the posterior ISFPPs as on the natural dentition. This is in accordance with the results by Khoury-Ribas et al.[13] who reported that patients rehabilitated with unilateral posterior ISFPPs increased their chewing on the treated side. Studies evaluating masticator function of partially edentulous patients show that implant-supported partial prostheses significantly improve masticatory performance and report high patient satisfaction with the treatment.[10,12–14,28] Further, considering the number of prosthetic complications reported in studies on ISFPPs, it is likely that implant-supported prostheses are used in normal chewing.[18,19] Therefore, we consider that the results from the present study confirm those of other studies that replacement of missing posterior teeth with implant-supported prostheses increases patients' perception of chewing ability and promotes bilateral chewing.

In contrast, Nissan et al.[22] reported that posterior tooth losses or the presence of implant-supported prostheses will not affect PCS. One possible reason for this difference may be the differences in recording PCS. Multiple recordings of bolus position were used in the present study and studies by Khoury-Ribas et al. and Martinez-Gomis et al., while Nissan and co-workers used a single recording.[21,22,24] This indicates that performing the test only once in order to determine chewing side preference may be inadequate and more trustworthy results for each participant may be recorded with repeated registration. With a single recording, bilateral chewing is not an option and chance may result in a perception that one side is predominantly used for chewing. The chewing gum method used by Nissan and co-workers was also tested by Flores-Orozco and co-workers, who evaluated the reliability of patient-reported PCS using the Visual Analog Scale (VAS) compared with different objective methods.[29] They stated that patient-reported PCS using VAS had a high reliability and that a low reliability was found for methods using the location of gum bolus.[29]

In the present study there was a significant correlation between objectively assessed and subjectively reported PCS, as was reported by Flores-Orozco et al. who concluded that the patient-reported PCS could be preferred for use in clinical practice and large observational studies.[29] Therefore, one could argue that in future studies, patient-reported PCS might be an alternative to evaluate the effect of prosthetic rehabilitation in patients' perception of the benefits of the prosthetic treatment.

Several authors have made attempts to investigate whether PCS is correlated with other kinds of laterality such as handedness, footedness and eyedness. Diverging results concerning relation between PCS and handedness have been reported in the literature. Predominantly no correlation or only a weak correlation is reported.[23,24,30,31]

In the present study, there was no correlation between PCS and handedness. Although the present findings suggest that the participants used their unilateral ISFPPs during a natural eating task, it should be borne in mind that the results may only be applicable to that type of food.

This study has obvious limitations; first, the number of participants is relatively small. Second, we introduced a new type of test food to assess the PCS without comparing it with a more standardised test food, such as bagged silicone. Further, with no natural

teeth posterior to the canine on the restored side a comparison before and after restoration would not have been meaningful.

Further studies with larger samples are required for a more trustworthy conclusion about the effect of unilateral oral rehabilitation with ISFPPs on chewing side preference. It would be of interest to study patients with natural dentition on one side and solely implant-supported prostheses on the other in order to compare chewing ability and PCS when there is no sensory input from one side. However, patients in this category are scarce.

If possible, further studies of patients with a partial loss of posterior teeth should evaluate chewing side preference and chewing performance before and after (at 3, 12 and 24 months) placement of unilateral ISFPPs, with repeated recordings.

Evaluation of chewing side preference may help to identify whether adaptation to a new prosthesis depends on a patient's age, the length of the period of edentulousness and time from prosthesis placement. If so, it would be of interest to know how much time is needed to adapt to a new prosthesis.

5 | CONCLUSION

Individuals with ISFPPs used both their prosthesis and their natural teeth during chewing. Chewing during the first three chewing cycles was always unilateral but was not always initiated on the same side. Later during the chewing sequence, most participants alternated chewing sides from initiation of chewing to swallow. No correlation was found between the preferred chewing side, objectively or subjectively assessed and hemispheric laterality.

AUTHOR CONTRIBUTIONS

The design and planning of the study were performed by ZA and KS, data collection was made by ZA. Data interpretation was performed by ZA and AE. The authors ZA, AE and LH have contributed to the discussion and writing of the manuscript, as well as revising it critically. VFS edited the manuscript.

CONFLICT OF INTEREST

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions.

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